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# ASSESSING THE ECONOMIC, ENVIRONMENTAL, AND SOCIAL SUSTAINABILITY OF BIOFUEL POLICIES

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*Alla mia famiglia, sempre vicina, seppur lontana.*

## Abstract

Biofuels started to raise interest almost 40 years ago, when the Arab oil embargo pushed oil prices up and therefore spurred the research towards new forms of energy. Nevertheless, biofuel production has not really taken off until recently, when the combination of high oil prices, concern about greenhouse gas emissions, and the progressive reduction of oil reserves induced many countries across the world to implement policies encouraging biofuels production.

At the beginning of the 2000s, biofuels were seen as a *panacea* for energy security (domestic energy source, highly reliable), economic stability (energy price stability, rural development, employment generation, reduce supply-demand gap for agricultural commodities), and for environment protection (better waste utilization, GHG emissions reduction), especially after the drawing up of the Kyoto protocol, according to which signatory countries had to reduce their GHG emissions by about 5% from their 1990 levels, by 2012.

Biofuels are currently produced from agricultural commodities, therefore their repercussions on the agricultural and food sector might be substantial. In this framework it is clear that the responsibility that big countries (those able to affect world prices) have is substantial. Countries like the US, Brazil, and the EU have been encouraging biofuel production in recent years and ended up artificially creating a new market for agricultural commodities without fully understanding, *a priori*, the possible negative consequences of such decision. They decided to subsidize renewables because of the increased pressure by the public opinion towards greenhouse gas emissions reduction, reduce dependency on oil imports, and the need to meet the targets set by both the Kyoto protocol.

Biofuel expansion took place not only in a controversial manner, without coordination at international level, but also in a critical historical moment. The past two decades have been characterized by a strong increase in world food demand, mainly due to economic expansion in emerging economies like China, India, Brazil, and some South East Asian countries. The strong increase in demand faces an agricultural supply that in the short period is inevitably inelastic, which results in higher prices and higher volatility (due to reduced stocks).

Much of the initial enthusiasm towards biofuels has been declining in the last few years. First of all, biofuel expansion has increased the demand for many agricultural commodities, which, in a framework of increasing food demand in the world, triggered a sharp increase in agricultural prices with strong negative implications for poor people especially in developing countries. Many doubts have also been raised concerning the real effectiveness of biofuels in reducing GHG emissions. Emission-computing methodologies are not always accurate and sometimes are difficult to put in practice. Agriculture intensification and land use changes, both consequences of biofuel expansion, are two of the factors more likely to have increased GHG emissions rather than reduced. Furthermore, biofuel policies have been designed and implemented by countries on an individual basis, without the coordination at international level that would have been needed to avoid the numerous side-effects that biofuels have been having on international food markets and on the environment.

My doctorate research analyzes all aspects of the biofuel sector at world level with special emphasis on its sustainability under an economic, environmental, and ethical point of view. The research starts with a description of what biofuels are and in which sub-categories they can be divided. Then, it provides a review of biofuel policies around the world and data on production, prices and trade. The work also provides figures on production, prices and trade of the main agricultural commodities used for biofuel production and the evolution of cropped and forest areas worldwide in the last twenty years. Main biofuel producers are the US, Brazil and the EU. In the first two countries is ethanol the main biofuel produced (obtained from corn in the US and from sugarcane in Brazil), while in the EU the leasing biofuel is biodiesel (from vegetable oils).

In 2011, 51.8% of Brazilian sugarcane production and 42.2% of US corn production were used to produce ethanol. Areas cropped with sugarcane and corn, in the two countries were 4.2 and 15.5 million hectares in 2011, which correspond to 1.5% and 16% of total agricultural area respectively. By 2021 ethanol production will absorb almost 61% of Brazilian sugarcane production and 57% of US corn production, *ceteris paribus*. In 2021 the amount of land needed to grow all sugarcane needed to produce ethanol in Brazil will be more than 8 million hectares, almost equal to the entire current sugarcane area in the South

American country. In the US the area that will be needed to cultivate corn for ethanol production will grow to slightly less than 20 million hectares, equal to 53% of current corn area in the US and 20% of current total agricultural area. These data highlight the different impact sugarcane- and corn-based ethanol have on agricultural production. Brazilian and American ethanol production was 22.9 and 52.8 million $m^3$ in 2011 respectively, implying an "ethanol yield" of 5.5 $m^3$/hectare for sugarcane ethanol and of 3.4 $m^3$/hectare for corn-ethanol. This means that producing ethanol from sugarcane is more efficient and less consuming in terms of land than corn-ethanol. Considering also biodiesel, the amount of land needed to crop biofuel feedstocks, in Brazil and the US grows to 3 and 18.4% of total agricultural land. These areas are forecasted to increase to 6.3 and 23% by 2021, implying an increasing competition for land.

In 2011 the EU used 5.4 million tons of domestically produced rapeseed oil and at least 3.9 million tons of imported palm oil to make biodiesel. The amount of land needed to grow rapeseed within the Union and oil palm in third countries (mainly Indonesia and Malaysia) was 5.2 and 1.3 million hectares respectively. The area needed to crop rapeseed for biodiesel production, in the EU, was equal to 5.2% of total agriculture area. Assuming that the percentage of rapeseed oil on total vegetable oil production in the EU will remain the same of 2011 and that the share of it employed in the food sector will also remain unchanged, it is possible to forecast that, in 2021, the EU will need 6.6 million tons of rapeseed oil and at least 10 million tons of palm oil from third countries to meet its consumption targets. This means that at least 3.4 million hectares of land, in South East Asia will be needed to produce palm oil destined to the EU.

The core of the thesis is the analysis of the sustainability of biofuels on one hand, and of biofuels' implications on food production on the other. The sustainability of biofuel production is analyzed through a literature review and re-interpretation of the existing literature on the topic, encompassing effects of mass biofuel production on the environment, GHG emissions, land use changes, water availability, and implications for developing countries. One of the most important aspects of biofuel sustainability is their effects on agricultural production and agricultural prices. The empirical part of this thesis employs econometric tools to assess the degree of integration between energy and agricultural markets in the main biofuel producing countries and price transmission elasticity between international and EU agricultural markets before and after the last reform of the CAP.

In the US and in Brazil energy and agricultural prices move together in the long-run and the influence of oil prices has been growing over time. This means that policy-makers, in the future, will have to pay great attention to the mutual influence energy and agricultural policies can have on each other. In Europe this close relationship between energy and agricultural prices was not detected, however European agricultural markets have been influenced by biofuel policies in the US, and to a lesser extent Brazil, indirectly, through their effects on international commodity prices.

What emerges from this work is that biofuels, in the current political, economic demographic, situation are, for many aspects, not sustainable. Side-effects of biofuel production are many and often even difficult to quantify. Solutions provided are often utopic or, even if good in theory, very difficult to implement. Biofuel production has been having negative effects on food production and prices, biodiversity and social welfare in the last decade, inside and outside the countries of production. The "original sin" was the initial lack of coordination between policies issued unilaterally by different countries, something that now seems extremely difficult to fix. Governments should, as it has been recently suggested by the United Nations, consider the option of modifying their biofuel programs because of their negative consequences on food security in many low-income countries. Also the promotion and implementation of biofuel policies in developing countries should be avoided as a measure for fostering development. It is very unlikely that rural poor will benefit from policies subsidizing the biofuel sector since most of the land in developing countries is owned by big multinational companies or by foreign states (land grabbing). The development of the biofuel sector would also increase food prices even in countries where such increase has been marginal so far because of scarce price transmission from the world market. Poor people living in urban areas would be worse off by higher food prices as well as small farmers who, in developing countries, are often net-purchasers of food.

It has been suggested by many scholars and international organizations that, in order to become sustainable, biofuel production should shift from first-generation to second-generation technologies (those that allow the use of non-food crops or wastes for biofuel production). This will not be easy to achieve. Current second-generation biofuel production is still very small and will not grow substantially unless major

investments are made by governments and, under the right conditions, private companies. Moreover it is not governments nor policy-makers who decides whether is profitable to put marginal land under cultivation and to crop non-food biofuel crops on it. Farmers are those making such decisions and they will not do it unless it is profitable. Current record-high agricultural commodity prices raise many doubts on the fact that farmers will shift from food to non-food crops without substantial government subsidies. An increase in subsidies to the agricultural sector, even just for energy crops, is unlikely to happen anytime soon because of the financial and economic crisis that hit many countries around the world and because of pressure by the WTO and other international organizations to reduce the degree of protection.

In case it will be decided to keep subsidizing biofuels, new polices will have to be designed and implemented at world level, needing a very high degree of coordination between countries and flexibility, which is difficult to imagine can be reached in the short or even the medium term. An emblematic case, in this sense, is GHG emission accounting mechanisms that currently are based on life-cycle assessment analysis and that are often incomplete (i.e. limited to a single country or region) or unable to take all factors into account (i.e. indirect land-use changes).

Research, in the next years, will have to focus on two main topics. On one hand second- and third-generation techniques for biofuel production will have to be refined and made economically (but also environmentally and socially) viable, possibly together with progressive reduction in the support in favor of first-generation biofuels. On the other hand, a better definition of the methodologies to assess the environmental, economic and social impacts of biofuel production will be crucial in order to correctly evaluate the sustainability of biofuel programs. In particular, the development of reliable methodologies to assess the environmental impact of biofuel production is very important since, in the future, subsidies could be calculated in a way to reward the production of biofuels able to provide (proved) positive externalities to the environment as well as increase social welfare.

## *Sommario*

*Di biocarburanti si iniziò a parlare circa 40 anni fa, in concomitanza con la crisi petrolifera determinata dall'embargo da parte dei paesi OPEC. Il conseguente forte aumento del prezzo del petrolio stimolò infatti la ricerca nel campo delle forme di energia alternative. La produzione di biocarburanti è tuttavia decollata solo di recente, grazie all'azione combinata di molteplici fattori: elevate quotazioni del petrolio, necessità di contenere le emissioni di gas serra e la riduzione delle scorte di combustibili fossili; tutte cose che hanno indotto molti paesi a mettere a punto programmi volti allo sviluppo del settore dei biocarburanti.*

*All'inizio degli anni 2000 i biocarburanti venivano considerati la soluzione ideale per risolvere i problemi dell'approvvigionamento energetico, della stabilità economica (stabilizzazione dei prezzi dell'energia, sviluppo rurale, creazione di posti di lavoro, aumento della domanda di materie prime agricole) e della protezione dell'ambiente (utilizzazione più efficiente dei rifiuti e riduzione delle emissioni di gas serra). Un impulso decisivo allo sviluppo delle politiche fu dato dalla stipula del Protocollo di Kyoto nel quale i paesi firmatari si impegnavano a ridurre le proprie emissioni di gas serra del 5% rispetto ai livelli del 1990 entro il 2012.*

*Al momento attuale i biocarburanti vengono in larga parte prodotti a partire da materie prime agricole, quindi le ripercussioni della loro produzione sul settore agricolo possono essere rilevanti. In tale àmbito appare chiara la forte responsabilità, in termini di effetti sui mercati agricoli mondiali, che hanno i paesi che più di tutti hanno sovvenzionato il settore: Stati Uniti, Brasile e Unione Europea. Tali paesi, tramite le loro politiche, hanno creato un nuovo mercato di sbocco per molte materie prime agricole, senza capire a fondo,* a priori*, le conseguenze di tale azione. Le principali motivazioni addotte dai decisori politici per giustificare le sovvenzioni al settore dei biocarburanti furono la necessità di ottemperare ai dettami del Protocollo di Kyoto, aumentare l'indipendenza energetica, creare nuovi posti di lavoro, migliorare il reddito degli agricoltori e stabilizzare i prezzi dell'energia.*

*L'espansione del settore dei* biofuel *è avvenuta non solamente in maniera quantomeno controversa, senza coordinazione a livello internazionale, ma anche in un momento storico molto delicato. Gli ultimi venti anni sono stati infatti caratterizzati da un grande aumento della domanda mondiale di cibo, soprattutto a causa della forte crescita economica dei cosiddetti paesi emergenti: Cina, India, Brasile e paesi del Sud-Est asiatico. Il forte aumento della domanda si scontra contro un'offerta di materie prime agricole giocoforza rigida nel breve termine, cosa che genera forti aumenti di prezzo e della volatilità delle quotazioni (soprattutto a causa del forte ridimensionamento delle scorte).*

*Negli ultimi anni gran parte dell'entusiasmo iniziale nei confronti dei biocarburanti è andato scemando. Per prima cosa l'espansione del settore dei combustibili "verdi" ha aumentato la domanda per molte materie prime agricole che, in un contesto contraddistinto da un forte aumento della domanda mondiale, ha generato un sensibile aumento dei prezzi alimentari, con ripercussioni particolarmente negative per le fasce più povere della popolazione, soprattutto nei paesi meno sviluppati. Anche l'effettiva efficacia dei biocarburanti nel ridurre le emissioni di gas serra è stata fortemente messa in dubbio. Le metodologie utilizzare per il conteggio delle emissioni non sono sempre accurate o di facile attuazione. L'intensivizzazione dei processi agricoli e i cambiamenti d'uso dei suoli, entrambi conseguenza dell'aumento della produzione agricola, sono due fattori che molto probabilmente hanno causato un aumento delle emissioni di gas serra invece che una diminuzione. Inoltre, le politiche a favore del settore delle energie rinnovabili sono state progettate e messe in pratica in maniera spesso unilaterale da parte dei vari paesi, senza quella coordinazione a livello internazionale che sarebbe stata essenziale a evitare le conseguenze negative sui mercati agricoli e sull'ambiente.*

*La mia ricerca di dottorato analizza tutti gli aspetti del settore dei biocarburanti a livello mondiale con particolare attenzione a quelli della sostenibilità: economica, ambientale e sociale. La ricerca inizia con una descrizione delle varie tipologie di biocarburanti attualmente prodotti a livello mondiale e prosegue con una rassegna delle politiche a favore dei biocarburanti nei principali paesi. In séguito vengono analizzate le produzioni, i prezzi e il commercio internazionale di biocarburanti e delle materie prime dalle quali sono ottenuti.*

*I principali paesi produttori di biocarburanti sono gli Stati Uniti, il Brasile e l'Unione Europea. Nei primi due viene prodotto principalmente etanolo (a partire dal mais negli Stati Uniti e dalla canna da*

*zucchero in Brasile), mentre nell'Unione Europea è il biodiesel il biocarburante di riferimento (prodotto a partire da oli vegetali). Nel 2011, il 51,8% della produzione brasiliana di canna da zucchero e il 42,2% di quella statunitense di mais sono state usate per produrre etanolo. Le superfici necessarie, nei due paesi, per la coltivazione della materia prima per la produzione del biocarburante sono state pari a 4,2 e 15,5 milioni di ettari, che rappresentano l'1,5 e il 16% della superficie agricola totale dei due paesi. Nel 2021,* ceteris paribus*, la produzione di etanolo assorbirà circa il 61% della produzione brasiliana di canna da zucchero e il 57% di quella statunitense di mais. Sempre nel 2021, in Brasile, le superfici necessarie per coltivare canna da zucchero destinata la settore dell'etanolo raggiungeranno gli 8 milioni di ettari, pari a tutta l'area attualmente coltivata a canna da zucchero nel paese sudamericano. Negli Stati Uniti le superfici necessarie a coltivare il granturco per la produzione di etanolo cresceranno fino a sfiorare i 20 milioni di ettari, un'estensione pari al 53% dell'area attualmente investita a mais e al 20% della superficie agricola totale del 2011. Da questi dati è possibile osservare la forte differenza, in termini di impatto sulle produzioni agricole, tra la produzione di etanolo brasiliana (imperniata sulla canna da zucchero) e quella statunitense (basata sul mais). La produzione brasiliana e statunitense di etanolo, nel 2011, è stata rispettivamente di 22,9 e 52,8 milioni di metri cubi, implicando una "resa" in etanolo di 5,5 e 3,4 metri cubi a ettaro. Ciò significa che la produzione di etanolo a partire dalla canna da zucchero è più efficiente in termini di superfici necessarie alla coltivazione della materia prima. Tenendo in considerazione anche il biodiesel, in rapida espansione in entrambi i paesi (dove viene ottenuto a partire dall'olio di soia), l'incidenza percentuale delle superfici utilizzate per coltivare la materia prima per la produzione di biocarburanti (etanolo e biodiesel) cresce fino a raggiungere il 3% del totale della superficie agricola in Brasile e il 18,4% negli Stati Uniti. Tali percentuali sono destinate a raggiungere il 6,3 e il 23% entro il 2021.*

*Nel 2011 l'Unione Europea ha impiegato 5,4 milioni di tonnellate di olio di colza (prodotto all'interno dell'Unione) e almeno 3,9 milioni di olio di palma (importato da Indonesia e Malesia) per produrre biodiesel. Le superfice necessaria, all'interno dell'UE, per la coltivazione della colza usata nel settore dei biocarburanti è stata di 5,2 milioni di ettari nel 2011, mentre quella impiegata per la produzione di olio di palma nei paesi terzi di almeno 1,3 milioni di ettari. Sempre nel 2011, il 5,2% della superficie agricola totale dell'Unione è stato utilizzato per la coltivazione di colza da destinare alla produzione di biocarburanti. Assumendo che la percentuale di olio di colza impiegata nel settore alimentare nell'Unione Europea rimarrà la stessa anche negli anni a venire, è possibile prevedere che, nel 2021, l'UE avrà bisogno di 6,6 milioni di tonnellate di olio di colza e di almeno 10 milioni di tonnellate di olio di palma (importato da paesi terzi) per raggiungere i suoi obiettivi di consumo in materia di biodiesel. Ciò implica che almeno 3,4 milioni di ettari di terreni, presumibilmente in Indonesia e Malesia, saranno necessari per produrre tutto l'olio di palma di cui il settore del biodiesel comunitario avrà bisogno.*

*Il fulcro di questa tesi è l'analisi della sostenibilità della produzione di biocarburanti e le sue conseguenze sulla produzione di materie prime agricole. La sostenibilità dei biocarburanti viene esaminata attraverso una revisione della letteratura esistente sull'argomento, con particolare enfasi sugli effetti della forte espansione del settore dei carburanti "verdi" sull'ambiente, sulle emissioni di gas serra, i cambiamenti d'uso del suolo, la disponibilità idrica e le implicazioni per i paesi in via di sviluppo. In termini di sostenibilità, uno degli aspetti più importanti riguarda gli effetti del forte aumento della produzione di* biofuel *sulla produzione e sui prezzi delle materie prime agricole. Questa tesi, nella sua parte empirica, utilizza tecniche econometriche per misurare il livello di integrazione tra i mercati energetici e quelli agricoli nei principali paesi produttori. Viene inoltre anche stimata l'elasticità di trasmissione dei prezzi tra il mercato mondiale e quello comunitario nel caso delle principali materie prime agricole, prima e dopo l'ultima riforma della Politica agricola comune (Riforma Fischler).*

*Negli Stati Uniti e in Brasile i prezzi agricoli e quelli dell'energia (petrolio ed etanolo) condividono il medesimo trend di lungo periodo, con l'influenza del prezzo del petrolio che è andata crescendo negli ultimi anni. Ciò implica che i decisori politici dovranno, in futuro, prestare grande attenzione agli effetti che le politiche energetiche hanno sui mercati agricoli e viceversa. In Europa non è stato possibile dimostrare la presenza di una relazione diretta tra prezzi agricoli e prezzo del petrolio, tuttavia è possibile affermare che i mercati agricoli europei subiscano le conseguenze delle politiche a favore dei biocarburanti di altri paesi, in particolare degli Stati Uniti, in maniera indiretta, cioè tramite l'effetto di tali politiche sui prezzi internazionali.*

*Ciò che merge da questo lavoro è che i biocarburanti, nella situazione economica, politica e demografica attuale, sono, per molti aspetti, non sostenibili. Gli effetti collaterali della produzione di* biofuel *sono numerosi e spesso difficili da quantificare. Le soluzioni proposte dalla letteratura sono spesso utopiche o, seppur corrette dal punto di vista teorico, molto difficili da applicare. L'espansione del settore dei biocarburanti sta avendo effetti negativi sulla produzione e sui prezzi delle materie prime agricole, sulla biodiversità e sul benessere sociale, sia all'interno dei principali paesi produttori che all'esterno di essi. Il "peccato originale" è stato la mancanza di coordinazione iniziale tra le varie politiche, progettate e messe in pratica in maniera unilaterale dai vari paesi; una cosa alla quale, oggi, è molto difficile porre rimedio. I governi dovrebbero, come è stato recentemente raccomandato dalle Nazioni Unite, considerare la possibilità di modificare in maniera sostanziale i propri programmi di sviluppo del settore dei biocarburanti a causa soprattutto delle pesanti conseguenze che hanno sulla sicurezza alimentare nei paesi a basso reddito. Per questa ragione l'utilizzo dei biocarburanti come misura volta a stimolare lo sviluppo nei paesi poveri dovrebbe essere evitata. È altamente improbabile che i poveri nelle zone rurali traggano alcun beneficio dallo sviluppo del settore dei biocarburanti nei loro paesi poiché gran parte della terra è posseduta da grandi compagnie multinazionali o, in alcuni casi, da paesi terzi (*land grabbing*). Lo sviluppo del settore dei biocarburanti nei paesi in via di sviluppo contribuirebbe, dall'interno, a mantenere elevati i prezzi dei generi alimentari anche dove finora tale effetto, a causa del basso livello di trasmissione dei prezzi agricoli mondiali, è stato marginale. L'aumento dell'inflazione alimentare causato dalla produzione di biocarburanti avrebbe effetti negativi sia sui poveri delle aree urbane che sue quelli delle aree rurali poiché in molti casi i piccoli coltivatori, nei paesi in via di sviluppo, sono compratori netti di generi alimentari.*

*Molti studi, anche da parte di organizzazioni governative internazionali, mettono in risalto il fatto che la produzione di biocarburanti possa diventare sostenibile solo attraverso lo sviluppo delle cosiddette tecnologie di seconda o terza generazione (cioè quelle che permettono l'uso di materia prima* non-food *per la produzione di biocarburanti) e l'uso di terreni degradati e marginali per la coltivazione delle materie prime. Tuttavia, tutto ciò è di difficile realizzazione. Attualmente i biocarburanti di seconda o terza generazione sono ancora in fase di sviluppo e la loro produzione non crescerà in maniera sostanziale se non tramite forti investimenti da parte dei vari governi e, in determinate circostanze, di investitori privati. Va ricordato che non sono i governi quelli che decidono se la coltivazione di materia prima per la produzione di biocarburanti in aree degradate o marginali sia economicamente conveniente: sono infatti i coltivatori quelli che prendono le decisioni ed essi non lo faranno se non vi troveranno alcun beneficio economico. L'attuale livello, molto elevato, dei prezzi agricoli pone seri dubbi sul fatto che i coltivatori siano disposti a passare dalla produzione di materie prime* food *a quelle* non-food *in assenza di forti incentivi pubblici in tal senso. Tuttavia, un aumento del livello di supporto all'agricoltura, anche solo nel caso delle colture energetiche, difficilmente avverrà nel breve termine, a causa soprattutto della crisi economica, che ha ristretto i* budget *di spesa di molti paesi, e le pressioni, in sede WTO, per una riduzione del livello di protezione dei mercati.*

*Nel caso in cui si decida di mantenere gli aiuti di stato al settore dei biocarburanti, sarà necessario progettare e sviluppare nuove politiche, questa volta a livello sovranazionale, cosa che implicherebbe un elevato livello di coordinazione e di flessibilità tra i vari paesi, oltre che difficile da raggiungere nel breve o medio termine. Un caso emblematico, in tal senso, è rappresentato dalle metodologie di conteggio delle emissioni di gas serra che sono attualmente basate sull'analisi del ciclo di vita e che sono molto spesso incomplete (limitate, ad esempio, a determinati paesi o regioni) o ancora non in grado di considerare il ruolo di tutti i fattori (es. cambiamenti indiretti d'uso del suolo).*

*La ricerca, negli anni a venire, dovrà focalizzarsi su due argomenti principali. Da una parte, le tecniche di produzione dei biocarburanti di seconda e terza generazione dovranno essere raffinate, rese economicamente convenienti e sostenibili dal punto di vista sociale e ambientale. Possibilmente ciò dovrà avvenire di pari passo con la progressiva riduzione del livello di supporto ai biocarburanti di prima generazione. Dall'altra parte, sarà necessario definire meglio le metodologie di quantificazione dell'impatto dei biocarburanti in termini ambientali, economici e sociali, in modo da determinare con certezza la loro sostenibilità e da consentire lo sviluppo di politiche più appropriate. In particolare, la messa a punto di metodologie affidabili per la valutazione dell'impatto dei vari biocarburanti è molto importante poiché, in futuro, le sovvenzioni potrebbero essere calcolate in maniera tale da premiare la produzione di quei biocarburanti in grado di fornire esternalità positive per l'ambiente e il benessere sociale.*

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# Introduction.

Ethanol and other biofuels have increased their importance in recent years and have become a "hot topic" in the political agenda of many governments. Biofuels started to raise interest almost 40 years ago, when the Arab oil embargo pushed oil prices up and therefore spurred research towards new forms of energy. Nevertheless, biofuel production have not really took off until recently, when the combination of high oil prices, concern about greenhouse gas (GHG) emissions, and the progressive reduction of oil reserves induced many countries across the world to implement policies encouraging biofuels production.

Nowadays ethanol and biodiesel, are the biofuels more extensively produced thanks to the strong subsidy schemes implemented by many governments. At the beginning of the 2000s, biofuels were seen as a *panacea* for energy security (domestic energy source, highly reliable), economic stability (price stability, rural development, employment generation, reduce demand-supply gap for agricultural commodities), and for environment protection (better waste utilization, greenhouse gas emissions reduction), especially after the drawing up of the Kyoto protocol, according to which signatory countries had to reduce their GHG emissions by about 5% from their 1990 levels, by 2012. Biofuels were considered carbon-neutral by the protocol, therefore many countries decided to promote their consumption. Since first-generation biofuels are those for which production technologies were already mature and available, they became the biofuel of choice to be subsidized.

After some years, however, they started to be heavily criticized because their production is in conflict with food supply and because they are not very efficient since for their production just a small fraction of the plant's biomass is used. Biofuels are currently produced from agricultural commodities and their repercussions on the agricultural and food sector are likely not to be marginal. It has been argued that one of the main causes of the recent substantial increase in agricultural prices and their volatility had biofuels among its main determinants. Moreover also the real effectiveness of biofuels in reducing (or at least limiting) GHG emissions has been questioned, as well as, their economic and environmental sustainability.

An increase in the demand for agricultural commodities can have a positive impact on growers worldwide because of higher selling prices, and can trigger an increase of total cropped area reducing soil degradation problems. On the other hand, final consumers as well as those using primary commodities as inputs can be worse off. An example of what an increase in agricultural prices can represent for some strata of the population in certain countries was given by the so-called *tortilla-riots* that unlashed in Mexico and other developing countries in 2008. Extremely high agricultural commodity prices eventually forced governments in several countries to ceil prices. In developed countries the problem for final consumers is less pressing because of relatively high incomes and the buffer effect highly concentrated retail sectors have on fluctuating production prices. However, in these countries, cattle, sheep, and pig farmers are those

likely to be more affected by sudden and strong upward spikes of the price of primary commodities. Cereals and oilseed are the main ingredient of animal feed, which in turn is the most important production factor. In other words, an increase in biofuel production can trigger a surge of commodity prices, raising production costs for breeders. This can either mean higher meat prices for consumers or – in the most extreme case – farmers exiting the market (survival of the fittest).

Biofuels not only are likely to have negative side-effects on agricultural markets, also their actual capacity in reducing GHG emissions has been heavily questioned, especially in recent years. The production process of feedstocks currently used in biofuel production might generate more GHG emissions than those that the plants, while growing, are able to absorb. Furthermore, increased agricultural production might trigger land use changes, which impact, in terms of carbon released into the atmosphere can be substantial. Land use changes (LUC) can be both direct and indirect. Direct LUC arise when, for example, forest land is converted into crop land like it happens in some tropical countries. Indirect LUC, conversely, arise when, for example, energy crops are planted on land previously used for food production and elsewhere land is converted to cropland to replace the previous production that has been displaced (Lahl, 2010). LUC can result in major releases of carbon into the atmosphere if forest or other types of land rich in vegetation are converted into agricultural land. Currently only GHG emissions from direct LUC are taken into account when evaluating the environmental performances of biofuels and often with a high level of efforts. There is still no consensus on how to measure GHG from indirect LUC and, most importantly, how to distinguish between those generated by biofuel production and those due to other factors. LUC can have negative repercussions also on the environment and on biodiversity, especially in tropical countries, which are, on average, characterized by richer ecosystems than temperate countries. In this framework the increasing use, by developed countries (i.e. the EU) of imported feedstock from tropical countries (palm oil) to produce biofuels to meet consumption targets, is particularly worrying.

Even if some biofuels can be produced from non-food crops (the so-called second- and third-generation biofuels), almost none of them is commercially available on a large scale and probably will not be anytime soon, unless massive investments are made both by governments and the private sector. Furthermore, even when second- and third-generation biofuels will become economically viable, it is possible that they will still be competing with food crops for land.

In this framework it is clear that the responsibility that big countries (those able to affect world prices) have is substantial. Countries like the US, Brazil, and the EU have been encouraging biofuel production in recent years and ended up artificially creating a new market for agricultural commodities without fully understanding, *a priori*, the possible negative consequences of their policies. They decided to subsidize renewable energy (among which biofuels) because of the increased pressure by the public opinion towards GHG emissions reduction, to reduce dependency on oil imports, and, in some cases, the need to meet the targets set by both the Kyoto protocol. (Sorda, Banse, & Kemfert, 2010).

Biofuel expansion took place not only in a controversial manner, without coordination at international level, but also in the "wrong" historical moment. The past two decades have been characterized by a strong increase in world food demand, mainly due to economic expansion in emerging economies like China, India, Brazil, and some South East Asian countries. The strong increase in demand faces an agricultural supply that in the short period is inevitably inelastic, which results in higher prices and higher volatility (due to reduced stocks). It has been argued that a new, more direct, link between energy and agricultural market has been created by the expansion of biofuel production, which have strong implication in terms of energy and agricultural policy planning. The new, closer, relationship between energy and agricultural prices is stronger in the US and Brazil, the two countries where the biofuel sector is more developed. However, since both countries are big enough, in terms of agricultural production and exports, to influence world prices, the closer interrelations between biofuel and agricultural prices in these two countries might have repercussions also in other countries, provided price transmission between international and domestic prices is at least partially present. This work, in its experimental part, employs time series econometric techniques to assess price relationships between energy and agricultural prices in the three major biofuel producing countries: the US, the EU and Brazil. Results show that energy and agricultural prices move together in the long-run in the US and Brazil but not in Europe, when the biofuel sector is smaller and based on biodiesel, which is produced from rapeseed, not a major agricultural commodity. Nevertheless, it is shown, using two different approaches, that in the last decade the reform process of the Common Agricultural Policy (CAP) of the EU increased the extent to which international prices are transmitted to domestic EU prices, meaning that, even indirectly, biofuel expansion in third countries can have an effect also on European agricultural prices. Even though it has not been formally tested, it can be argued that these findings can be extended to all countries characterized by a non-zero price transmission elasticity between the international and the domestic agricultural market. This can have particularly negative implication for developing countries, which are usually net-importers of food.

Even though biofuels are mainly subsidized by developed countries, implications for developing ones are not marginal. First, some of the feedstock cultivation for producing in developed countries, as noted above, can be displaced in developing countries, where environmental regulations are less stringent and weakly enforced. It is also worrying the fact that many indicate the development of the biofuel sector also in developing countries as a way to boost economic development and rural income. In developing countries agricultural production is often in the hands of big multinational companies (often owned by foreign governments originating the land-grabbing phenomenon) or big local landowners and it is very likely that are they those that will benefit from policies encouraging biofuel expansion. In other words, it is quite unlikely that the rural poor will benefit from biofuel subsidy unless policies are specifically designed to target them. A good example of how bad-designed biofuel policies can have negative effects on the poor is provided by Brazil's ethanol policies, which, since the 70s, have been favoring big sugarcane landowners

and the construction of big refinery plants. Small sugarcane farmers were cut-off from all the befits that the development of the ethanol sector could give them and ended up working as cane-cutters in large plantations, often in very bad working conditions. Still today, slave work is reported in some Brazilian sugarcane farms. Nevertheless, the Brazilian government acknowledged the problem and designed its polices in favor of biodiesel in a different way. In the new Brazilian biodiesel program small farmers are granted access to the market since biodiesel producers have to use minimum quantities of soybean produced in marginal areas by small farmers. In Brazil, however, awareness towards human rights has been increasing to a great extent in recent years, but the situation in many developing countries where biofuels are proposed as a way to enhance living conditions of the poor is much different in somehow similar to that of Brazil of the 70s.

My doctorate research analyzes all aspects of the biofuel sector at world level with special emphasis on its sustainability under an economic, environmental, and ethical point of view. The research starts with a description of what biofuels are and in which sub-categories they can be divided. Then it provides a review of biofuel policies around the world and data on production, prices and trade. The work also provides data on production, prices and trade of the main agricultural commodities used for biofuel production and the evolution of cropped and forest areas worldwide in the last twenty years. The core of the thesis is the analysis of the sustainability of biofuels on one hand, and of biofuels' implications energy-food price relationships. The sustainability of biofuel production is analyzed through a literature review and re-interpretation of the existing literature on the topic, encompassing effects of mass biofuel production on the environment, GHG emissions, land use changes, water availability, and implications for developing countries. One of the most important aspects of biofuel sustainability is its effects on agricultural production and agricultural prices. The empirical part of this thesis employs econometric tools to assess the degree of integration between energy and agricultural markets in the main biofuel producing countries and price transmission elasticity between international and EU agricultural markets before and after the last reform of the CAP. Even though in the EU energy and agricultural markets are not so interrelated like in Brazil and the US, agricultural markets can be still be indirectly affected by biofuel policies in third countries through their effect on agricultural prices in their country of implementation.

# 1 Biofuels, an overview.

Biofuels are substitutes for conventional fuels, mainly those of fossil origin. The prefix “bio” means that they are produced from biomass (plant matter), which can be solid, liquid or gas (European Commission, 2010). The term “biomass” refers to the biodegradable fraction of products, waste and residues from agriculture, forestry and the biodegradable fraction of industrial and municipal waste (Heinimo, 2008). Examples of biomass are: microbes, plants, trees, animals, vegetable oils, animal fats, manure, and garbage. Biofuels are not the only form of bioenergy though, since several kinds of biomass can be used to generate electricity, heat, power, *etc.*

Biofuels can be in the form of solid, liquid or gas and can be classified as primary (unprocessed) or secondary (processed). The former are directly combusted, usually for cooking, heating or electricity production. The former can be solid (charcoal, or wood pellets), liquid (ethanol, biodiesel, or bio-oil) or gaseous (biogas and hydrogen) and can be used for a very wide range of applications, including transport and high-temperature industrial processes. The exponential growth that the biofuel sector experienced in recent years is mainly due to secondary liquid biofuels used for transport, namely ethanol and biodiesel, which are produced from agricultural and food commodities (Payne, 2010).

Biofuels, that is fuels produced from biomass and can be obtained through a wide range of different processes. The next sections provide a detailed description of current technologies available for biofuels production, with special emphasis on the so-called first-generation biofuels that is those currently being produced at a commercial scale around the world and which consequences are being assessed in this thesis.

## 1.1 First-generation biofuels.

First-generation biofuels are secondary biofuels, that is modified primary fuels (oil, coal, natural gas, solar energy, biomass, *etc.*) which have been processed and transformed in the form of solids (charcoal), liquids (ethanol, biodiesel and bio-oil) or gases (biogas, synthesis gas, and hydrogen). Secondary biofuels are used for a wide range of applications, especially transportation. Secondary liquid biofuels are generally produced from sugars, grains, or oilseeds, and require a relatively simple process to be produced. The most well-known first-generation biofuels are ethanol (obtained by fermenting sugar or starch) and biodiesel (produced from vegetable oils by transesterification processes) (Nigam & Singh, 2011).

The next sub-sections provide a brief description of the main first generation biofuels: ethanol and biodiesel.

### 1.1.1 Ethanol

Almost all the ethanol currently produced in the world is obtained from feedstock rich in either sugar or starch. Sugar crops are sugarcane, sugar beet, and sweet sorghum, while feedstocks containing starch or cellulose (which are converted into sugar in order to be used in ethanol production) are corn, wheat, and cassava.

In tropical countries, such as Brazil, the most common feedstock is sugarcane, while in countries located in temperate zones, cereals (mainly corn) are more commonly used. Compared with corn-based or sugar beet-based ethanol, Brazil's sugarcane-based ethanol yields considerably more favorable results in terms of energy balance and in GHG emissions (Nigam & Singh, 2011).

Ethanol can be either blended with gasoline or burned in its pure form in internal combustion engines (Payne, 2010). Conventional engines can be fueled with a mixture of ethanol and gasoline containing, at most, 10% of ethanol. Special engines (among which the *flex-fuel* ones, that can run on either gasoline, ethanol or a mixture of the two) are required to use fuels containing higher proportions of ethanol. Cars endowed with special engines (*flexy-fuel*) are quite common in Brazil, where ethanol is blended with gasoline at higher percentages.

One liter of ethanol contains 66% of the energy contained in 1 liter of gasoline, but it has a higher octane level, so when it is mixed with gasoline improves performances and fuel combustion in vehicles. A more efficient combustion reduces emissions of carbon monoxide (CO), unburned hydrocarbons and carcinogens (among which sulfur oxide). However, the combustion of ethanol result in a reaction with the nitrogen in the atmosphere, which leads to a marginal increase in nitrogen oxide gasses (Payne, 2010).

### 1.1.2 Biodiesel

Biodiesel is produced by combining vegetal oil or animal fat with an alcohol and a catalyst through transesterification. Normally the oil needed for biodiesel production is extracted from oil crops such rapeseed (Europe) and soybean (Brazil and United States). In tropical countries, such as Indonesia and Malaysia, biodiesel is produced from coconut, jatropha, and, especially, palm oil.

The production of biodiesel yields some by-products that can be used as animal feed and to produce glycerine. Since biodiesel can be produced from many different kinds of oils, it is characterized by a wider range of viscosity and combustibility than ethanol. Its energy content is almost 95% of regular diesel but it helps improving its lubricity and raises the cetane value[1]. It also has a higher oxygen content than regular diesel and therefore helps reducing emissions of particulate air pollutants, carbon monoxide and hydrocarbons (Payne, 2010). Biodiesel has been mainly produced from edible vegetable oils (95%).

[1] It is a measure of the ignition quality of a diesel fuel. Fuels with a high cetane number will have short ignition delays, which correspond to greater efficiency, especially in case of cold weather. The cetane number for most plant oils is around 10-20% lower than that of fossil diesel (Russo, Dassisti, Lawlor, & Olabu, 2012).

However, since the rapidly growing world population is increasing food demand considerably, the production of biodiesel from different non-edible oilseed crops has been heavily investigated in recent years: alternative feedstock are cottonseed oil, opium poppy oil, jatropha oil, and rubber seed oil (Russo, Dassisti, Lawlor, & Olabu, 2012).

Biodiesel, similarly to ethanol, it is almost never sold in purity but blended with regular diesel. Usually the mixture used contains 80% regular diesel and 20% biodiesel. Although biodiesel could be used in purity, it is normally blended since, on the long term, it can have negative effects on engines, like erosion of some functioning parts and carbon build up. This is particularly true in the case of rapeseed oil.

Even though biodiesel can be produced from a wide range of different vegetable oils, the most commonly used ones are palm oil in Asian tropical countries, soybean oil in the United States and rapeseed oil in Europe. Also used vegetable fats (like oil used for frying) can be used for producing biodiesel but with negative repercussions on the quality of the final product.

## 1.2 Second-generation biofuels.

Second-generation biofuels are produced from biological or thermochemical processes using, as feedstock, agricultural lignocellulosic biomass, which can be either non-edible residues of food production or non-edible whole plant biomass (Nigam & Singh, 2011).

The main advantage of second generation biofuels is that their impact on food production and food prices is much lower than that of first generation ones. However, lower impact does not necessarily mean zero impact. Crops used for second generation biofuel production can still compete for land with food crops, therefore they can still have an indirect effect on both food production and food prices through land use changes.

Second-generation biofuels are more efficient than first-generation ones since a greater amount of above-ground plant material can be used to produce them. However, they also require much more sophisticated processing and production equipment, which in turn implies larger unit costs. Moreover, in order to reach economies of scale, very large production facilities are needed (Nigam & Singh, 2011).

Second-generation biofuels are still not ready to be produced at large scale: further research on feedstock production and conversion technologies is needed. Many countries, though, have been subsidizing research on second generation biofuels, especially now in a context characterized by high food prices.

Second-generation biofuels can be further classified into two broad categories according to the method used to convert the biomass into fuel: biochemical and thermochemical. Ethanol and butanol belong to the first category, while methanol, dimethyl ether and pyrolisis oils to the second one. Thermochemical biomass conversion require much more extreme temperatures and pressures than biochemical methods.

The most promising second generation biofuel is cellulosic ethanol, that is ethanol obtained from cellulose, hemicelluloses and lignin. Currently, for producing first-generation ethanol, only a very small fraction of a crop's total biomass (starch and sugar components) is used, while for producing second-generation ones the whole plant can be employed. There is currently much ongoing research on converting cellulosic biomass (the most abundant on earth) into ethanol but very little commercial production. Cellulosic biomass can come also from waste products from agriculture (straw, stalks, leaves) and forestry, waste generated from food processing and even organic parts of municipal waste. Potential crops that could be used as feedstock for cellulosic ethanol are short-rotation woody crops, fast-growing trees, and grassy species such as switchgrass (*Panicum Virgatum*). Since the entire crop can be used to produce fuel, it would be possible to produce more fuel per hectare of land than with current production systems. Furthermore, since some of the species suitable for cellulosic ethanol production can be grown on poor or degraded land, it would be possible to reduce competition for land with food crops (Payne, 2010).

## 1.3 Third-generation biofuels.

Even if second-generation biofuels address some of the problems caused by the exponential diffusion of first-generation ones (perturbations on food markets, increase in water consumption, increase in deforestation), they can still, indirectly, interfere with food production and prices, because they, to a certain extent, compete for land with food crops.

Therefore researchers are starting pay increasing attention to third-generation biofuels, produced from algae or with the help of micro-organisms. Some microbial species (yeast, fungi, and microalgae) can be used as a potential source of biofuels as they can biosynthesise and store large amounts of fatty acids in their biomass. Also algae, one of the oldest life-forms, can be used for biofuel production. They are present in all existing earth ecosystem. They can produce lipids, proteins and carbohydrates that can in turn be processed into biofuels and other useful co-products. However, the commercial production of biofuels from algae will be necessarily limited to areas with high solar radiation all year around. Currently only few private companies and some publicly-funded research groups are working on algae cultivation and on bringing the production of oil from algae down to levels competitive with those of gasoline (Nigam & Singh, 2011).

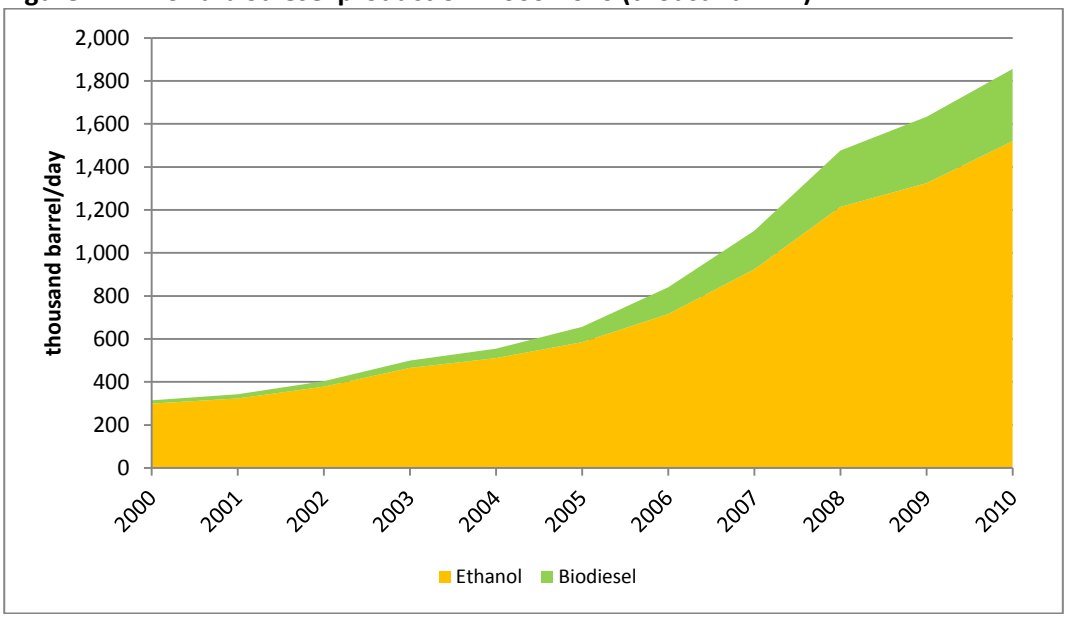
# 2 Production and international trade of biofuels and agricultural commodities used in biofuel production.

This chapter identifies the major players in the international biofuel and biofuel feedstock markets and provide insights on the markets analyzed in this research. Section 2.1 is about biofuel production, section 2.2 about biofuel trade, and section 2.3 on biofuel feedstock production, areas harvested, trade, and prices. Section 2.3 also includes a comparison between biofuel expansion and the evolution of agricultural production, areas harvested, and GHG emissions, highlighting possible interdependencies.

## 2.1 Biofuel production.

World biofuel production started to be recorded only recently, when it began to become significant thanks to the introduction of subsidies by both the US and Brazil. In ten years the world total output grew from 314.6 thousand barrels per day (BPD) in 2000 to over 1,855 in 2010. If in 2000 biodiesel accounted for less than 5% of the total biofuel production, in 2010 biodiesel's share increased to 18.1%, mainly thanks to government incentives in the European Union. Production growth had been exponential until 2008, while in the following two years slowed down, probably because of the world recession (Figure 2.1).

**Figure 2.1. World biodiesel production: 2000-2010 (thousand BPD).**



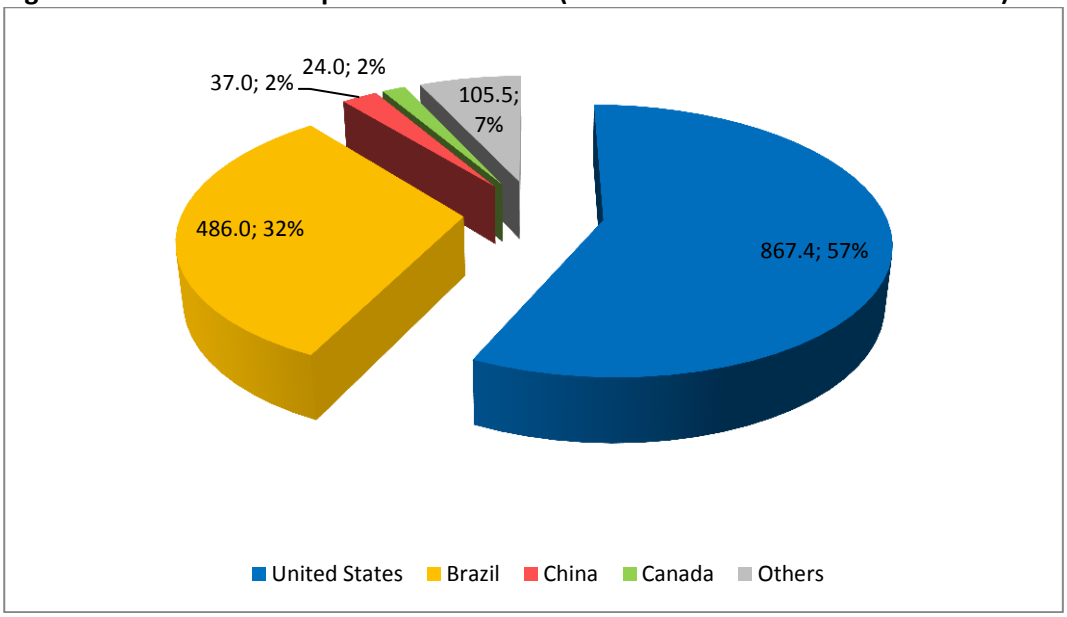

Source: own elaboration on US Energy Information Energy data.

In 2010 the main ethanol producing country was the United States, which output totaled 867.4 thousand BPD, up more than +21,6% from the previous year. The second-largest ethanol producer was Brazil, with 486.0 thousand BPD in 2010, 8.0% more than in 2009. The US output, in 2010, was more than eight times bigger than in 2000, while the Brazilian production was just 2.6 times larger than ten years

before. At the beginning of the decade Brazil was the leading ethanol producer, but the US public subsidies led the US ethanol sector to overtook the Brazilian one in 2006.

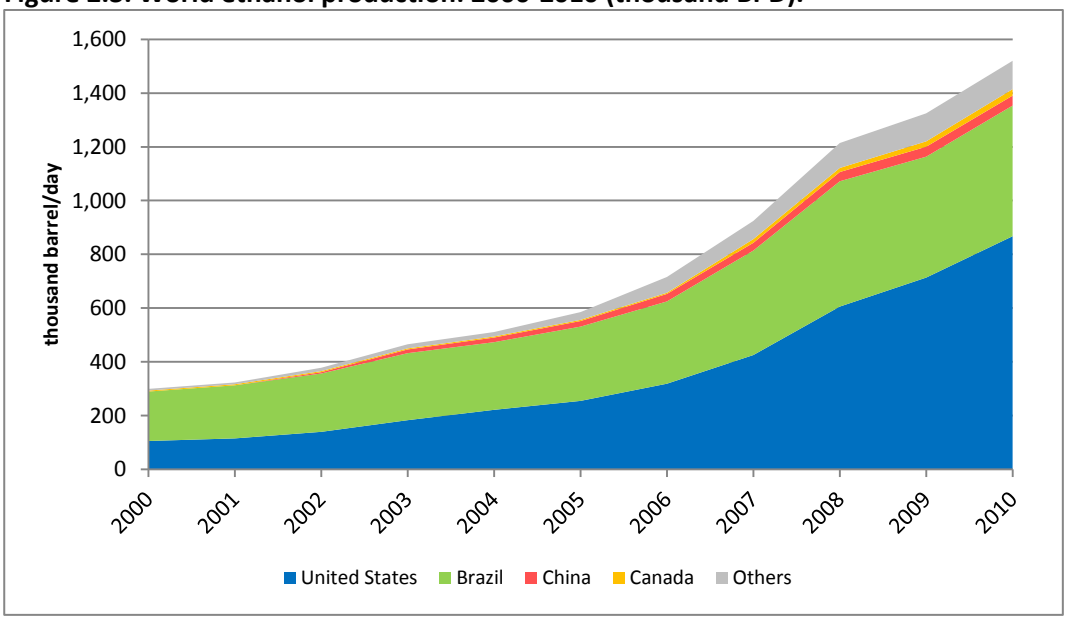
The two countries, in 2010, represented 89% of the world total ethanol output (Figure 2.2). However, production from other countries, even if still quite small if compared to the two main producers is steadily increasing, growing from 3.5% in 2000 to 11% of total world output in 2010. The third-largest producer, in 2010, was China, with 37 thousand BPD, a quantity almost stable with respect to the previous year. Other countries characterized by an output greater than 10 thousand BPD were Canada (24), France (18), and Germany (13). It must be highlighted the fact that China, in ten-year time, passed from not producing ethanol at all to be the third-largest producer in the world (Figure 2.3).

**Figure 2.2. World ethanol production in 2010 (thousand BPD and % on world total).**




Source: own elaboration on US Energy Information Energy data.

**Figure 2.3. World ethanol production: 2000-2010 (thousand BPD).**

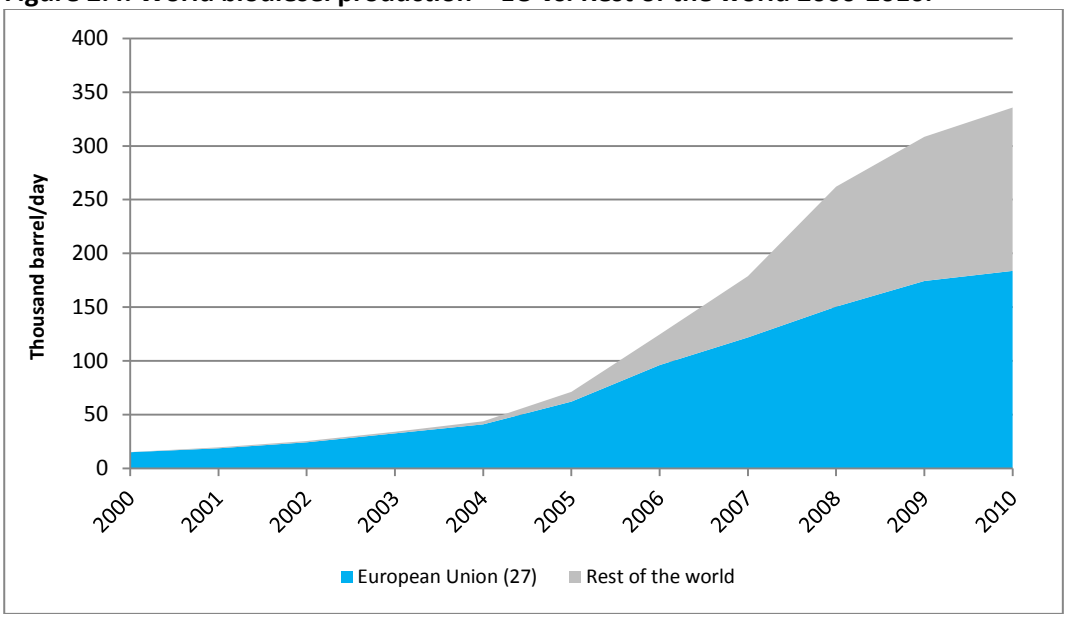



Source: own elaboration on US Energy Information Energy data.

When it comes to biodiesel, the picture changes significantly. The leading producing country is the European Union, which accounted for more than 50% of the total world output in 2010. EU production was equal to 173.7 thousand BPD, up +4,9% from 2009 levels. The second-largest producing country was Brazil, which output totaled 41.3 thousand BPD in 2010, almost 50% more than in 2009. Other big producers were Argentina (36.0 thousand BPD) and the United States (20.2). If Argentina's production increased by +55.8% with respect to 2009 levels, United States' decreased quite abruptly during the same time span (-39.0%). In 2000 almost all the biodiesel produced in the world was produced in the European Union but the output of other countries increased dramatically during the decade since even countries that have historically subsidized ethanol (like Brazil) have recently started supporting also biodiesel production (Figure 2.4).

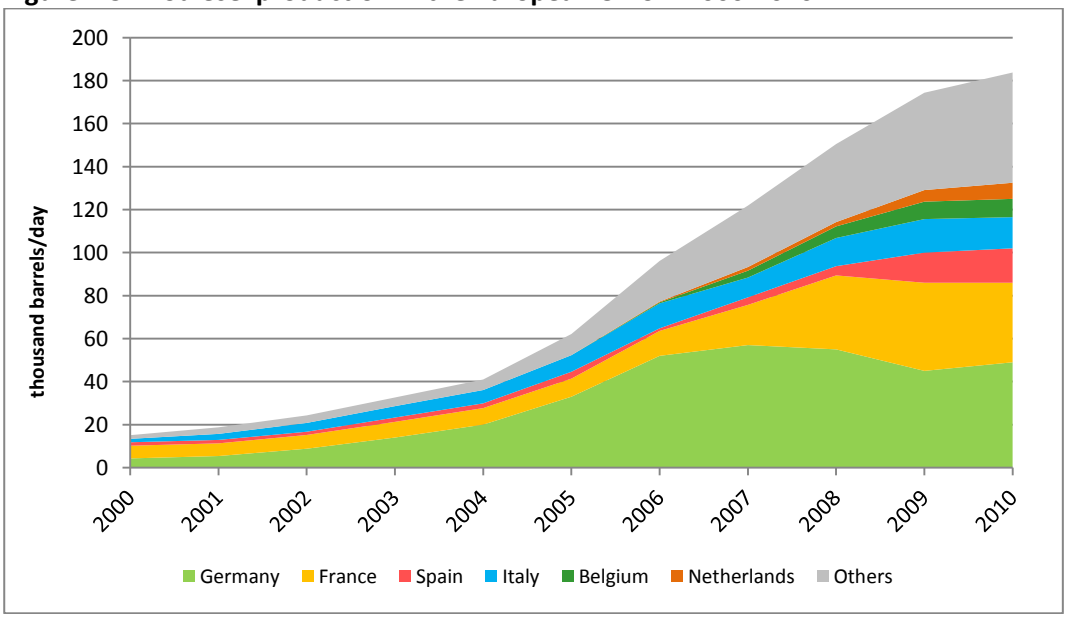
In 2010, within the European Union, Germany was the main producing country, with 49 thousand BPD, 8.8% up from 2009. The second-largest producer was France (37 thousand BPD), which output decreased by 9.8% from 2009 levels. Together, Germany and France, represented almost 47% of the whole EU production, a share that has been decreasing in the last 10 years: in 2000 the two countries accounted for more than 67% of the European output. Other large producing countries in 2010 were Spain and Italy, with 16 and 14.5 thousand BPD respectively. With respect to 2009, the Spanish output increased by +14.2% while the Italian one declined by -7.1%. During the last decade biodiesel production grew by more than 12 times in the European Union as a whole. In the main producing countries, biodiesel output increased 10 times in Germany, almost 5 times in France and 9 and 8 times in Spain and Italy (Figure 2.5).

**Figure 2.4. World biodiesel production – EU vs. Rest of the world 2000-2010.**




Source: own elaboration on US Energy Information Energy data.

**Figure 2.5. Biodiesel production in the European Union: 2000-2010.**




Source: own elaboration on US Energy Information Energy data.

## 2.2 Biofuel trade.

Although the biofuel sector has expanded substantially in recent years, due to policies promoted by many countries around the world, trade in biofuels is not very significant yet. Biofuel production is concentrated in the main producing countries, which are also those that are subsidizing more the sector. Most of the trade in biodiesel takes place within the European Union, where biodiesel is the leading biofuel. Ethanol trade is mainly a prerogative of the US and Brazil, with the latter being historically the leading exporting country.

Even if it is still relatively small, biodiesel trade is expanding rapidly. Since 2000, the WTO has received, by 20 member states, 37 notifications of measures in the context of the Agreement on Technical Barriers to Trade (WTO, 2012).

Until recently both ethanol and biodiesel used to be traded as agricultural products, however, in 2005, the World Custom Organization decided to put biodiesel in Chapter VI on "products of chemical and allied industries" (HS 3824.90), while bioethanol has always been traded under HS 2207, in Chapter XXII on "beverages, spirits and vinegar." Therefore, biodiesel, even if produced from agricultural biomass is considered a chemical product, while ethanol an agricultural one. This might have important implications since WTO regulations vary greatly across sectors. In any case, the WTO states that any outcome of the Doha negotiations (still in progress) on agriculture or non-agricultural market access will apply to the biofuel sector.

In this section the international trade of ethanol and biodiesel in analyzed in depth, through UN Comtrade data (at 6-digit level). These data, although in some cases incomplete, are the best source available on international trade. While in the case of ethanol, the HS classification is quite narrow and one can be reasonably sure that all flows of HS 2207 (undenatured and denatured ethyl alcohol) are in fact ethanol flows, in the case of biodiesel this is less straightforward since HS 3842.90 refers to "chemical products and preparations of the chemical or allied industries, not elsewhere specified or included, other." Put in another way, flows of HS 384290 might include also products other than biodiesel. Even though Eurostat do publish trade data up to 8 digits, they refer to the EU only so not useful to analyze world trade flows. For this reason it has been decided to use UN Comtrade data, less detailed (6 digits) but complete for all countries.

International biofuel trade is both supply and demand driven. The demand side is shaped by support policies , which generally increased the domestic market value of biofuels and trade takes place when policies are not accompanied by trade measures. Lamers et al. (2011) found that import duties largely influence trade volumes, while trade routes are mainly driven by tariff preferences. National trade policies have been causing market disruptions, trade inefficiencies and disputes. The authors claim that it is necessary to explicitly consider international trade implications of national trade policies and improve the quality of current statistics on biofuel production and international trade.

However, analyzing trade in biofuels only might be misleading since, while the final transformation from biomass to biofuel takes place in a given country, the biomass itself might have been produced elsewhere and then shipped to the country of production. This is particularly true in the case of biodiesel, which is obtained from vegetable oils such as rapeseed oil and palm oil. It is reasonable to think that biofuel producers, mainly located in Europe, might consider the option of importing palm oil from tropical countries in order to produce the biofuel they need to meet their consumption mandates. Of course, it is not possible to say whether a given quantity of corn or palm oil or rapeseed oil has been imported to

produce food, feed or biofuels. In other words, biofuel expansion might have triggered an increase in the trade of certain agricultural commodities but it is difficult to say to what extent. Since it is reasonable to think that almost all of the ethanol produced in the US is from domestic corn (the US is the biggest corn producer and exporter in the world) and all ethanol produced in Brazil is from Brazilian sugarcane, it is vegetable oil trade the one that might have been affected the most by biofuel policies.

This section is structured as follows: sub-section 2.2.1 contains a review of current policies and measures affecting the international biofuel trade, subsection 2.2.2. analyzes, on the basis of UN Comtrade data, international biofuel trade flows in the last two decades, while subsection 2.2.3. is about international vegetable oil trade and sub-section 2.2.4 provides some final considerations.

### 2.2.1 Policies and measures affecting biofuel trade.

Support policies in favor of biofuels can be grouped in three main categories since they can aim at different stages of the supply chain. The first category is made up by measures aimed at promoting domestic consumption through consumption mandates. Examples are minimum biofuel content in conventional fuels, minimum GHG saving through biofuels or incentives, like tax exemptions for the fuel at the pump of promotion of dedicated biofuel vehicles. The second category contains measures that promote domestic production via production mandates, investment support for production facilities, demonstration projects, infrastructure or R&D, feedstock support or tax incentives (like the former US excise tax exemption). The third group of measures refers to trade-related measures, which shield local production (and therefore market prices) via protective measures like import tariffs, eligibility requirements within biofuel quota and quality standards. Trade measures can also prevent exports thought export tariffs. Most of the countries implement a portfolio of measures, which are briefly reassumed in the following paragraphs.

#### *2.2.1.1 Biofuel trade policies in the European Union.*

Biofuel production, in the EU, started to increase substantially during the 90s, when the Common Agriculture Policy (CAP) began indirectly subsiding it through guaranteed minimum prices, per-hectare payments and set-aside payments for land that could be nonetheless used for biofuel production. In 2003, the Fischler reform introduced a crop premium for the production of energy crops on basic land. Always in 2003 the EU implemented the so-called Biofuels Directive (2003/30/EC) that introduced biofuel quotas by energy content thus requiring member states to guarantee a minimum market share for biofuels. Targets were 5.75% by 2010 and 10% (in the transport sector) by 2020. In order to help member states (MS) in reaching the targets, the EU allowed MS to exempt or reduce excise duties on biofuels through the Energy Tax Directive 2003/96/EC. Even though the tax incentives and quotas spurred production, the 2005 target

was not met so the EU decided to revise the policy. A revision was needed also because of the international debate on the real effectiveness of biofuels and rising agricultural commodity prices. The current EU approach is reflected by the Renewable Energy and Fuel Directive (RED, 2009/28/EC) and the Fuel Quality Directive (FQD, 2009/30/EC). The RED requires an overall 10% share of renewable energy in the transport sector in 2020 for all member states. It also provides mandatory sustainability criteria (that have been heavily criticized, a review of such critics is provided in chapter 4), which at the moment takes into consideration direct land use changes only. The FQD aims at a 6% reduction of GHG emissions from fuel consumed in the EU by 2020 by introducing technical regulations for gasoline, diesel and gas oil as well as sustainability criteria similar to those of the RED. Several technical industry standards for fuels provided in the FQS might be regarded as potential non-tariff barriers to trade.

EU biofuel trade regimes are governed by various regulations which define import duties and tariff preferences, which are in turn differentiated between commodity and country of origin. Preferential access to the EU market is given for goods from developing countries under the *Generalized System of Preferences* (GSP), the GSP+, the *Cotonou Agreement*, the *Everything But Arms Initiative* and the *Economic Partnership Agreement*. As stated earlier, it is difficult to analyze biodiesel flows because the category under which they are classified (HS 3824.90) consists of several sub-categories and it is not clear which of them is primarily used for biodiesel trade. This uncertainty created problems also to the EU when in 2009 it established an anti-dumping countervailing duty against US biodiesel imports, and the list of goods under the duty had to be updated in 2010 with other sub-categories that were not included at the first place. All EU tariff lines apply to biofuel concentration of B20 or higher, meaning that B19 mixtures do not fall under these tariffs, therefore creating further ambiguity.

Trade regimes for vegetable oils, that is the substance from which biodiesel is made, are similar. A duty of 3.2% (*ad valorem*) is imposed on imports of vegetable oils that compete with EU vegetable oil production (rapeseed, sunflower, and soy oil). Soybean, rapeseed, and palm oil enter the EU duty-free.

Some tariffs are in place also for ethanol but many countries, including Brazil, are exempted. Tariffs on imported ethanol are in place since 2000 but, experts say, it is very difficult to verify the purpose of imported ethanol due to the various end uses: industrial, pharmaceutical and beverage (Lamers, Hamelinck, Junginger, & Faaij, 2011).

#### *2.2.1.2 Biofuel trade policies in the United States.*

The structure of the US biofuel support policies is similar to the EU's since the implementation of federal targets is left to individual states. In 2005, the *Energy Policy Act* was passed, which contained a Renewable Fuels Standard (RFS1) that prescribed the production of 7.5 billion gallons (or 28.4 billion liters) of biofuels by 2012. This target was reached already in 2008 since many states banned methyl tertiary butyl ether as petrol additive, which was largely replaced with ethanol.

In 2007 the Energy Independence Fuels Standard (RFS2) emended the RFS1 and fixed a 36 billion gallons (or 136.3 billion liters) biofuel production target by 2022. The target is split in two sub-targets for conventional and advanced biofuels depending on their ability in reducing GHG emissions. Conventional biofuels (>20% GHG savings) are allowed to contribute for 15 billion gallons (56.8 billion liters) and will be mostly represented by corn ethanol. Advanced biofuels (> 50% GHG savings) will cover the remaining 21 billion gallons (79.5 billion liters). Biodiesel is considered an advanced biofuel and its share must not be lower than 1 billion gallons (3.8 billion liters), while the share of cellulosic ethanol must also be at least 16 billion gallons (60.6 billion liters). It is important to highlight the fact that corn-based US ethanol is considered a conventional biofuel, while sugarcane Brazilian ethanol is considered advanced. Until January 2012 also Volumetric Excise Tax Credits (VETC) for the blending of fuel ethanol and biodiesel were in place. They were the largest biofuel subsidy in the US since they were neither capped nor linked to oil price developments but they rose in correlation to the amount of domestic consumption and exports. other forms of support are capital investment support measures, such as loans, grants, guarantees for the construction of biofuel plants, governmental investment in infrastructure for transport, storage, distribution of biofuels, and crop subsidies (especially for corn) (Lamers, Hamelinck, Junginger, & Faaij, 2011).

Like in the EU, US biofuel trade regimes are differentiated between commodities and country of origin. Preferential access is granted to developing countries and members of the North American Free Trade Agreement (NAFTA) and the Caribbean Basin Initiative (CBI). The US has one code for biodiesel (HS 3824.90.40.30), which applies to B30[2] or higher and imposes a 4.6% ad valorem duty in imports from countries with which the US does not have any free-trade agreement. Import duties on vegetable oils and biodiesel feedstock apply largely to commodities competitive to local production with the exception of soybeans, which are duty-free.

US ethanol production is protected from international competition through a 2.5% ad valorem rate for undenatured and a 1.9% ad valorem rate for denatured ethanol. Some countries can import ethanol duty-free as long as they stay below a quota set by the US International Trade Commission every year. Since imported ethanol could still qualify for the excise tax credit within the US, an additional duty of US$ 0.1427 was leveled on ethanol imports but not for biofuel imports (Lamers, Hamelinck, Junginger, & Faaij, 2011).

#### *2.2.1.3 Biofuel trade policies in the rest of the world.*

Biodiesel markets are very closely linked to vegetable oil markets, that it those for palm soybean and rapeseed oil. Indonesia and Malaysia are the most important palm oil exporting countries, Argentina

[2] B30 means a mixture of diesel and biodiesel in which biodiesel's share is 30%.

and Brazil for soybean oil and Canada for rapeseed oil. Among these Indonesia, Malaysia and Argentina are also key biodiesel exporting countries.

In Brazil the government introduced a mandatory biodiesel quota of 2% in 2010 progressively increased to 5% by 2010. Biodiesel production is encouraged also through purchase auctions, tax reductions/exemptions and a 14% import tariff.

In Argentina the biodiesel sector is very export-oriented. In Argentina export taxes on agricultural products are in place in order to keep domestic prices low. However, these taxes are 18.5% lower than soybean oil in the case of biodiesel. Biodiesel producers are also granted tax exemptions. Argentina has recently introduced a 5%-minimum blending requirement for biodiesel.

### 2.2.2 International biofuel trade flows

International biofuel trade flows have been analyzed through the UN Comtrade database, which is considered the most complete trade database in the world. Trade data are available up to a 6-digit level. Even though, especially in the case of biodiesel, a 6-digit level of detail might not be enough to isolate the effective trade of the commodities of interest from that of other goods (the EU tariff scheme for biodiesel refers to 10-digit codes), it should be enough to, at least, give an idea about the order of magnitude of trade flows. Ethanol trade is classified under HS 2207[3], while biodiesel trade is under HS 3824.90[4]. Only figures in volume have been analyzed and quantities, when expressed in kilograms, have been converted into liters (this is because for some years volumes traded are reported in kilograms and for some others in liters) through conversion coefficients[5].

#### *2.2.2.1 International ethanol trade.*

Brazil and the US are, by-far, the most important ethanol producing countries in the world and they have also dominated the international trade of the commodity in the last two decades. The two countries are the most important ethanol exporting and importing countries.

Over the past two decades, the international ethanol trade grew exponentially. In 1990 world ethanol exports amounted to little more than 300 million liters, while they reached 9.9 billion liters in 2011. In the last ten years Brazil, the US and, to a lesser extent, the EU have been the almost exclusive ethanol consumers in the world. Consumption in other countries can be considered marginal. Brazil, in the last ten years has been, by far, the major ethanol exporter, even if in 2011 it imported large quantities of ethanol

[3] 2207.10 – "Undenatured ethyl alcohol of an alcoholic strength by volume of 80 % vol. or higher" and 2207.20 – "Ethyl alcohol and other spirits, denatured, of any strength."
[4] 3824.90 – "Binders made for foundry moulds or cores; chemical products and preparations, including residual products, of the chemical or allied industries, nesoi, Others."
[5] Density of denatured ethanol is 0.78934 Kg/l, density of undenatured ethanol at 80% volume is 0.82062 Kg/l, while biodiesel density is 0.875 Kg/l.

from the US due to domestic supply problems. All Brazilian ethanol exported to Caribbean countries has, as final destination, the US and most of the ethanol trade taking place within the EU is, in fact, re-exporting of ethanol shipped from Brazil or other countries.

In 2011 (the last year for which data were available), the United States was the leading exporter of ethanol in world with over 3.8 billion liters shipped abroad. In 2011 the United States replaced Brazil as major exporting country. US exports rose by over 238% with respect to 2010, while Brazilian ones almost stagnated (+3.3%), for a total quantity of nearly 2 billion liters (Table 2.1). This is explained by the fact that Brazil, in 2001, was hit by a severe drought that jeopardized sugar cane production, therefore forcing the country to buy abroad (in the US) the ethanol it needed to meet its consumption targets.

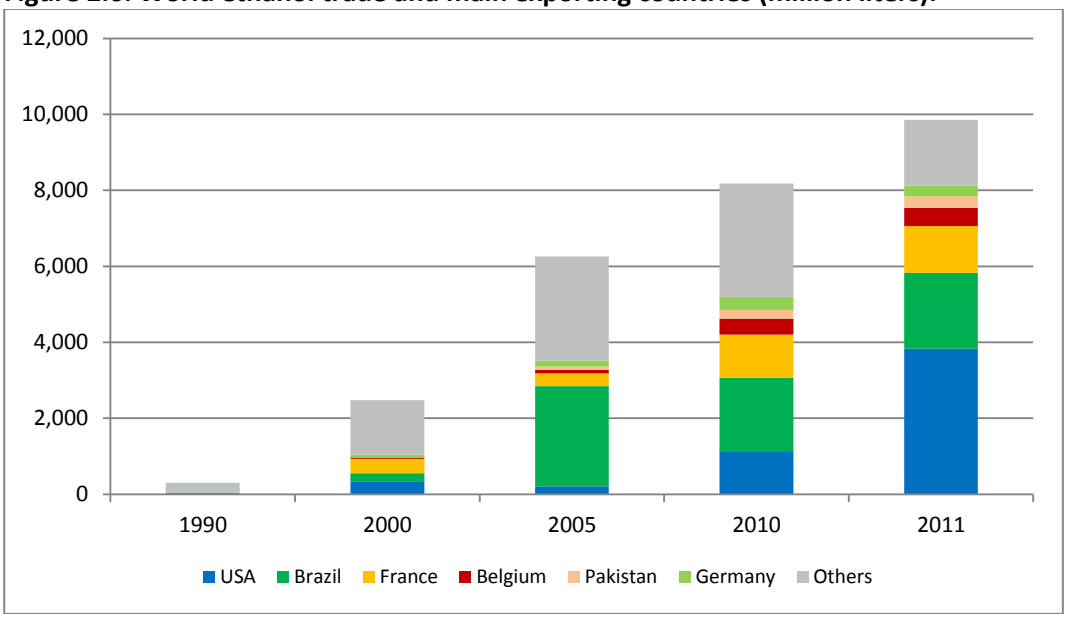
**Table 2.1. Most important ethanol exporting countries in volume (million liters).**

| Country | 1990 | 2000 | 2005 | 2010 | 2011 | % Changes | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 2011/10 | 2011/05 | 2011/96 |
| USA | 0.0 | 323.9 | 211.5 | 1,133.3 | 3,831.6 | *238.1* | *1,711.2* | *n.a.* |
| Brazil | 37.7 | 230.5 | 2,637.1 | 1,932.0 | 1,995.1 | *3.3* | *-24.3* | *5,187.2* |
| France | 0.0 | 379.8 | 337.7 | 1,135.3 | 1,232.0 | *8.5* | *264.8* | *n.a.* |
| Belgium | 0.0 | 32.6 | 88.2 | 427.4 | 484.6 | *13.4* | *449.7* | *n.a.* |
| Pakistan | 0.0 | 0.0 | 86.2 | 223.9 | 303.1 | *35.4* | *251.5* | *n.a.* |
| Germany | 0.0 | 73.5 | 156.0 | 341.6 | 275.1 | *-19.5* | *76.3* | *n.a.* |
| South Africa | 0.0 | 122.9 | 250.5 | 179.2 | 156.3 | *-12.8* | *-37.6* | *n.a.* |
| Slovakia | 0.0 | 0.0 | 1.4 | 87.6 | 94.8 | *8.2* | *6,601.2* | *n.a.* |
| Guatemala | 0.0 | 32.5 | 57.6 | 123.6 | 92.9 | *-24.9* | *n.a.* | *n.a.* |
| United Kingdom | 0.0 | 187.6 | 320.5 | 42.8 | 58.1 | *35.8* | *-81.9* | *n.a.* |
| Others | 266.0 | 1,095.4 | 2,114.9 | 2,556.1 | 1,332.6 | *-47.9* | *-37.0* | *400.9* |
| EU (27) | 0.0 | 155.1 | 45.7 | 61.6 | 68.5 | *11.1* | *49.9* | *n.a.* |
| **World** | **303.7** | **2,478.6** | **6,261.7** | **8,182.8** | **9,856.2** | ***20.5*** | ***57.4*** | ***3,144.9*** |

Source: own calculations on UN Comtrade data.

In 2011 the third-largest ethanol exporting country was France (1.2 billion liters, 8.5% up from 2010), which supplied most exclusively the German market. Together, the US, Brazil, and France represented more than 70% of world ethanol exports in 2011. Other countries which ethanol exports are not negligible are Belgium, Pakistan, and Germany that in 2011 exported 485, 303 and 275 million liters of ethanol respectively (Figure 2.6).

**Figure 2.6. World ethanol trade and main exporting countries (million liters).**




Source: own calculations on UN Comtrade data.

The external trade of the EU is limited. In 2011 the EU exported just 69 million liters of ethanol, meaning that most of the trade of its member states takes place within the Union.

In 1990 only Brazil, among the 10 most important exporting countries in 2011, was selling ethanol abroad, while flows from countries such as the US and France were zero. US exports grew exponentially over the period, while Brazilian ones grew until the mid-2000s and then started to decline: from 2005 to 2011 exports decreased by -24.3%. Brazilian exports reached an all-time high in the mid-2000s, when, due to high international crude oil prices, Brazilian ethanol was cost competitive despite EU and US tariffs. The subsequent decline is due to the fact that Brazil had to decrease its ethanol production and divert part of the sugarcane to sugar production to “fill the gap” created in the international sugar market by a decrease in production in other sugar producing nations such as India.

As stated earlier, most of US ethanol exports went to Brazil in 2011: as a matter of fact the strong increase in total ethanol exports that the US experienced in 2011 is due to the large amount of ethanol shipped to Brazil: 1.3 billion liters. This is quite surprisingly since in 2010 the US exported just 55 million liters to Brazil and the South American country has historically been a net exporter of the commodity, especially to the US. Other important destination markets for US ethanol, in 2011, were Canada (823 million liters), the Netherlands (416 million liters) and the United Kingdom (371 million liters). Over the years the importance of the Mexican market, for US exports, decreased (

Table 2.2).

**Table 2.2. United States: ethanol exports by country of destination (million liters).**

| Country | 1990 | 2000 | 2005 | 2010 | 2011 |
|---|---|---|---|---|---|
| Brazil | 205.9 | 0.3 | 0.5 | 54.9 | 1,347.6 |
| Canada | 2.5 | 78.7 | 95.2 | 342.8 | 822.6 |
| Netherlands | 10.1 | 23.5 | 12.6 | 197.3 | 415.6 |
| United Kingdom | 3.9 | 2.2 | 8.2 | 80.3 | 371.3 |
| United Arab Emirates | 0.1 | 3.6 | 0.1 | 73.3 | 188.2 |
| Finland | 0.4 | 0.0 | 2.4 | 33.6 | 135.5 |
| Mexico | 12.2 | 57.0 | 23.8 | 69.0 | 128.2 |
| Nigeria | 0.0 | 1.0 | 0.0 | 28.0 | 71.5 |
| Jamaica | 0.0 | 0.1 | 0.5 | 47.4 | 53.2 |
| Philippines | 0.0 | 0.7 | 0.0 | 23.6 | 46.8 |
| Others | 151.7 | 156.8 | 68.2 | 183.2 | 251.1 |
| **World** | **386.8** | **323.9** | **211.5** | **1,133.3** | **3,831.6** |

Source: own calculations on UN Comtrade data.

In 2011, main destination markets for Brazilian ethanol were the US (686 million liters), South Korea (384 million liters), Japan (267 million liters), Jamaica (141 million liters), and Trinidad and Tobago (140 million liters). Form these data one can see that, even though Brazil imported large quantities of ethanol from the US in 2011, it also exported to the North American country considerable quantities. This phenomenon, known as intra-industry trade, might indicate the fact that the ethanol market is not well integrated in Brazil, and therefore gasoline blenders might not be able to get the ethanol they need on the domestic market (even if it is present) and are forced to import it from abroad. Finally, the fact that Brazil exports large quantities of ethanol to small Caribbean countries is explained by the fact that Brazilian ethanol exporters use the Caribbean free-trade agreements of the US as a stratagem to import their ethanol to the US duty-free (Table 2.3)

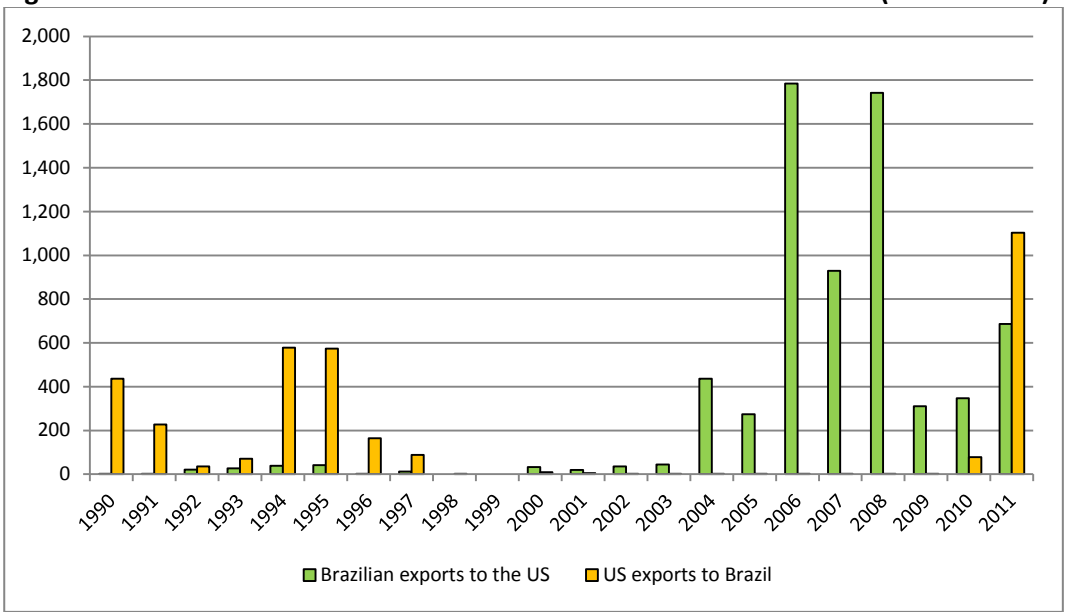
**Table 2.3. Brazil: ethanol exports by country of destination (million liters).**

| Country | 1990 | 2000 | 2005 | 2010 | 2011 |
|---|---|---|---|---|---|
| USA | 0.1 | 33.4 | 274.8 | 347.5 | 685.9 |
| South Korea | 0.0 | 35.8 | 221.5 | 384.3 | 307.3 |
| Japan | 31.9 | 57.7 | 322.3 | 267.4 | 286.7 |
| Jamaica | 0.0 | 25.5 | 136.6 | 142.0 | 140.6 |
| Trinidad and Tobago | 0.0 | 0 | 37.0 | 6.8 | 139.3 |
| Netherlands | 5.8 | 37.2 | 268.1 | 243.3 | 97.8 |
| Switzerland | 0.0 | 10.1 | 10.0 | 53.3 | 81.4 |
| Nigeria | 0.0 | 3.3 | 121.3 | 82.1 | 75.4 |
| El Salvador | 0.0 | 0.0 | 151.6 | 0.0 | 51.3 |
| India | 0.0 | 0.0 | 420.0 | 60.0 | 28.3 |
| Others | 0.0 | 27.3 | 674.1 | 345.3 | 101.2 |
| **World** | **37.7** | **230.5** | **2,637.1** | **1,932.0** | **1,995.1** |

Source: own calculations on UN Comtrade data.

Figure 2.7 illustrates Brazilian-American bilateral trade in ethanol since 1990. From the picture one can see that during the 90s Brazil was occasionally importing moderate quantities of ethanol from the United States, probably to integrate domestic production. It must be noted that, in that period, Brazil ethanol production was declining due to the end of some support programs. Only at the end of the decade the Federal Government started to invest in the sector again. In the second half of the 2000s, Brazilian exports to the US boomed (even without taking into consideration those passing through Caribbean countries) since Brazilian ethanol was very cost-competitive due to high oil prices. When oil price dropped, in 2009-2010, Brazilian exports also declined. In 2011 bad weather negatively affected the Brazilian sugar cane production and forced Brazil to buy large quantities of ethanol from the United States.

**Figure 2.7. Bilateral ethanol trade between Brazil and the United States (million liters).**



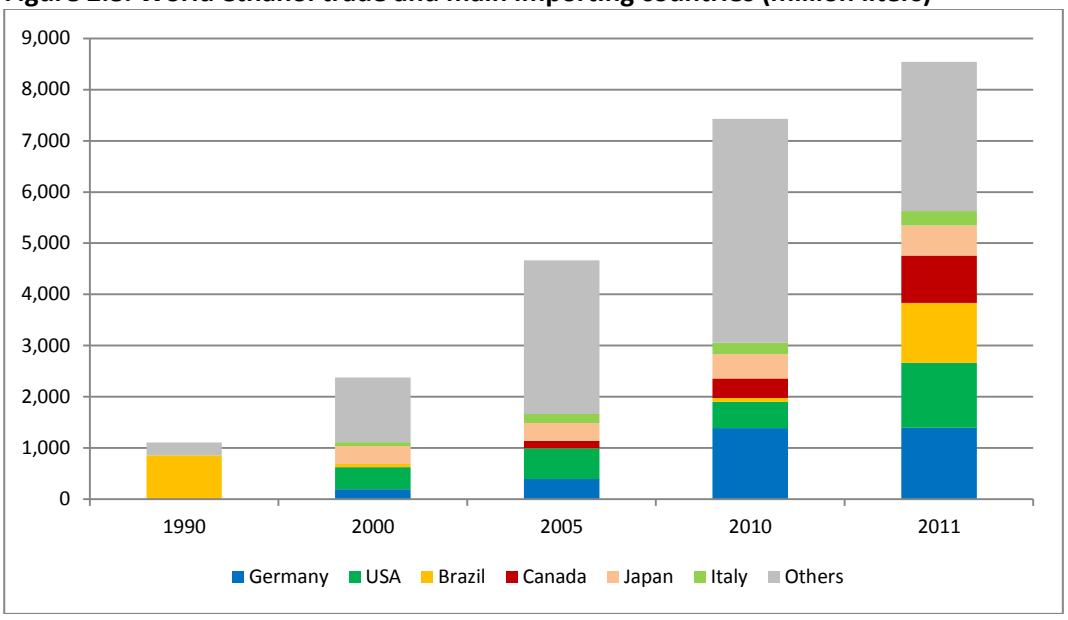

Source: own calculations on UN Comtrade data.

In 2011 the most important ethanol importing country was not Brazil nor the United States, but Germany, which bought on the international market almost 1.4 billion liters of ethanol, most of it from France (Figure 2.8). The United States and Brazil imported, more or less the same quantity of ethanol, almost 1.2 billion liters. The most important (and almost only) Brazilian supplier was the United States, with more than 1.1 billion liters. The United States imported ethanol mainly from Brazil (781 million liters), Caribbean countries like Jamaica and Trinidad and Tobago (for a total of about 300 million liters) and, marginally, Canada, and El Salvador.

Other important importing countries were Canada and Japan that, in 2011, imported respectively 928 and 586 million liters. Most of the ethanol entering Canada was from the United States, while the major supplier of Japan was Brazil. The European Union imported, from third countries, 513 million liters of ethanol, an amount that has been decreasing since the mid-2000s, maybe because of increasing domestic production (Table 2.4). Over the last two decades imports have expanded in all major importing countries. In some cases the increase was gradual (Japan, South Korea), while in the case of Germany and the United States, the process speeded up in the last few years. Brazilian imports passed from being very high (860 million liters in 1990) to almost zero in the mid-2000s to increase again substantially in the last two years, due to the bad weather that negatively affected sugar cane production.

The EU imports one-third of its ethanol from Brazil, while the rest is more or less equally distributed between Egypt, Pakistan, Peru, the US, and Guatemala (40 to 60 million liters from each country).

**Figure 2.8. World ethanol trade and main importing countries (million liters)**




Source: own calculations on UN Comtrade data.

**Table 2.4. Most important ethanol importing countries in volume (million liters).**

| Country | 1990 | 2000 | 2005 | 2010 | 2011 | % Changes 2011/10 | % Changes 2011/05 | % Changes 2011/96 |
|---|---|---|---|---|---|---|---|---|
| Germany | n.a. | 196.9 | 393.8 | 1,391.4 | 1,396.9 | *0.4* | *254.7* | *n.a.* |
| USA | n.a. | 428.9 | 604.0 | 507.5 | 1,267.8 | *149.8* | *109.9* | *n.a.* |
| Brazil | 859.3 | 64.8 | 0.2 | 79.5 | 1,166.2 | *1,366.5* | *499,823.4* | *n.a.* |
| Canada | n.a. | n.a. | 140.8 | 377.0 | 928.0 | *146.1* | *559.0* | *n.a.* |
| Japan | n.a. | 347.0 | 347.5 | 478.4 | 586.1 | *22.5* | *68.7* | *n.a.* |
| Italy | n.a. | 74.0 | 174.9 | 222.8 | 284.6 | *27.8* | *62.8* | *n.a.* |
| Rep. of Korea | 89.0 | 203.4 | 241.2 | 261.9 | 280.9 | *7.3* | *16.5* | *215.6* |
| Philippines | n.a. | 37.0 | 49.6 | 307.0 | 246.1 | *-19.8* | *395.8* | *n.a.* |
| Sweden | n.a. | 21.5 | 180.0 | 210.3 | 195.6 | *-7.0* | *8.7* | *n.a.* |
| United Kingdom | n.a. | 76.1 | 326.8 | 291.2 | 185.7 | *-36.2* | *-43.2* | *n.a.* |
| Others | 162.3 | 926.1 | 2,208.1 | 3,304.4 | 2,000.9 | *-39.4* | *-9.4* | *1,132.9* |
| EU (27) | n.a. | 139.1 | 692.3 | 571.4 | 513.1 | *-10.2* | *-25.9* | *n.a.* |
| **World** | **1,110.6** | **2,375.8** | **4,667.0** | **7,431.5** | **8,538.9** | ***14.9*** | ***83.0*** | ***668.9*** |

Source: own calculations on UN Comtrade data.

Within the EU, production is concentrated in France, Germany, Spain, the Benelux and Poland. These countries are also the most important consumers. Imports to these countries have grown substantially in recent years because of high grain and oil prices that made international ethanol imports, especially from Brazil, particularly cost-competitive, despite import tariffs. Since 2002 almost 90% of total EU ethanol imports have been of undenatured ethanol, despite the fact the entry tariff is almost twice than that of denatured ethanol. Over the years there have been many efforts to circumvent EU ethanol tariffs.

The most popular one was the so-called “Swedish Loophole” that exploited the absence of specific fuel ethanol codifications. Ethanol was imported under alternative tariff lines (with lower duties). Specifically, ethanol was mixed with gasoline (12.5-20%) just prior to customs declaration, in order to be imported into Sweden under the “other chemicals” tariff line (6.5% rather than 63% for undenatured and 39% for denatured). Moreover ethanol imported to Sweden was eligible for tax exemptions as a biofuel until 2006 but from 2007 only biofuel entering under the higher duty could benefit from the tax break. Brazilian ethanol import to the EU are however likely to decline by 2013 because of the new sustainability requirements of the EU Renewable Energy Directive (Lamers, Hamelinck, Junginger, & Faaij, 2011).

#### *2.2.2.2 International biodiesel trade.*

In 2011, the most important biodiesel importers were all European countries, since the EU is the leading biodiesel producer in the world, however, in the last few years exports from countries such as China, Argentina and Indonesia increased substantially. In Argentina and South-East Asian countries, biodiesel production is export-oriented, while in the EU it is spurred by consumption targets. Within the EU, trade balance varies across individual member states: in Germany and the Netherlands, for instance, EU-external trade is not very important, while for Spain and Italy it is of great significance. This is explained by the fact that the major biodiesel production facilities are located in Central and Northern European countries, often nearby big harbors such as Rotterdam’s or Hamburg’s where imported vegetable oils are transformed into biodiesel. Other countries, like Spain and Italy, do not have transformation facilities and have to import biodiesel from third countries to meet their consumption targets.

Among the top European exporters, only biodiesel from Germany can be assumed to locally produced, while volumes originated in the Netherlands and in Belgium can be assumed to be re-exports of international imports.

In 2011 the biggest biodiesel exporting country in the world was the Netherlands, with 4.5 billion liters, followed by Germany with 4.1 billion liters and China with 2.7 billion liters. Other important exporting countries were Argentina (2.0 billion liters), United States (1.6 billion liters), Indonesia (1.6 billion liters) and Belgium (1.5 billion liters). In all cases trade flows increased from 2010 levels, especially in the case of Indonesia (+126.7%), the Netherlands (+65.6%), and Argentina (+20.9%) (Table 2.5)

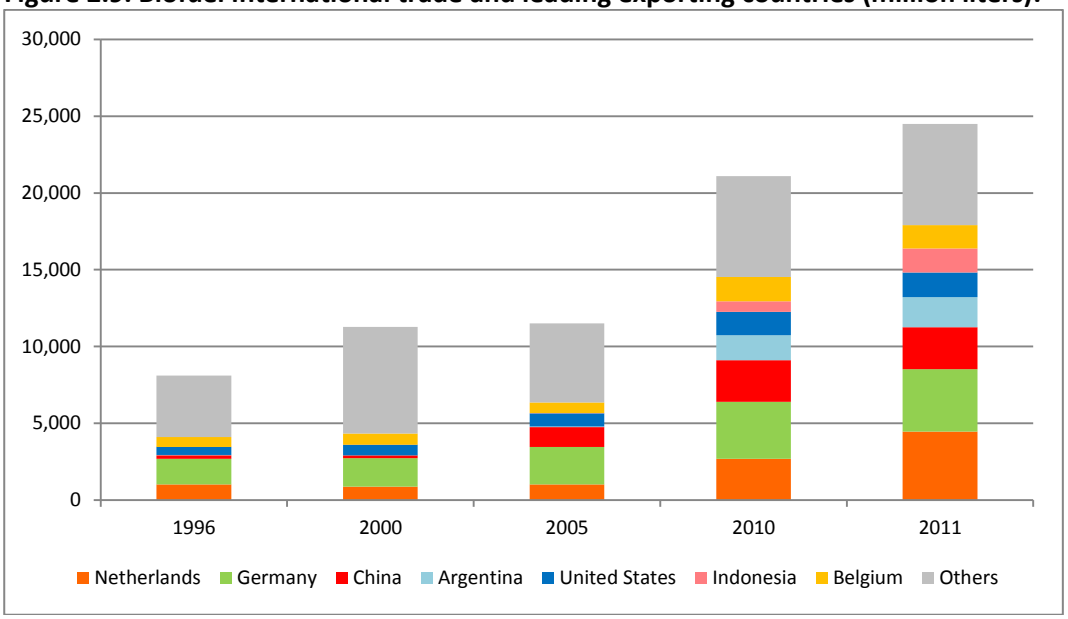
**Table 2.5. Most important biodiesel exporting countries in volume (million liters).**

| Country | 1996 | 2000 | 2005 | 2010 | 2011 | % Changes | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 2011/10 | 2011/05 | 2011/96 |
| Netherlands | 1,025.5 | 879.9 | 1,034.5 | 2,699.8 | 4,470.8 | *65.6* | *332.2* | *336.0* |
| Germany | 1,675.9 | 1,862.3 | 2,421.5 | 3,704.6 | 4,058.8 | *9.6* | *67.6* | *142.2* |
| China | 218.1 | 174.8 | 1,295.4 | 2,710.4 | 2,726.2 | *0.6* | *110.5* | *1,149.7* |
| Argentina | 12.4 | 11.2 | 41.4 | 1,614.5 | 1,952.5 | *20.9* | *4,614.0* | *15,586.1* |
| United States | 531.6 | 672.7 | 865.7 | 1,527.4 | 1,604.3 | *5.0* | *85.3* | *201.8* |
| Indonesia | 5.2 | 5.2 | 17.0 | 691.2 | 1,567.2 | *126.7* | *9,142.9* | *29,817.0* |
| Belgium | 641.9 | 741.3 | 680.8 | 1,579.4 | 1,531.1 | *-3.1* | *124.9* | *138.5* |
| France | 530.3 | 719.6 | 895.6 | 716.3 | 758.8 | *5.9* | *-15.3* | *43.1* |
| United Kingdom | 249.9 | 428.0 | 383.8 | 280.2 | 509.5 | *81.8* | *32.7* | *103.9* |
| Italy | 189.5 | 338.7 | 496.2 | 457.1 | 469.7 | *2.7* | *-5.3* | *147.8* |
| Others | 3,025.1 | 5,435.8 | 3,384.1 | 5,105.7 | 4,841.4 | *-5.2* | *43.1* | *60.0* |
| **World** | **8,105.7** | **11,269.5** | **11,515.7** | **21,086.5** | **24,490.2** | ***16.1*** | ***112.7*** | ***202.1*** |

Source: own calculations on UN Comtrade data.

During the last 15 years (biodiesel trade data are available only since 1996), the main exporting countries remained, more or less, the same, with the notable exceptions of Argentina, Indonesia, and China, which exports expanded exponentially. These countries passed from almost not exporting biodiesel at all to being leading exporting countries. Like in the case of ethanol, exporting countries are relatively few: the first 6 exporters, in 2011, represented more than 73% of total exports (Figure 2.9).

**Figure 2.9. Biofuel international trade and leading exporting countries (million liters).**

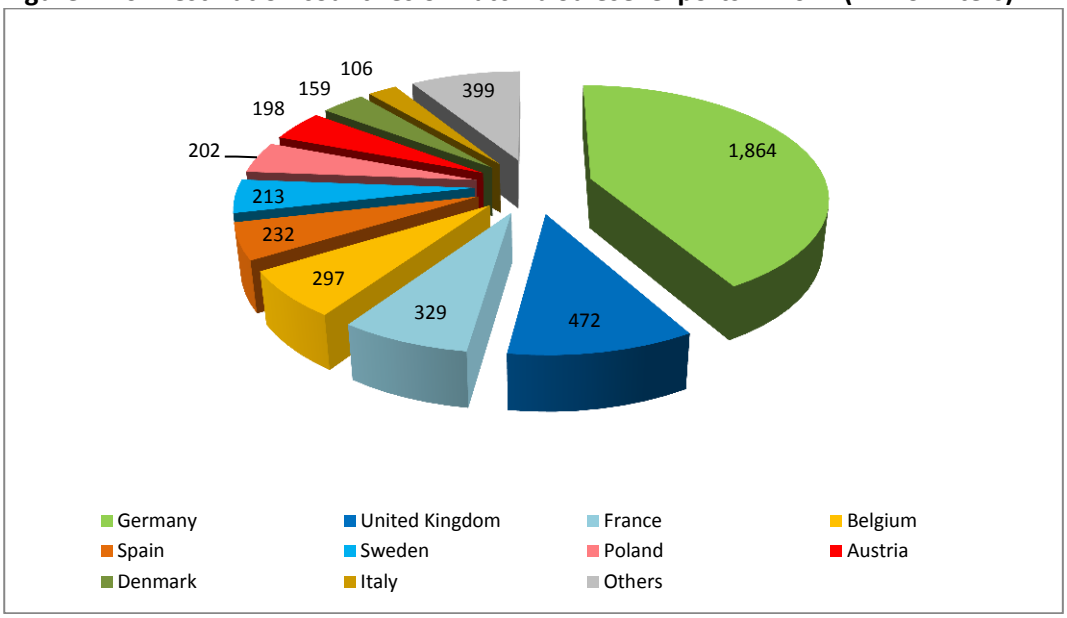



Source: own calculations on UN Comtrade data.

In 2011, almost 42% of Dutch biodiesel exports went to neighboring Germany, 10.5% to the United Kingdom and 7.4% to France. In the same year, German exports were more equally distributed among

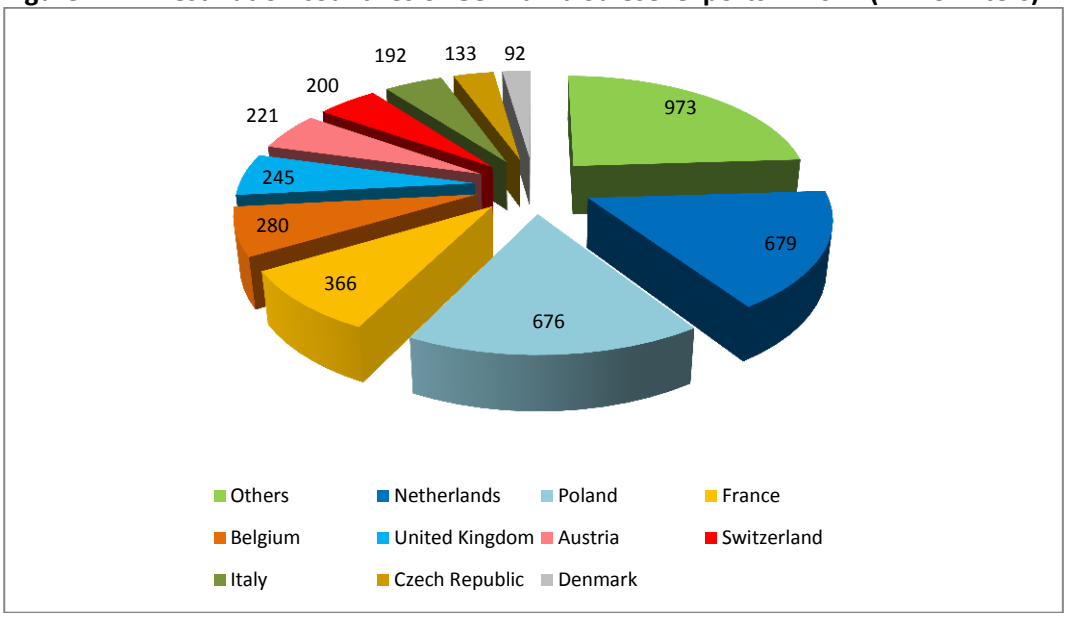
trading partners: 16.7% of German biodiesel exports went to both the Netherlands and Poland, 9% to France, 7% to Belgium and 6% to the United Kingdom. In the case of China, most of the biofuel exported in 2011, went to Japan (34.0%), while more than two-thirds of Argentinean exports went to either Spain (52.0%) or Italy (22.5%). Indonesian biofuel, always in 2011, went almost exclusively to Italy (45.9%), the Netherlands (25.2%), and Spain (21.9%) (Figure 2.10, Figure 2.11, Figure 2.12, Figure 2.13, Figure 2.14).

**Figure 2.10. Destination countries of Dutch biodiesel exports in 2011 (million liters).**



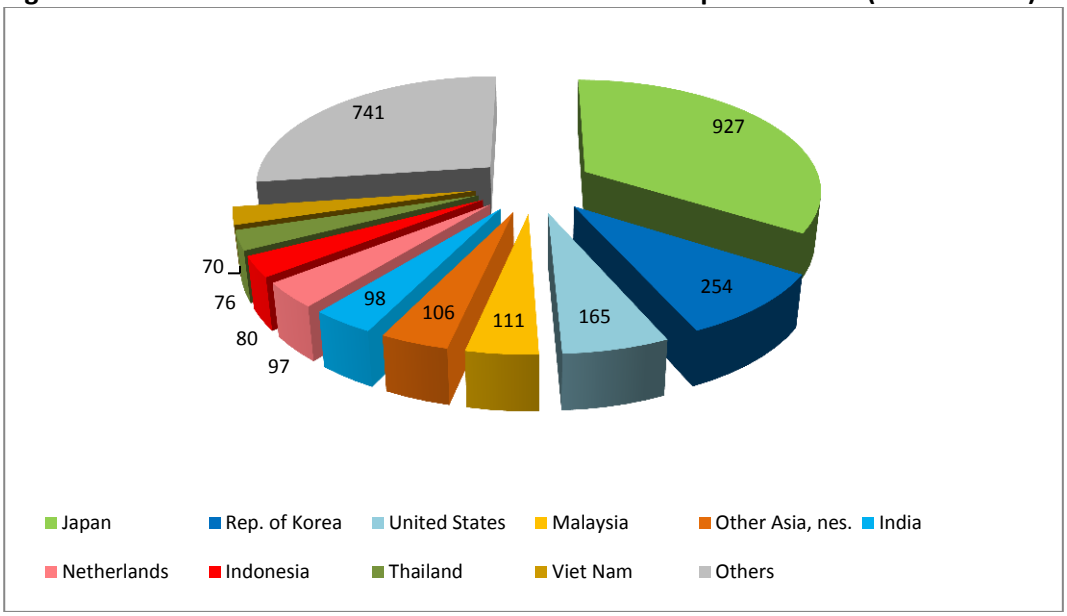

Source: own calculations on UN Comtrade data.

**Figure 2.11. Destination countries of German biodiesel exports in 2011 (million liters).**



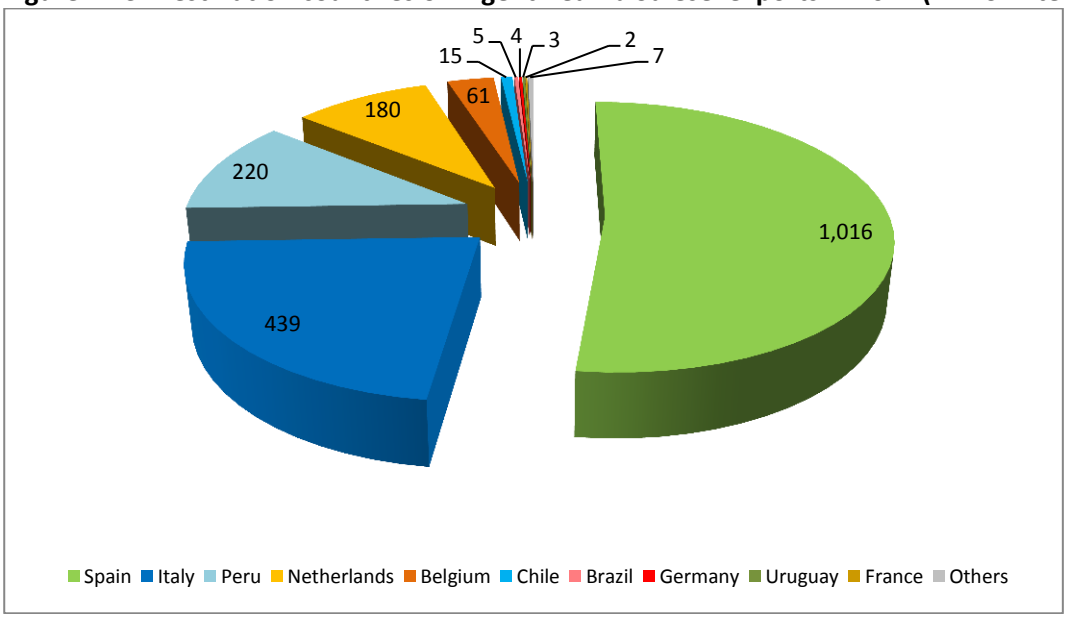

Source: own calculations on UN Comtrade data.

**Figure 2.12. Destination countries of Chinese biodiesel exports in 2011 (million liters).**



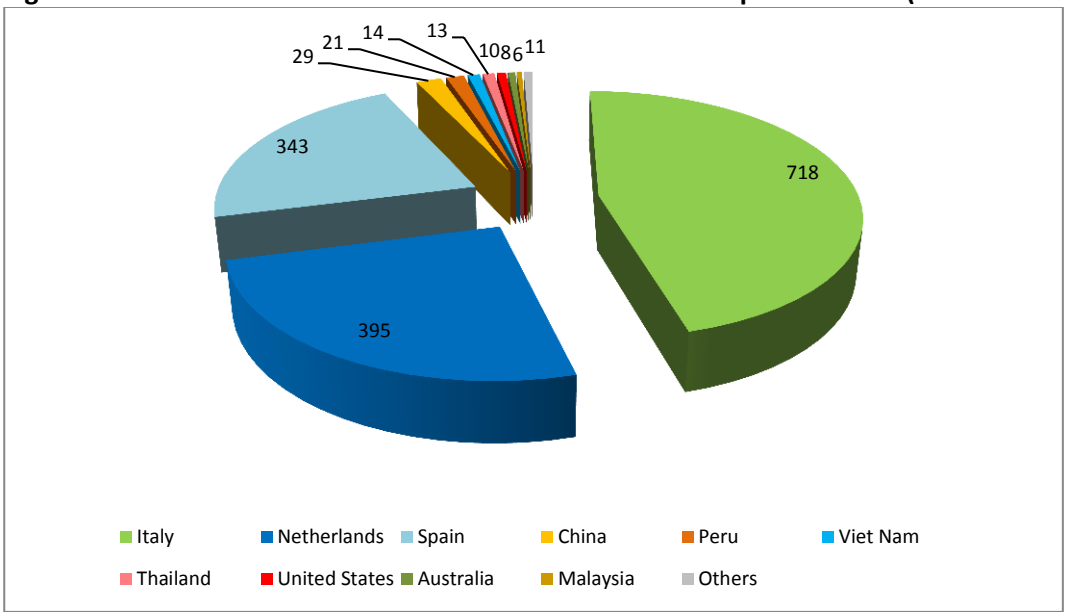

Source: own calculations on UN Comtrade data.

**Figure 2.13. Destination countries of Argentinean biodiesel exports in 2011 (million liters).**




Source: own calculations on UN Comtrade data.

**Figure 2.14. Destination countries of Indonesian biodiesel exports in 2011 (million liters).**




Source: own calculations on UN Comtrade data.

In 2011, Germany and the Netherlands were also the two major biodiesel importing countries, with 2.9 and 2.3 billion liters respectively. They were followed by two other European countries, Italy and Spain, which imported 1.8 and 1.6 billion liters of biodiesel. If in the case of the two North European countries, most of the trade was bilateral (Germany bought biodiesel from the Netherlands and vice versa), while in the case of the two Mediterranean countries, most of the imports came from overseas, especially Argentina and Indonesia.

Other important importing countries, always in 2011, were China (1.5 billion liters), France (1.2 billion liters), and Belgium (1.1 billion liters). In all cases imports increased with respect to 2010, except than for Belgium. Import increases in the other countries ranged from +38.4% for the Netherlands and +16.6% for China (Table 2.6).

**Table 2.6. most important biodiesel importing countries in volume (million liters).**

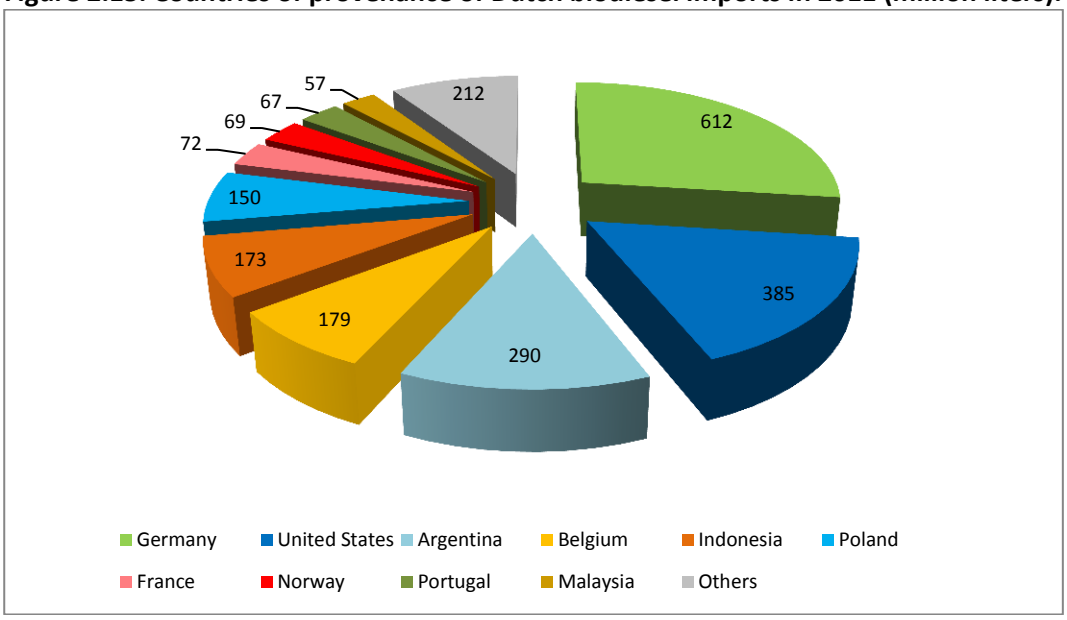
| Country | 1996 | 2000 | 2005 | 2010 | 2011 | % Changes 2011/10 | % Changes 2011/05 | % Changes 2011/96 |
|---|---|---|---|---|---|---|---|---|
| Germany | 1,307.6 | 1,090.2 | 1,781.0 | 2,803.0 | 2,903.2 | *3.6* | *63.0* | *122.0* |
| Netherlands | 691.5 | 643.9 | 660.0 | 1,637.7 | 2,266.8 | *38.4* | *243.5* | *227.8* |
| Italy | 381.4 | 538.0 | 513.7 | 1,443.7 | 1,758.3 | *21.8* | *242.3* | *361.0* |
| Spain | 116.2 | 216.2 | 252.8 | 1,348.5 | 1,625.0 | *20.5* | *542.7* | *1298.3* |
| China | 163.6 | 385.3 | 788.0 | 1,261.6 | 1,471.1 | *16.6* | *86.7* | *799.0* |
| France | 1,008.5 | 1,102.5 | 919.4 | 855.5 | 1,183.4 | *38.3* | *28.7* | *17.3* |
| Belgium | 374.3 | 581.5 | 386.3 | 1,237.7 | 1,091.7 | *-11.8* | *182.6* | *191.7* |
| United Kingdom | 302.9 | 888.2 | 473.8 | 1,149.5 | 952.2 | *-17.2* | *101.0* | *214.4* |
| Poland | 50.4 | 155.8 | 179.4 | 538.6 | 833.2 | *54.7* | *364.5* | *1553.1* |
| United States | 277.0 | 388.1 | 581.7 | 756.1 | 787.3 | *4.1* | *35.3* | *184.2* |
| Others | 2,324.2 | 3,888.2 | 6,125.9 | 7,288.0 | 7,659.8 | *5.1* | *25.0* | *229.6* |
| **World** | **6,997.6** | **9,877.8** | **12,662.1** | **20,320.1** | **22,531.9** | ***10.9*** | ***77.9*** | ***222.0*** |

Source: own calculations on UN Comtrade data.

During the last 15 years Germany has always been the leading biodiesel importing country, while France progressively lost importance: in 1996 it was the second-largest biodiesel importing country, while in 2011 it was just the sixth. Since 1996 Spain, China and Poland significantly increased their share among the most important biodiesel importing countries, while Belgium and the United Kingdom reduced it.

In 2011, 27% of Dutch biodiesel imports came from Germany, 17.0% from the United States and 12.8% from Argentina, while the rest from other countries, most of which Europeans (Figure 2.15).

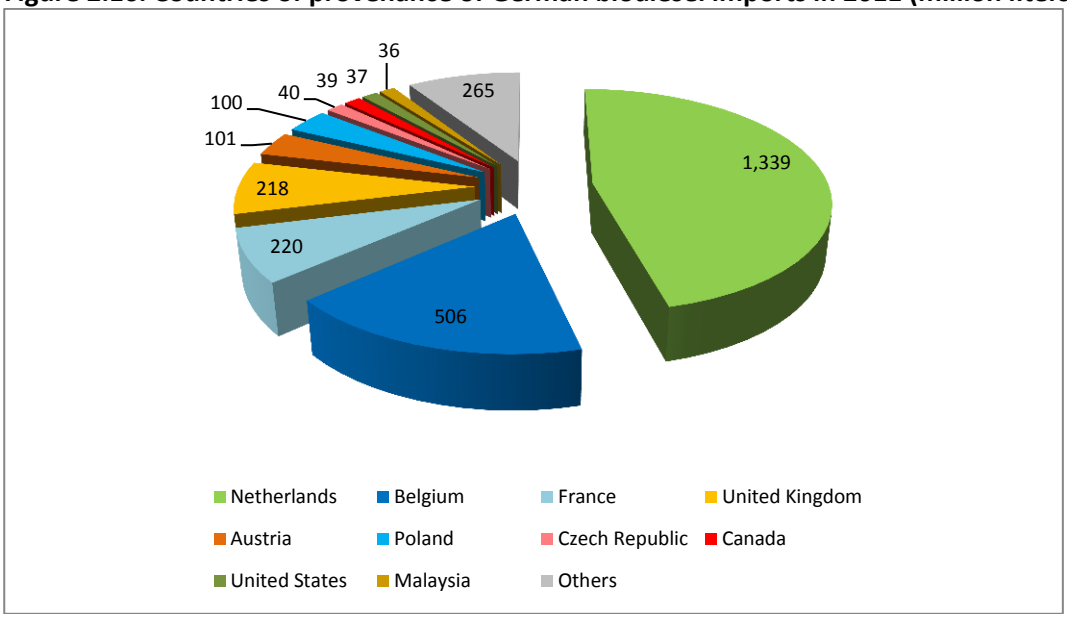
**Figure 2.15. Countries of provenance of Dutch biodiesel imports in 2011 (million liters).**




Source: own calculations on UN Comtrade data.

In the case of German imports, the situation is quite different. More than 46% of German biodiesel imports, in 2011, had as country of provenance the Netherlands. Belgium (17.4%), France (7.6%), and the United Kingdom (7.5%) are other important suppliers (Figure 2.16).

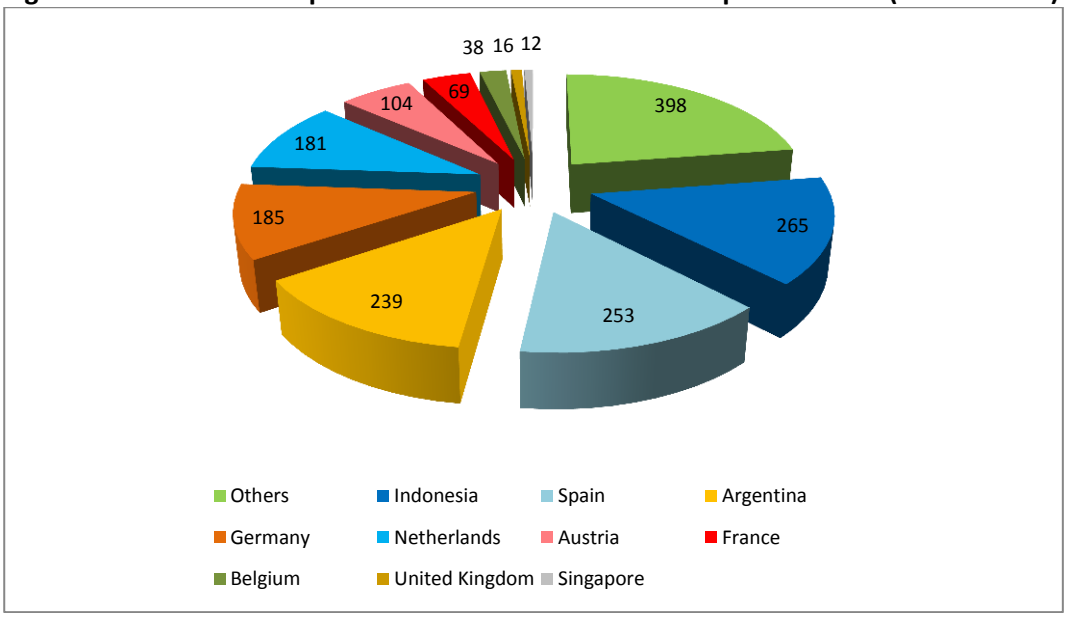
**Figure 2.16. Countries of provenance of German biodiesel imports in 2011 (million liters).**




Source: own calculations on UN Comtrade data.

Italy's suppliers are very different than those of Germany and the Netherlands. Italy imported, in 2011, almost 15% of its biodiesel from Indonesia, another 15% from Spain and 13.6% from Argentina. Imports from Germany and the Netherlands were, on the whole, 20% of total imports (Figure 2.17).

**Figure 2.17. Countries of provenance of Italian biodiesel imports in 2011 (million liters).**




Source: own calculations on UN Comtrade data.

From this data it seems clear that the biodiesel import portfolio of the EU is influenced by EU tariff regimes. US imports dominated until the mid-2000s and were then replaced by imports from Argentina, Indonesia, and Canada that is all countries subject to a 0.0% tariff preference for biodiesel (except than for Canada) (Lamers, Hamelinck, Junginger, & Faaij, 2011).

Argentina exports almost exclusively go to Europe, while Indonesian and Malaysian also go to the United States. In all these three countries domestic consumption of biodiesel is negligible, since almost all production is exported.

### 2.2.3 International vegetable oils trade.

Since biodiesel can be produced from a wide range of vegetable oils, it seems reasonable to analyze vegetable oil international trade since the main biodiesel producing countries might import from abroad the raw material (that is vegetable oils) they need for biodiesel production. This might happen because of insufficient domestic supply or because foreign raw materials are more economically convenient. The most popular vegetable oils used in biodiesel production are rapeseed oil (in Europe), soybean oil (in Argentina and the United States), and palm oil (in South-East Asia and Europe).

In the last ten years the international production and consumption of vegetable oils increased constantly and international trade almost doubled (Lamers, Hamelinck, Junginger, & Faaij, 2011). Palm oil and soybean oil trade are the fastest growing segments. Palm oil is mainly produced in Indonesia and Malaysia, which are also the two main exporters (90% of the global market). Major soybeans and soybean oil exporters are Argentina, Brazil, and the United States, which primarily supply Asian countries such as India and China, even though flows to Europe have increased in recent years. Finally, the most important rapeseed oil exporter in the world is Canada, which supplies the US, the EU, and China.

The fact that palm oil can be imported duty-free to the EU led to an increase in palm oil imports to the European Union since it is more price-competitive than rapeseed oil, which nevertheless remains the main feedstock for European biodiesel.

This section about international trade of vegetable oils is focused on the European Union since it is the main producer of biodiesel in the world, and therefore the economic entity more likely to play a relevant role in international trade.

#### *2.2.3.1 International palm oil trade.*

In 2011 the most important palm oil[6] exporting country was Indonesia, with 16,4 million tons of merchandise sold abroad. The second-largest exporter was another South-East Asian country, Malaysia,

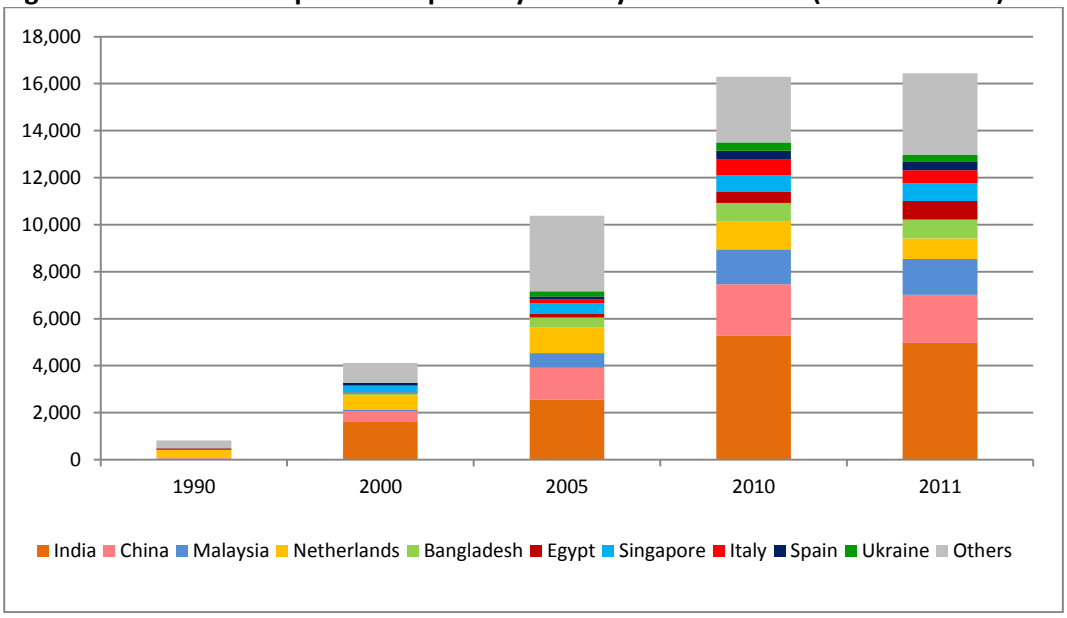
[6] HS code 1511.

with 15.8 million tons. In the case of Indonesia exports increased by 0.7% with respect to 2010, and in the case of Malaysia by 7.1%.

In both cases most of the exports go to other Asian countries, such as India, China, and Pakistan. Both for Indonesian and Malaysian palm oil, the fourth-largest importer is the Netherlands, which in 2011 bought almost 2 million tons of palm oil from the two Asian countries. However, if exports from Indonesia to the Netherlands decreased by 27.1% in 2011 with respect to 2011, those from Malaysia increased by 17.9%. Also Italy and Spain imported significant quantities of Indonesian palm oil in 2011: 562,500 and 349,900 tons respectively. In the first case imports decreased by over 17%, while in the second case they remained almost stable with respect to 2010.

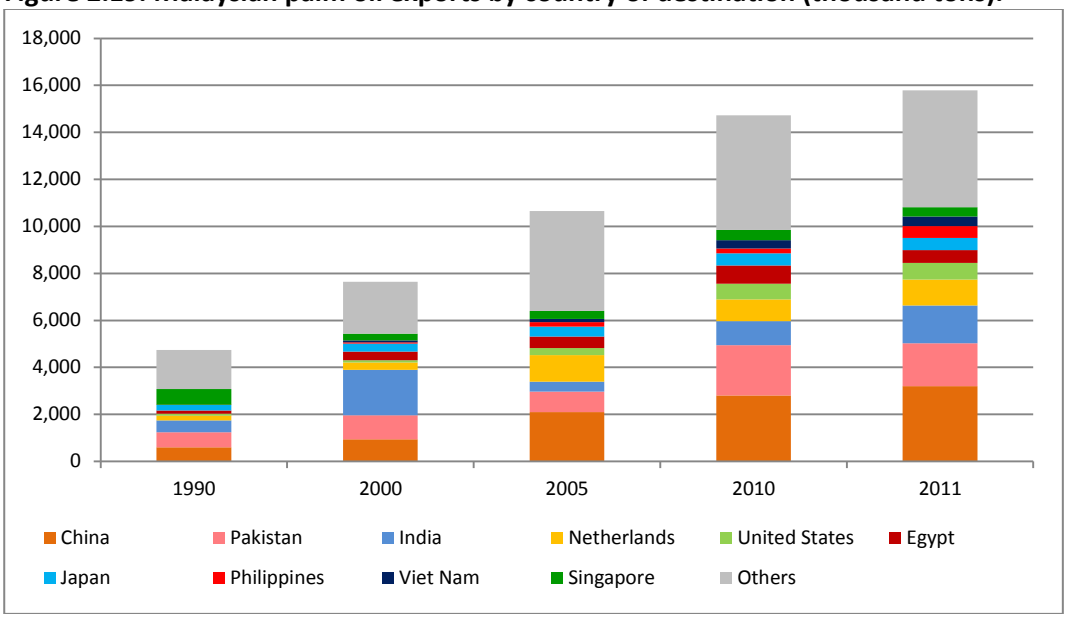
Since 1990 Indonesian palm oil exports increased exponentially. In 1990 Indonesia was exporting 815,400 tons (almost half of which to the Netherlands), which increased twenty times by 2011. The expansion of Malaysian exports has been relatively less evident: exports grew three times from 4,7 million tons in 1990 to 15.8 million in 2011 (Figure 2.18 and Figure 2.19).

**Figure 2.18. Indonesian palm oil exports by country of destination (thousand tons).**




Source: own calculations on UN Comtrade data.

**Figure 2.19. Malaysian palm oil exports by country of destination (thousand tons).**

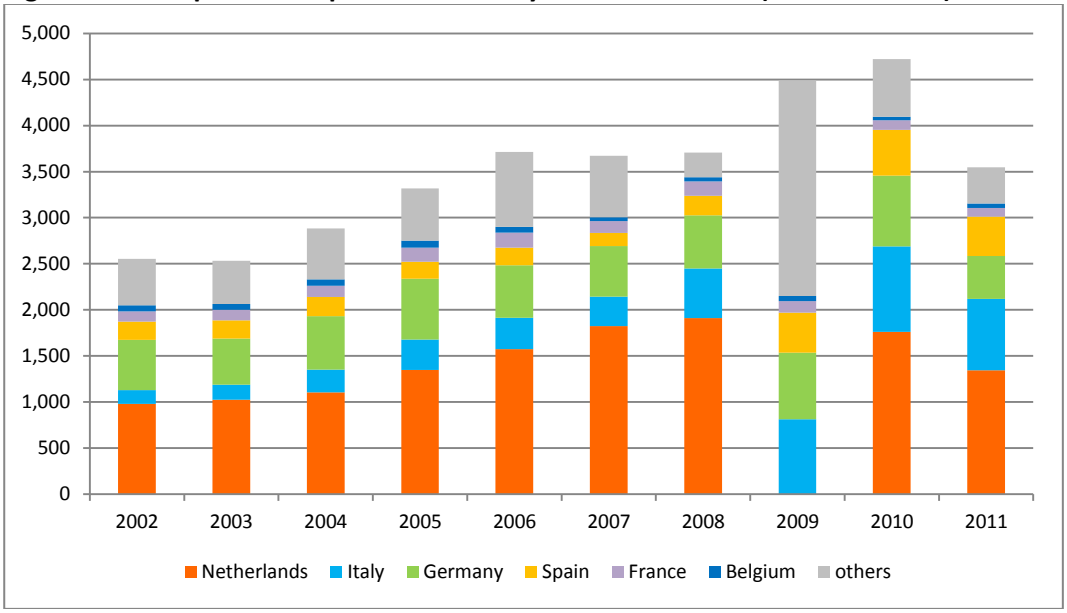



Source: own calculations on UN Comtrade data.

EU palm oil imports from both Indonesia and Malaysia increased substantially until 2010 (when they peaked) and then declined in 2011.

In 2009, the EU imported the record quantity of 4.5 million liters of palm oil from Indonesia and Malaysia, almost two times more than in 2002 (last year for which data are available). Historically the EU countries that imported the most palm oil from Indonesia and Malaysia have been the Netherlands and Germany, even though, since the mid-2000s Italian imports also increased substantially and in 2010 Italy replaced Germany as second-largest palm oil importer. Also Spanish imports increased over the years. The fact that palm oil imports increased more for Italy and Spain can be explained by the fact that these two countries, in order to meet EU's biodiesel consumption mandates, are forced to import vegetable oils from abroad since domestic production is not sufficient to meet demand and palm oil is cheaper than rapeseed oil from Northern European countries (Figure 2.20).

**Figure 2.20. EU palm oil imports from Malaysia and Indonesia (thousand tons).**




Source: own calculations on UN Comtrade data.

### *2.2.3.2 International rapeseed oil trade.*

The European Union is the biggest rapeseed and rapeseed oil producer in the world[7], therefore imports from third countries are not very large. Most of the rapeseed oil trade of EU member states is intra-community trade. Nevertheless it can be of interest to analyze trade flows from Canada, the second-largest exporter of the commodity. In 2011 the EU and Canada exported, more or less, the same quantity of rapeseed oil, about 2.8 million tons.

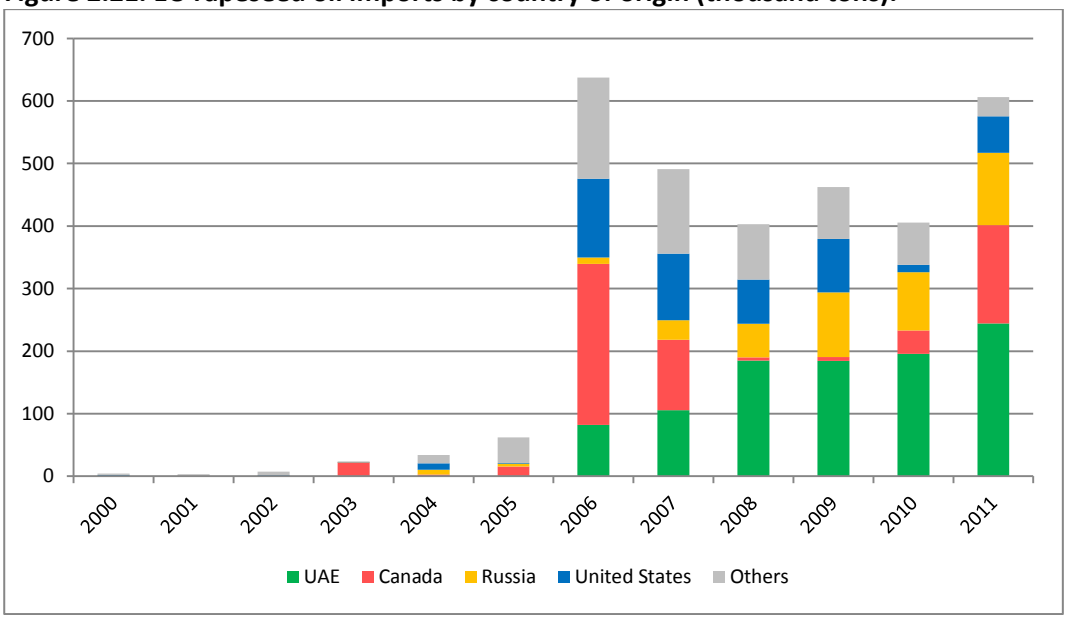
In 2011, almost 60% of Canadian rapeseed oil exports went to the United States, 22% to China, and just a small fraction to European countries like the Netherlands (61,100 tons, 2.5% of total Canadian exports), Germany (48,000 tons, 1.8%), and France (47,100 tons, 1.8%). However, quantities imported by EU countries from Canada have been increasing in recent years.

As a matter of fact, if in 2000 the EU almost did not import rapeseed oil at all, in 2011 it bought on international markets over 606,000 tons of rapeseed oil. Quite surprisingly, 40.3% of EU imports, in 2011, came from the United Arab Emirates (UAE), which notoriously are not a major producer of rapeseed. Rather, it is likely that the Arabic country acts like a "hub" for international trade (such as Singapore), and that UAE's exports to the EU are in fact re-exports of rapeseed oil coming from third countries. The second-largest rapeseed oil imported to the EU, always in 2011, was Canada, with 157,000 tons and the third-largest Russia, with 115,000 tons. The role of other countries in marginal. Over the years the importance of the various importing countries to the EU changed. In 2006, when imports boomed, Canada was the main

[7] According to the FAO, in 2010, the EU (27 members) produced more than 20 million tons of rapeseed, much more than the second-largest producer, China, with 13 million.

supplier but already in 2008 its importance substantially decreased in favor of the US and, especially, the UAE (Figure 2.21).

**Figure 2.21. EU rapeseed oil imports by country of origin (thousand tons).**



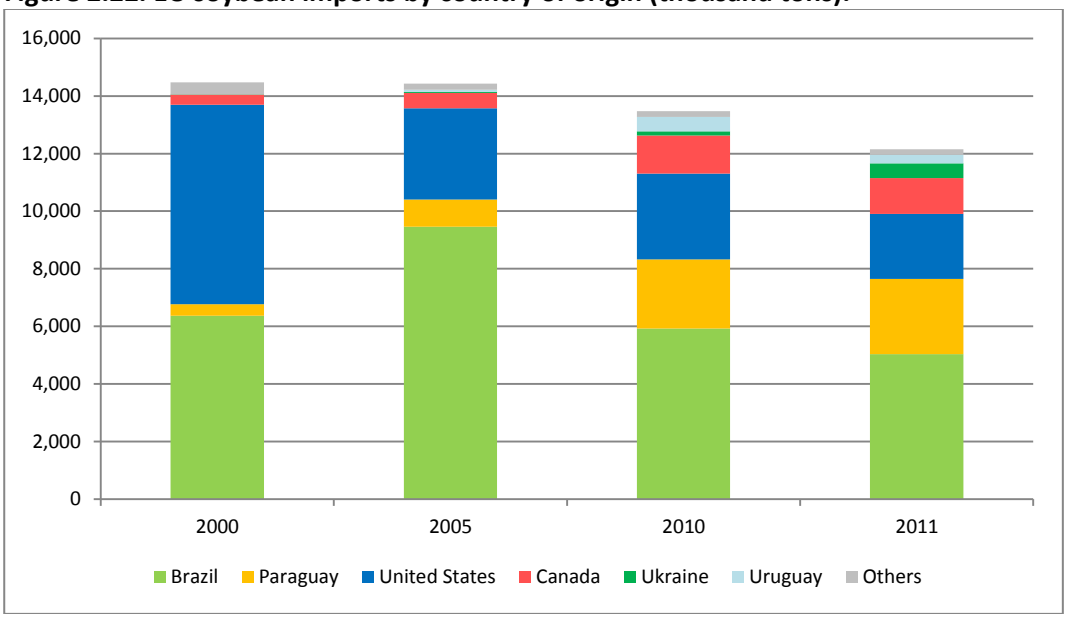

Source: own calculations on UN Comtrade data.

### *2.2.3.3 Soybean and soybean oil international trade.*

The main soybean and soybean oil producing and exporting countries are Brazil, Argentina, and the United States. Even though the majority of their exports goes to Asian countries like China, India, and Pakistan, the share taking the way to Europe is not marginal, and the fact that soybeans and soybean oil imports of some EU countries (Germany, the Netherlands and Spain) peaked in the mid-2000s, might be interpreted as a consequence of biodiesel expansion.

On the whole, however, EU soybean imports declined during the 2000s. total imports were more than 14.4 million tons in 2000 and just 12.1 million in 2011 for a 16% decrease. Imports from Brazil and the US both declined while those from Paraguay and Canada increased: this might indicate that part of Brazilian and American exports take the Paraguayan or Canadian "route". In the last years increased also the role of Ukraine, which imported over 500,000 tons of soybeans to the EU in 2011 (in 2000 just 4,500) (Figure 2.22).

**Figure 2.22. EU soybean imports by country of origin (thousand tons).**




Source: own calculations on UN Comtrade data.

In 2011, none of the ten first destination countries of Argentinean soybeans exports was an European country, but Spain, the Netherlands, the United Kingdom (UK) and Germany were amongst Brazil's top-ten trade partners. Germany and Spain were also the seventh and the ninth-largest importing countries of US soybeans. In 2011, Spain imported 2.4 million tons of soybeans from Brazil (6.4% of total Brazilian export that year), the Netherlands 1.5 million, the UK 687,000 tons and Germany 370,000 tons. In all cases imports increased with respect to the previous year, especially in the case of Span (+26.4%) and the UK (+15.0%). In 2011, German and Spanish imports of soybeans from the US sharply declined (by about a half) and amounted to 555,000 and 362,000 tons respectively.

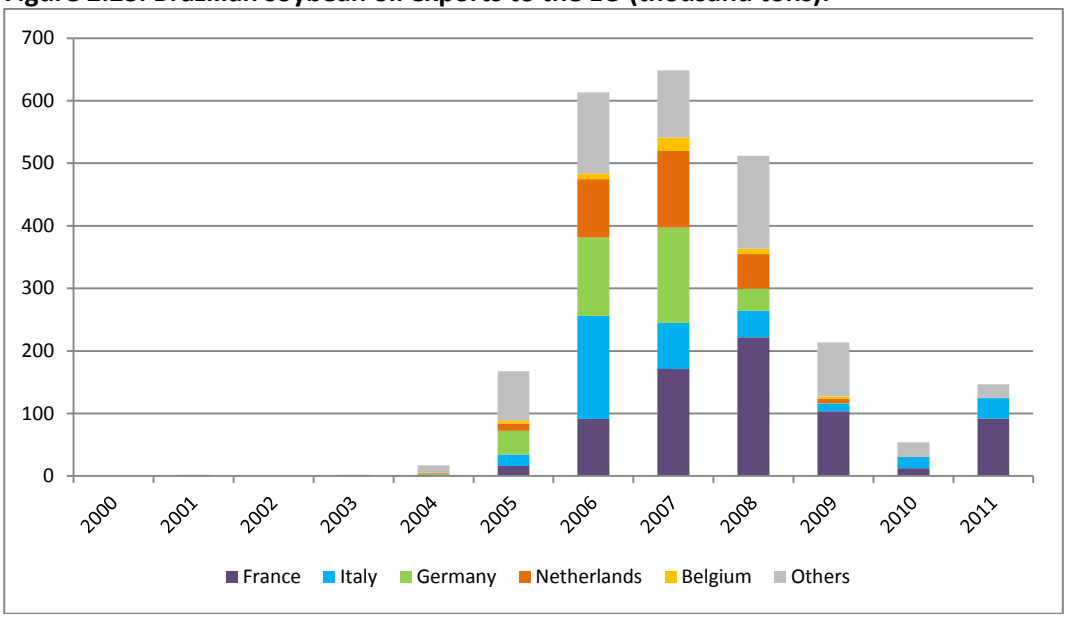
The main soybean oil producers and exporters, similarly to what happens for soybeans, are always Argentina, Brazil and the US. In this case, however, EU imports are much more limited than in the case of soybeans. This might be due to the fact that it is more convenient to process soybeans into oil rather than import directly the transformed product.

The only European country that in 2011 imported significant quantities of soybean oil from Argentina and Brazil was France, for a total of almost 230,000 tons. Again, main destination countries for Argentinean, Brazilian and American soybean oil are Asian countries, especially China and India.

On the whole, the EU imported 740,000 tons of soybean oil in 2011, most of which from Argentina and Brazil (61%). Other important suppliers were Russia (102,000 tons) and Norway (67,000 tons), which probably represents a pass-through for US soybean oil. Imports from Argentina slightly decreased with respect to 2010 (-5.9%), while those from Brazil strongly increased (+173%). It must be highlighted the fact that in 2000, the EU imported almost zero soybean oil from third countries and that only in very recent years trade flows became relevant, possibly as a consequence of biodiesel expansion in Europe. During the years the role of the different suppliers of the EU changed: at the beginning of the 2000s most of the

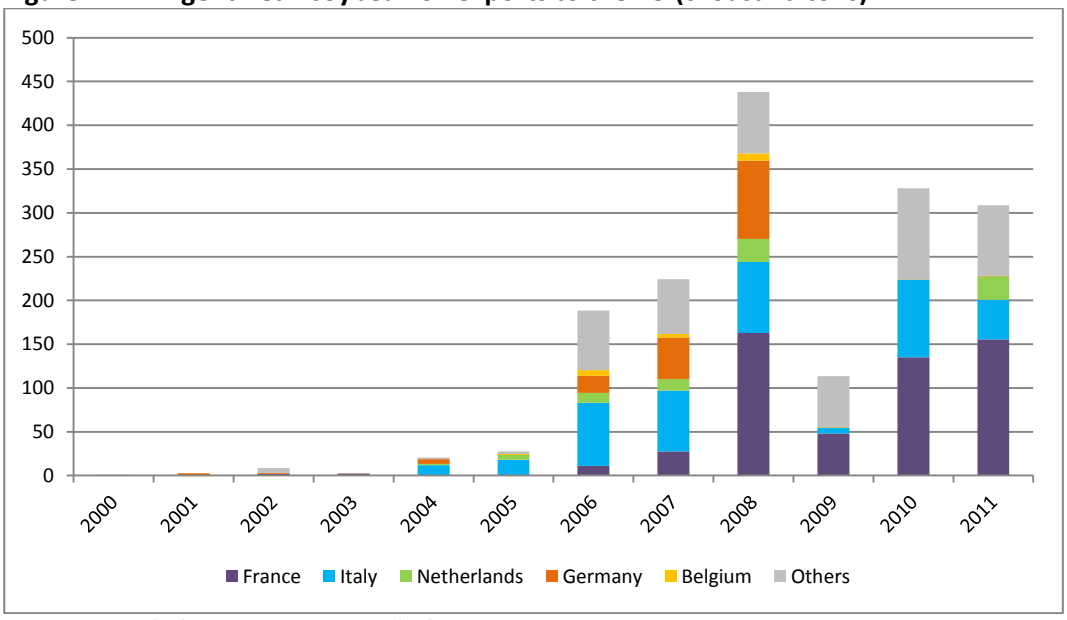
imports came from the US, then Brazil and Argentina took over, especially in the second half of the decade. Major destination countries within the EU, in 2011, were France and, to a lesser extent, Italy and the Netherlands (Figure 2.23 and Figure 2.24).

**Figure 2.23. Brazilian soybean oil exports to the EU (thousand tons).**




Source: own calculations on UN Comtrade data.

**Figure 2.24. Argentinean soybean oil exports to the EU (thousand tons).**




Source: own calculations on UN Comtrade data.

**Final considerations.**

Trade in biofuels is not very developed yet, since biofuel production is concentrated in very few countries (mainly the US, Brazil, and the EU) and because of protectionist measures implemented by governments to protect domestic producers over foreign. Most of the trade in biodiesel takes place within the European Union, where biodiesel is the leading biofuel. Ethanol trade is mainly a prerogative of the US and Brazil, with the latter being the leading exporting country. Historically ethanol has been considered an agricultural production (HS 2207), while biodiesel a chemical one (HS 3824.90), which has important implications since WTO regulations vary greatly between agricultural and non-agricultural products. In the case of biodiesel (and to some extent also in the case of ethanol) it is not straightforward to identify exactly biofuel trade flows since the HS classification includes biodiesel in the same 6-digit category of "other chemical products" and it is difficult to find data at a greater level of detail.

While most of the ethanol produced in the main producing countries (US and Brazil) can be assumed to be obtained from domestically produced feedstocks (corn and sugarcane), this might not be the case in case of biodiesel, especially in the European Union. The EU does not produce enough vegetable oil to produce all the biodiesel EU policies mandate to consume, therefore, in recent years, vegetable oil imports from third countries have been increasing. Even though it is not possible to say how much imported vegetable oil is used in the food industry of for biofuel production, it is a fact that EU imports, especially of palm oil, have substantially increased during the last decade.

Brazil and the US, the two main ethanol producing countries, have been dominating the international trade of the commodity in the last few years. Historically Brazil has been the most important exporter (especially to the US, despite trade restrictions) but in the last two years, due to poor harvests in the South American country, US exports increased substantially, especially to Brazil, where domestic production was not sufficient to meet demand. Nevertheless in 2011, when the Brazilian sugarcane harvest was particularly poor and consequently also ethanol production, Brazil exported a significant quantity of ethanol to the US, implying a certain degree of inter-industry trade. It is important to highlight the fact that Brazilian ethanol exporters have been circumventing US trade barriers by exporting their ethanol to Caribbean countries and thence to the US. In this way ethanol could be exported to the US almost duty-free since the US have in place free-trade agreements with many Central American and Caribbean countries (NAFTA).

In the case of biodiesel, most the world trade takes place within the European Union, even though in recent years exports from China, Argentina and Indonesia have increased substantially. in the case of Argentina and Indonesia most of the exports goes to the EU. In the EU main exporting countries are Germany and the Netherlands, which trading partners are mostly other EU countries. Spain and Italy are the most important importers, after Germany and the Netherlands (which trade is mostly bilateral), and,

contrary to North European countries, they trade especially with third countries. Argentina exports almost exclusively go to Europe, while Indonesian and Malaysian also go to the United States.

International trade in vegetable oils has been increasing in recent years, especially because of increased food demand in emerging counties, even though the role played by biodiesel expansion is not to irrelevant. Palm oil and soybean oil are the most important vegetable oils traded globally, the first is mainly produced in South-East Asia: Malaysia and Indonesia represent 90% of world exports. In the case of soybean and soybean oil major producers and exporters are the US, Argentina and Brazil, however soybean oil is used as biodiesel feedstock mainly in Latin American countries and in the US, while in the EU, the most important biodiesel producer in the world rapeseed and palm oil are preferred.

The fact that palm oil can be imported duty-free to the EU led to an increase in palm oil imports to the European Union since it is more price-competitive than rapeseed oil, which nevertheless remains the main feedstock for European biodiesel. EU palm oil imports have been increasing in the last decade by almost 50%, even though 2011 was characterized by a significant decrease, possibly due to the difficult economic situation. EU rapeseed oil imports have been increasing substantially since 2006, year in which biodiesel production in the EU started to become significant. The main supplier of the EU was, in 2001, the United Arab Emirates, which probably acts like a “hub” for international trade (such as Singapore), which re-exports to the EU rapeseed oil coming from third countries, such as Canada, the US, or Russia. EU soybean and soybean oil imports have been decreasing over time, confirming the hypothesis that soybean oil is not a major feedstock for biodiesel production in the US, probably because more expensive than palm or rapeseed oil.

Form these figures one can conclude that biofuel expansion had an impact also on trade flows. It created a new market, that for biofuels, which, even if still not very important, is in rapid expansion, especially in the case of biodiesel. Ethanol, at the moment, is still mainly produced domestically by major producing countries like Brazil and the EU but an increase in trade flows is possible in the future when local supply might not be able to meet demand, fostered by government policies.

In the case of biodiesel the effect of production and consumption subsidies on trade flows is already quite strong, especially in the case of feedstocks. The EU, the main biodiesel producing country, is not able to produce all biodiesel it needs to meet its consumption targets from domestically produced feedstock due to land availability and stringent environmental policies. Therefore, in recent years, rapeseed and, especially, palm oil imports from third countries have been increasing substantially, more than biodiesel imports since vegetable oils are considered agricultural commodities and can be imported to the EU (especially from developing countries) at a much lower tariff rate than biodiesel.

Despite a reclassification of ethanol blends to a higher tariff rate, EU ethanol imports from the US are forecasted to remain stable, while biofuel imports from third countries are expected to decrease as a

result of enforcement of the Spanish quota system, which only accepts biodiesel produced in the EU (USDA, 2012a).

## 2.3 Production and prices of agricultural commodities used for biofuel production.

This section analyzes the world production of the main agricultural commodities used for biofuel production in the world and the evolution of harvested area, yields and prices. Biofuel expansion might have affected the production of some agricultural commodities and their relative importance on total agricultural output. The first part of the section is about world production, harvested areas, and yields of the major agricultural crops used for biofuel production: corn, sugar cane, soybeans, wheat, rapeseed, and palm oil fruit. Data are from the FAOSTAT database.

The second part of the section is about the evolution of agricultural and forest land worldwide and other agriculture indicators in the last five decades. A complete understanding of the evolution of farm and forest land and fertilizer use in both developed and developing countries is essential to better assess the impact that biofuel expansion has been having on the agricultural sector and the environment. Data for this sub-section are from the World Bank World Development Indicators database. The third part of the section illustrates the evolution of biofuel and agricultural prices in the US, Brazil and the EU in the last two decades, while the fourth concludes.

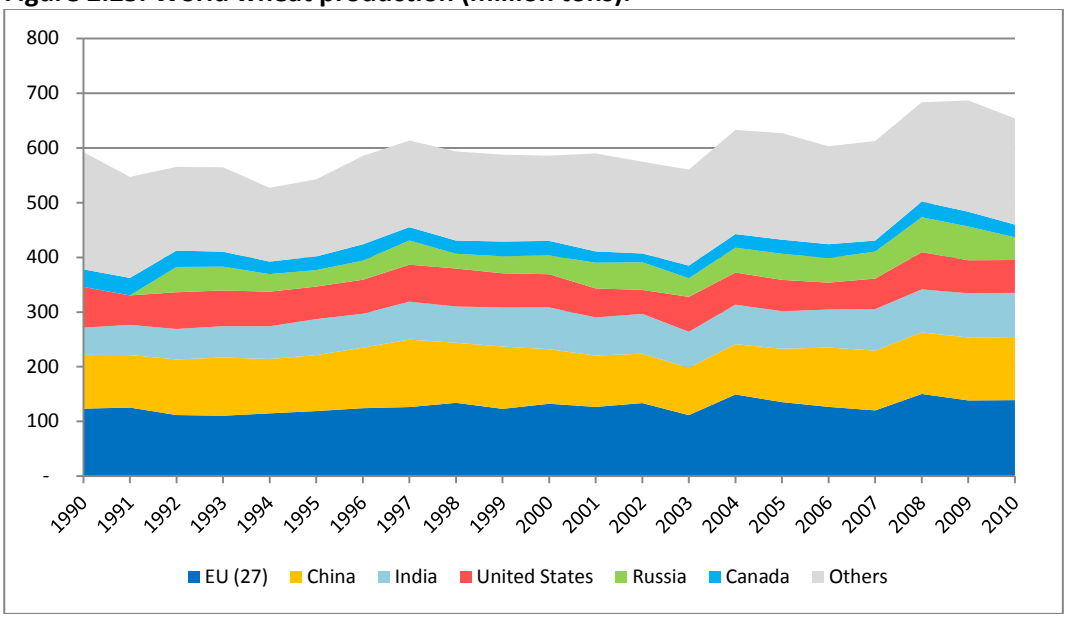
### 2.3.1 World production of agricultural commodities.

This subsection is about production, harvested areas, and yields of the main agricultural commodities used in biofuel production: corn, sugarcane, soybean, rapeseed, and oil palm fruit. The section includes also figures on wheat (the major food crop in the world that could have been indirectly affected by biofuel production) and on the main vegetable oils.

#### *2.3.1.1 Wheat production.*

In 2010 (last year for which data are available), the world wheat production was equal to almost 654 million tons, in decline with respect to the previous year (-4.8%). Main production countries were the EU (that accounted for almost 21.2% of world production), China (17.6%), India (12.4%), and the US (9.2%). Russia and Canada, together, account for 9% of the world production. Over the last 20 years, world wheat production increased by 10%, a relatively low percentage (Figure 2.25).

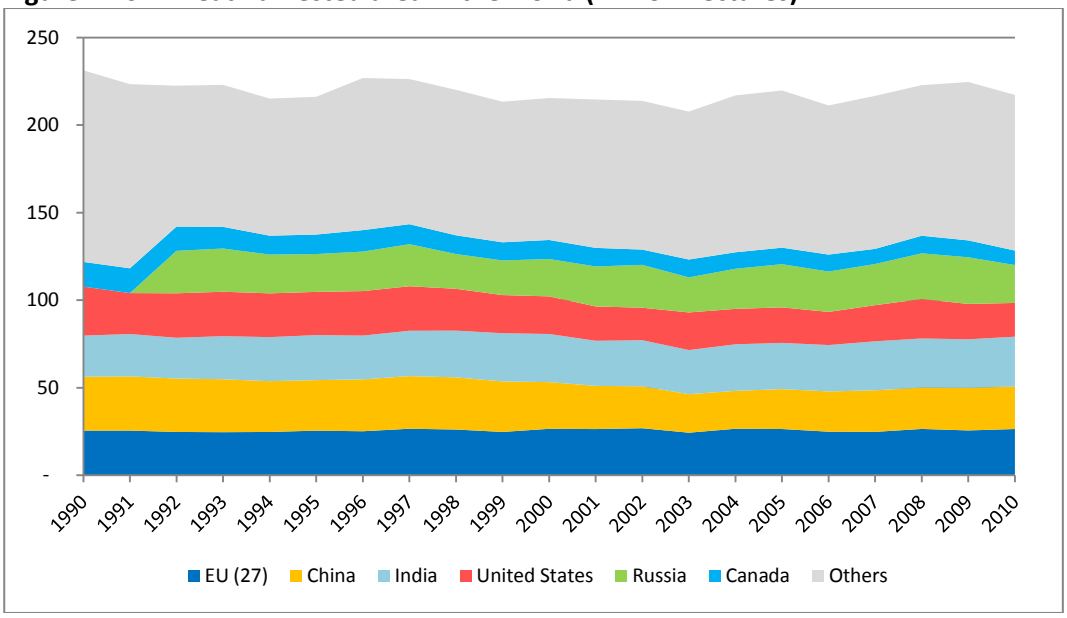
**Figure 2.25. World wheat production (million tons).**




Source: own calculation on FAO data.

The evolution of the area harvested has been similar to that of quantities produced: it fluctuated around 220 million hectares during the entire period considered. In this case, however, the share of the major producing countries is lower since they are characterized by a more intensive agriculture (Figure 2.26).

**Figure 2.26. Wheat harvested area in the world (million hectares).**



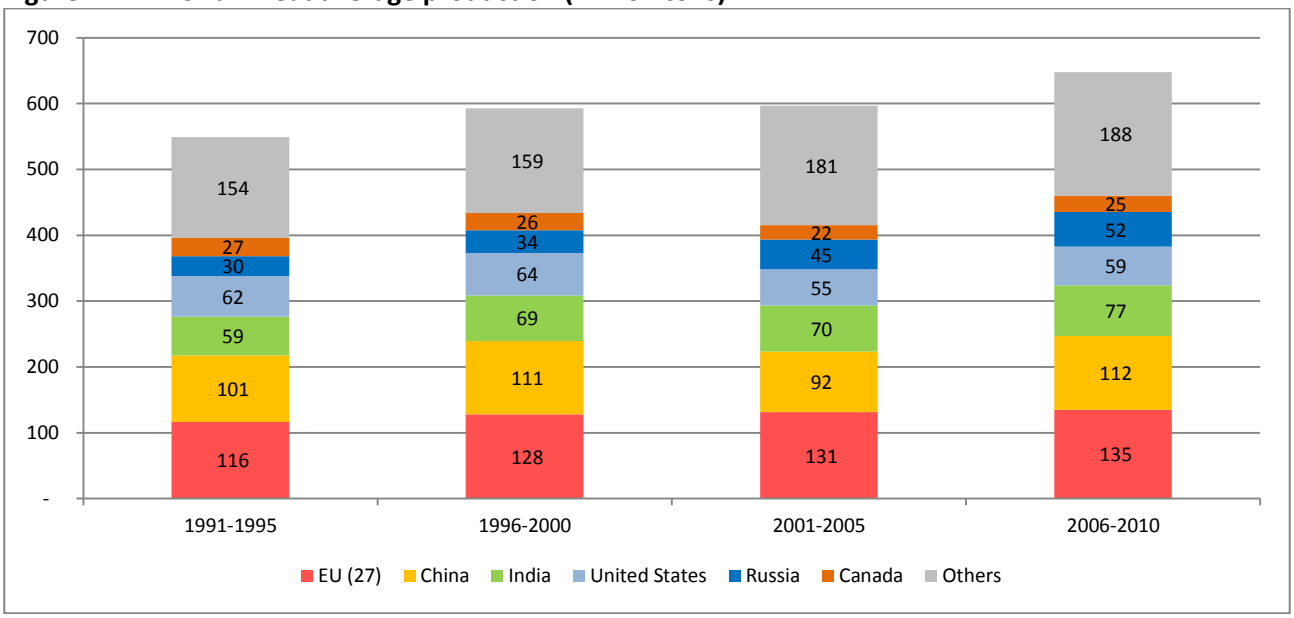

Source: own calculation on FAO data.

Analyzing production on a year-by-year basis can be, however, misleading, since production can be affected not only by structural factors (i.e. changes in the demand structure) but also by short-term ones

such as weather patterns. Therefore the last two decades have been divided into 4 periods (5 year-long) for each of which average production, areas harvested, and yields have been computed.

World average production indeed increased during the last 20 years, passing from an average of 549 million tons in 1991-1995 to 648 in 2006-2010. Nevertheless the relative importance of the main producing countries (EU, China, India, US, Russia, and Canada) remained almost unchanged (Figure 2.27).

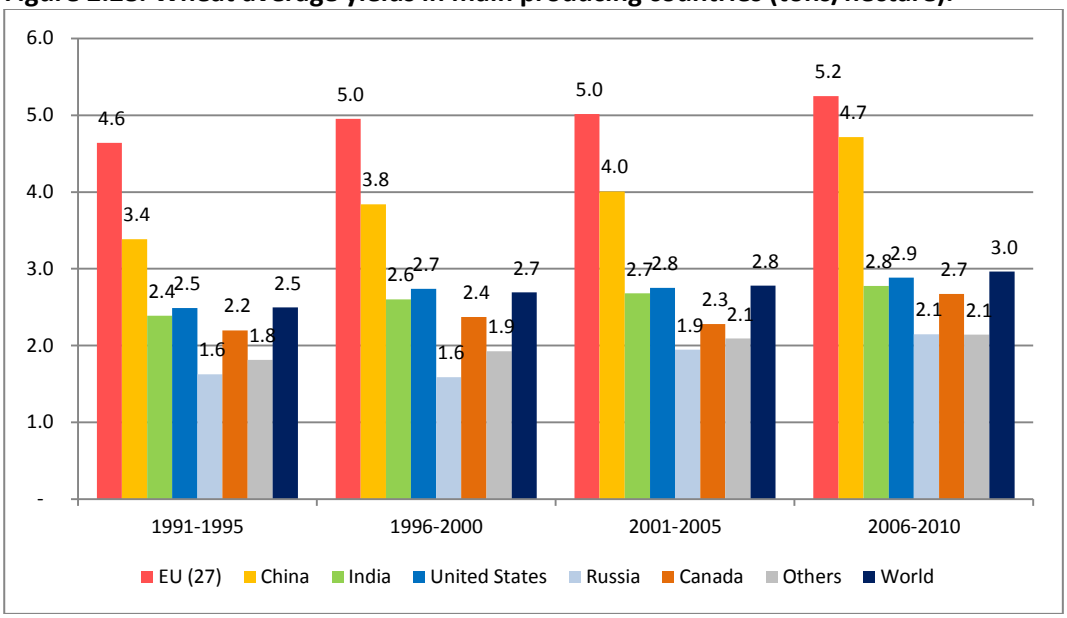
**Figure 2.27. World wheat average production (million tons).**




Source: own calculation on FAO data.

Since areas harvested remained almost unchanged but production increased, yields improved during the period under analysis. The country characterized by the most productive wheat sector is the EU, which average yield, in the 2006-2010 period, was about 5.2 t/ha, higher than in 1991-1995, when it was 4.6 t/ha. During the last 20 years Chinese yields increased substantially, passing from 3.4 t/ha in 1991-1995 to 4.7 t/ha in 2006-2010. Yields in other countries are significantly lower and have not changed substantially in the period under consideration (Figure 2.28).

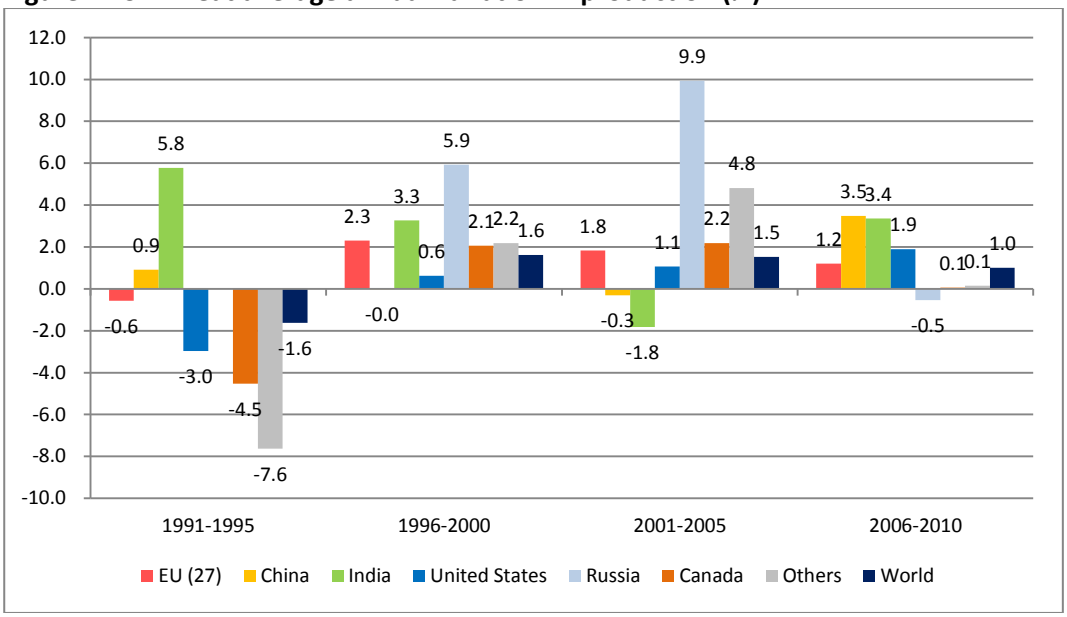
**Figure 2.28. Wheat average yields in main producing countries (tons/hectare).**




Source: own calculation on FAO data.

Average annual production variation was quite erratic during the time span considered. In the 1991-1995 period Indian wheat production increased, on average, by 5.8% per year, the Chinese one by 0.9% while in all the other major producing countries declined. In the subsequent periods, production, on average increased, especially in Russia and, in the 2006-2010 also in India and China (Figure 2.29).

**Figure 2.29. Wheat average annual variation in production (%).**

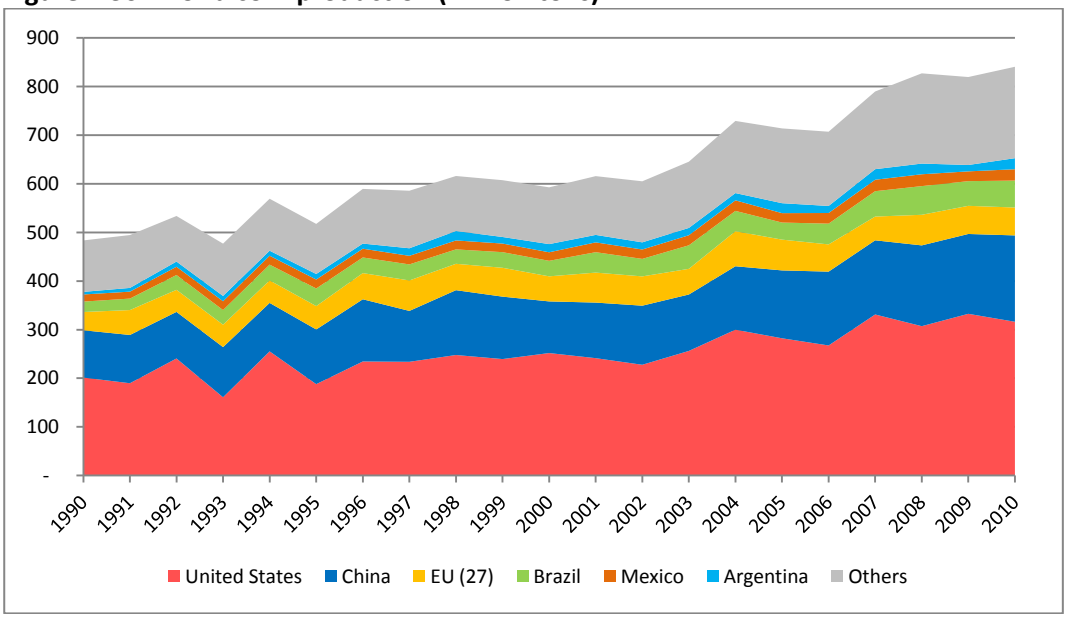



Source: own calculation on FAO data.

### *2.3.1.2 Corn production.*

Contrary to what happened in the case of wheat, world corn production increased substantially in the last 20 years, especially during the 2000s, in coincidence with biofuel expansion in the United States (Figure 2.30).

**Figure 2.30. World corn production (million tons).**

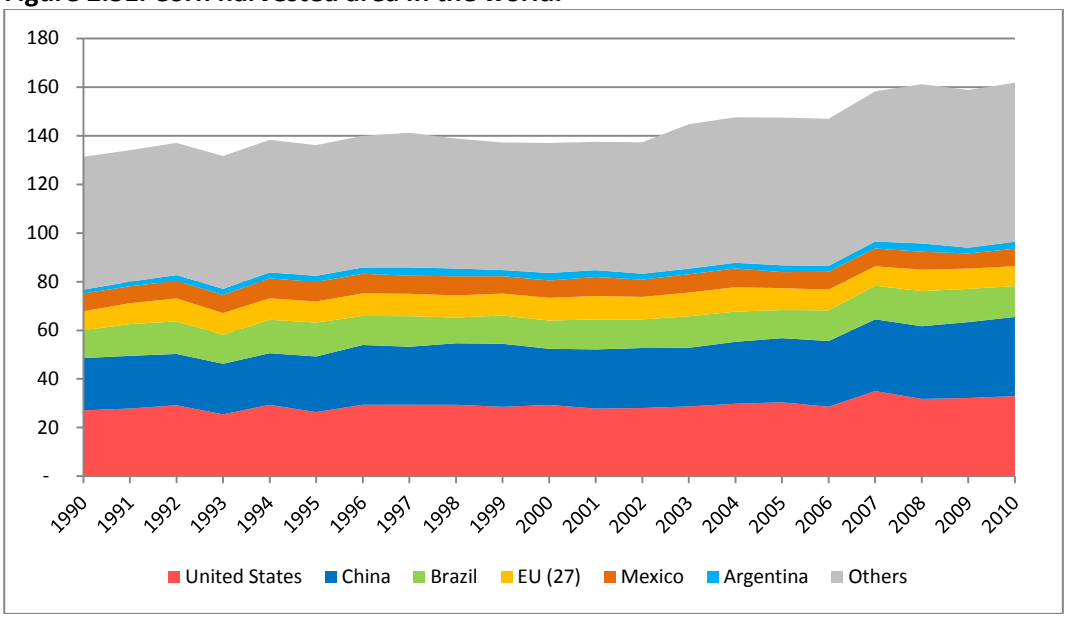



Source: own calculation on FAO data.

The major producing country is the United States, which in 2010 accounted for almost 38% of the world production. The other major corn producer is China that represents 21% of the world output. However, while a significant share of the US production is exported, almost the entire Chinese output is consumed domestically. Other important producers are the EU and Brazil, which represent together 14% of the world output.

Cropped area increased less substantially than production, meaning that in the last 20 years the degree of intensity in corn production increased. Most of the area cropped is in the main producing countries (US, China, Brazil, and the EU), however, in this case, the share of the "rest of the world" is much higher (40%) than in the case of quantities produced (22%) (Figure 2.31). This means that production is concentrated in very few countries, where corn is cropped with very intensive techniques. In these countries corn is used almost exclusively for feed and biofuel production, while in the rest of the world, especially in developing countries, it is cropped with more extensive techniques and used also for direct human consumption.

**Figure 2.31. Corn harvested area in the world.**

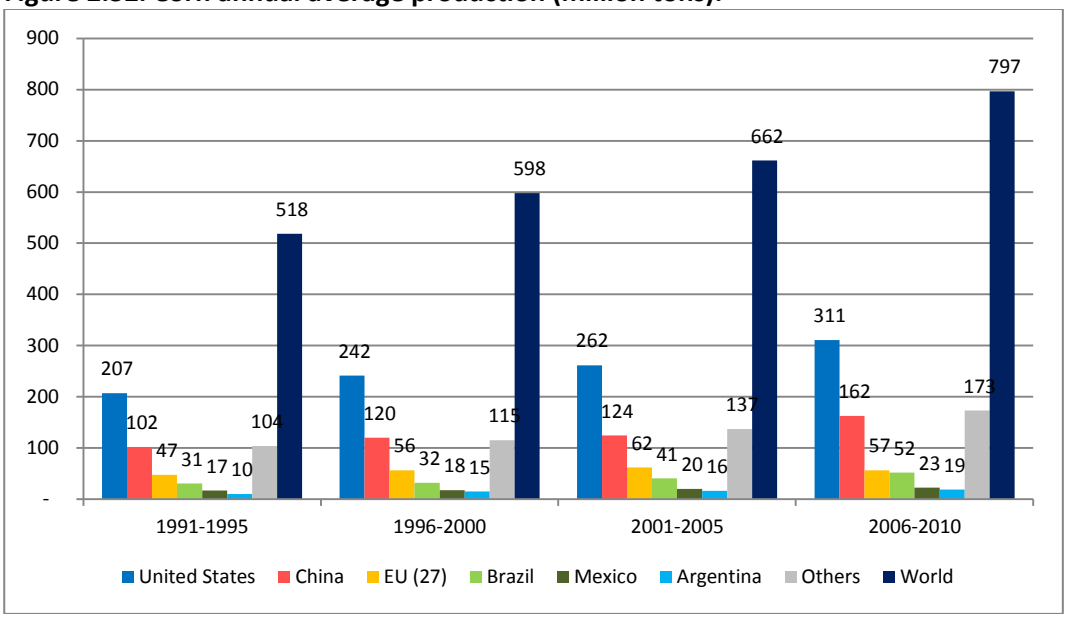



Source: own calculation on FAO data.

Similarly to wheat, also in this case average production in 5-year-long periods has been calculated, in order to analyze the evolution of production net of short-term factors. On average, in 1991-1995, world corn production was about 518 million tons, while in 2006-2010 it averaged 797 million tons. Production increased especially in the United States, where corn-based ethanol is heavily subsidized: if in 1991-1995 average US production was 207 million tons/year, in 2006-2010 it had increased up to 311 million tons/year. Production increased also in China (from an average of 47 to 57 million tons/year) but in this case because of the strong expansion in demand for feed. Finally, EU output also increased over the period but much less than in the US and in China. EU 5-year average corn production expanded by 19% fin 2006-10 with respect to 1991-95 levels, while that of the US and China by 50 and 59% respectively (Figure 2.32).

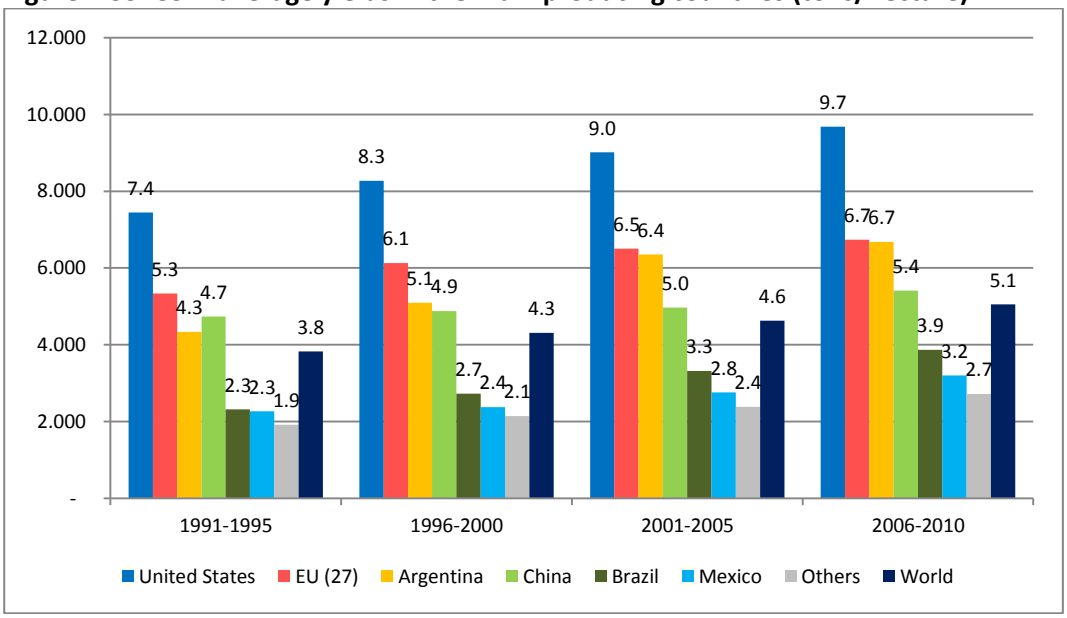
Yields have been increasing in the last 20 years, especially in the United States. The average corn yield in 1991-95 was 7.4 t/ha in the US, growing up to 9.7 in 2006-10. Also the average yield at world level augmented (from 3.8 to 5.1 t/ha) as a result of yield increases in all major producing countries. In the EU yields increased from 5.3 t/ha in the 1991-95 period to 6.7 t/ha in 2006-2010, while in Argentina they passed from 4.3 t/ha to 6.7. Also the yield growth in Brazil was substantial (from 2.3 t/ha to 3.3) (Figure 2.33).

**Figure 2.32. Corn annual average production (million tons).**




Source: own calculation on FAO data.

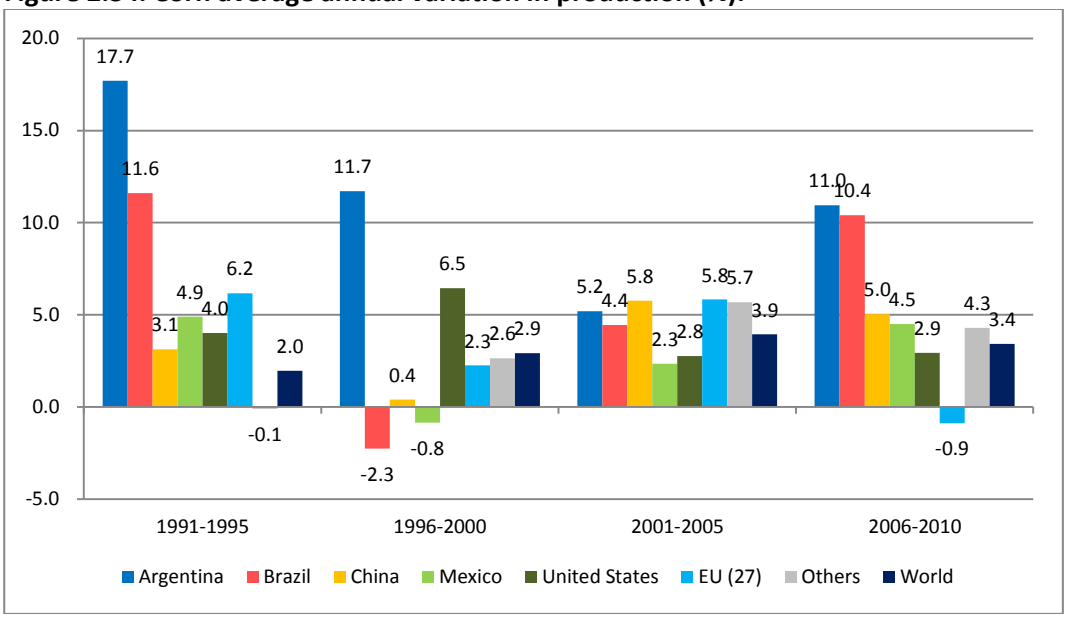
**Figure 2.33. Corn average yields in the main producing countries (tons/hectare).**




Source: own calculation on FAO data.

The average annual production variation has been positive for the whole period considered for almost all major producing countries. The major increases were recorded in emerging countries such as Argentina and Brazil, especially in the first half of the 90s. The average annual variation of the production had been lower in the US and in the EU (where it was negative in 2006-2010) where production systems are already very intensive and it is difficult to achieve substantial increases in production (Figure 2.34).

**Figure 2.34. Corn average annual variation in production (%).**



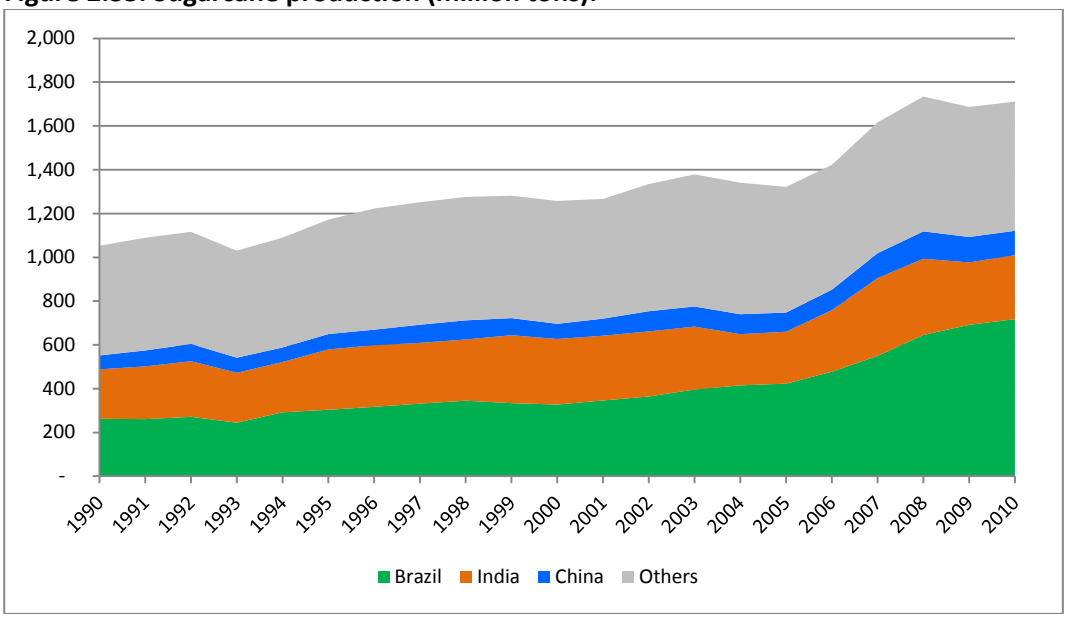

Source: own calculation on FAO data.

### *2.3.1.3 Sugarcane production.*

Sugarcane production is concentrated in very few countries: in 2010 the first three producers (Brazil, India, and China) accounted for 66% of the world production with Brazil only accounting for 42%. In 2010 world production was 1.7 billion tons, more or less stable with respect to the previous year but much higher than in the previous decade (+36%). Brazil produced 717 million tons of sugarcane in 2010, India 292 million tons and China 111 million tons. It must be highlighted the fact that, while the Indian output remained more or less constant during the last 20 years, that of China and, especially, Brazil grew significantly. In the case of the South American country, the increase can be easily explained with the expansion of the ethanol sector. Brazilian production, in 1990, was about 263 million tons, while in 2010 it had almost triplicated (Figure 2.35).

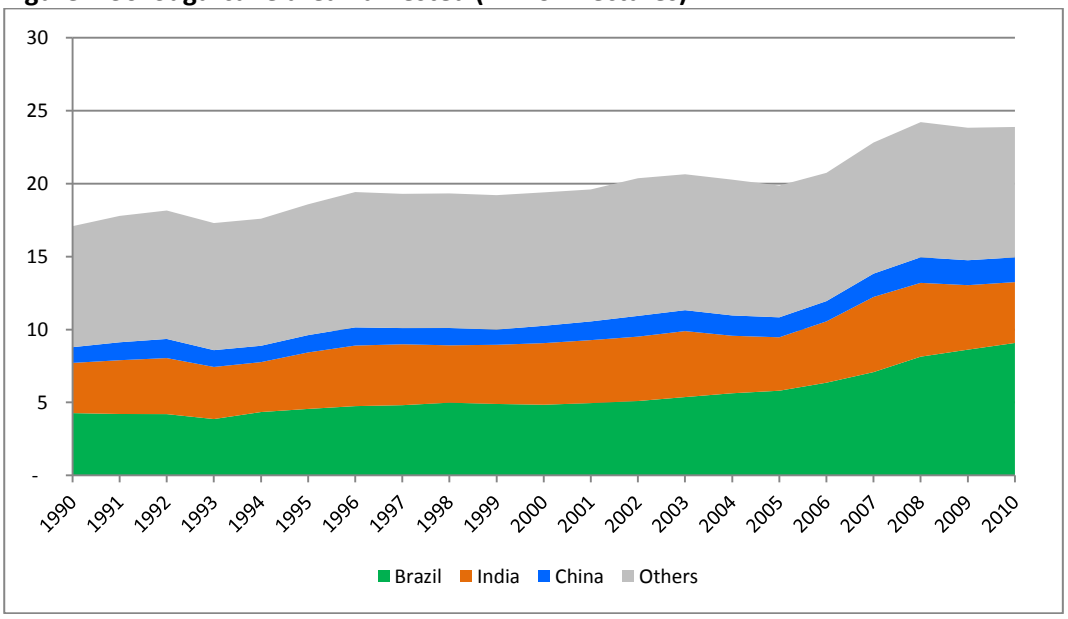
The evolution of the area harvested was somehow similar to that of production: it increased during the whole period under consideration (1990-2010) but especially in the second half of the 2000s and especially in Brazil, as a consequence of biofuel expansion. In 2010 in the world almost 24 million hectares were cropped with sugarcane, 9 million of which in Brazil. Area under cultivation in India was 4.2 million ha, and in China 1.7 million. During the last two decades cropped area increased almost exclusively in Brazil, while in the other producing countries remained almost stable (Figure 2.36).

**Figure 2.35. Sugarcane production (million tons).**




Source: own calculation on FAO data.

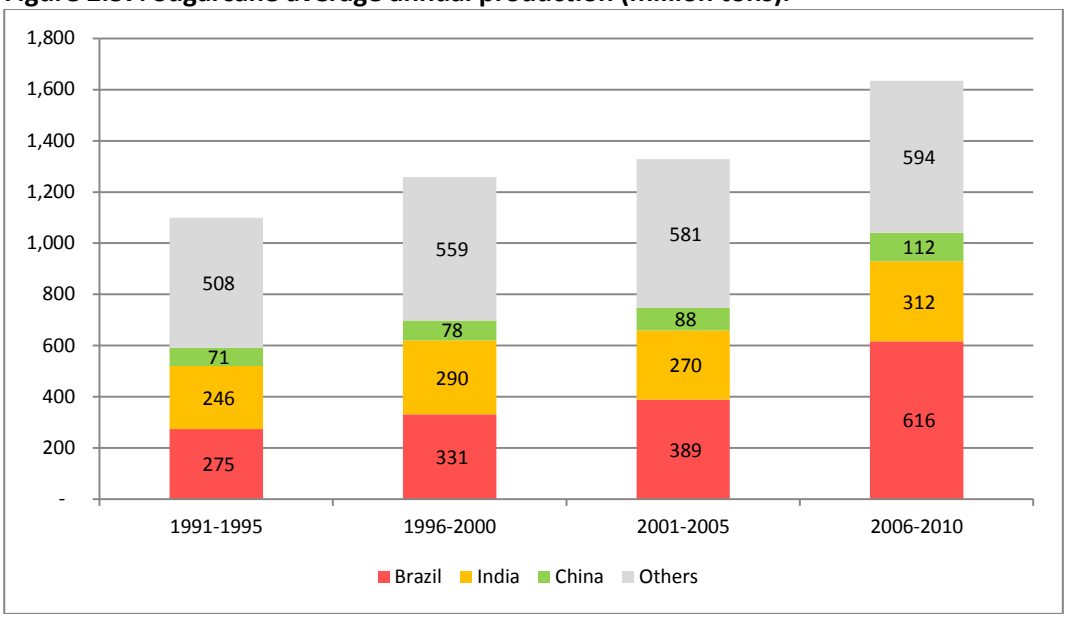
**Figure 2.36. Sugarcane area harvested (million hectares).**




Source: own calculation on FAO data.

The expansion of Brazilian production is even more evident when one takes into account average production calculated over five-year periods in order to minimize the influence of short-term events that might have affected production. On average, world sugarcane production, was 1.1 billion tons in 1991-95 and grew up to 1.6 billion in 2006-10. The most of such increase was due to the expansion of Brazilian production. The Latin American country produced, on average, 275 million tons of sugarcane per year at the beginning of the 90s, while in the second half of the 2000s average production was 2.2 times higher (Figure 2.37).

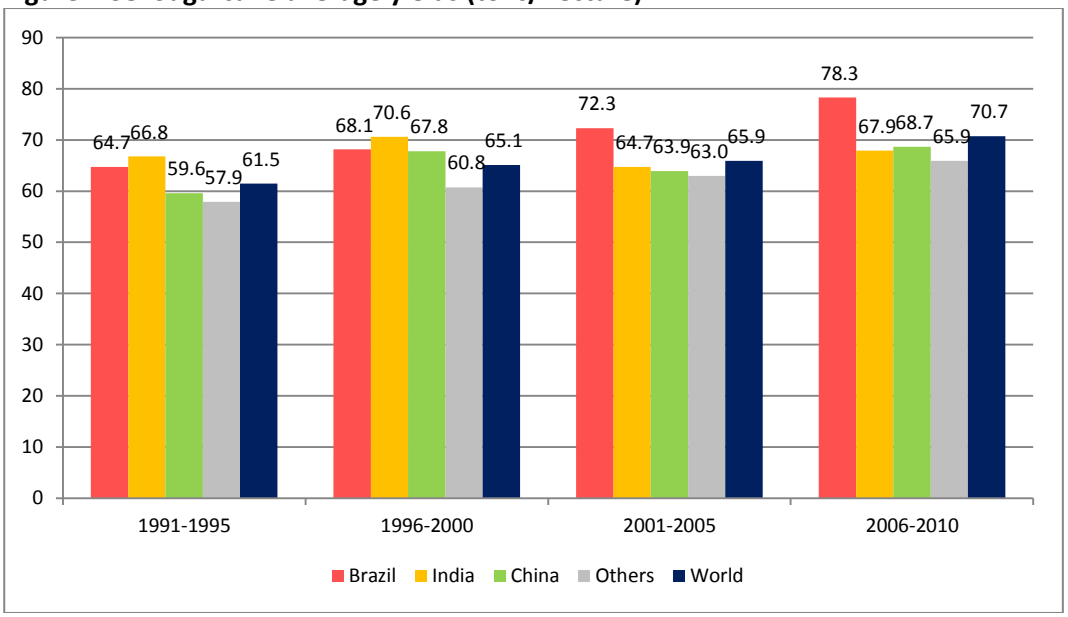
**Figure 2.37. Sugarcane average annual production (million tons).**




Source: own calculation on FAO data.

Also yields increased over time: at global level, the average yield, in the first half of the 90s, was about 61.5 t/ha, while in the second half of the 2000s about 70.7 t per ha. The increase was particularly strong in Brazil (+21%) where average yield in 2006-10 was 78.3 t per ha. In the other major producing countries average yields are lower and more or less in line with the world average (Figure 2.38).

**Figure 2.38. Sugarcane average yields (tons/hectare).**

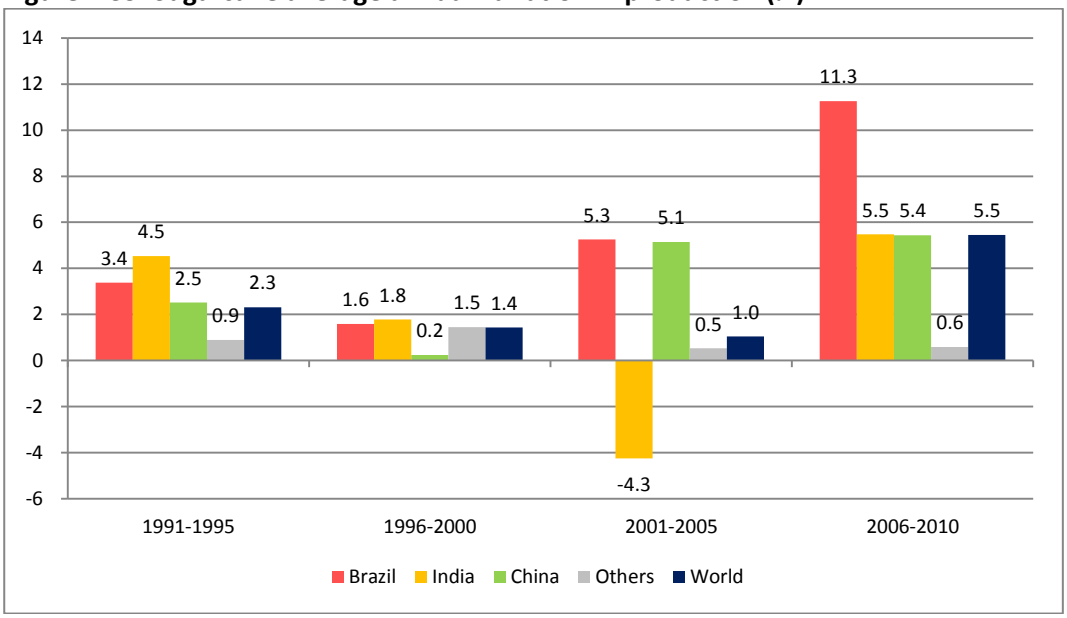



Source: own calculation on FAO data.

Also the analysis of the average annual variation in production showed the important role ethanol production had in explaining the strong increase in sugarcane production in Brazil. The rate at which Brazilian production increased was declining during the 90s but it started to grow again in the first half of

the 2000s and substantially increased in the second half of the decade, when production grew on overage by 11.3% per year. In the last ten years production growth rate increased also in China and in India (+5% per year on average in 2006-10) but the increase, in this case, can be explained by the expansion in domestic demand rather than by the expansion of the biofuel sector (Figure 2.39).

**Figure 2.39. Sugarcane average annual variation in production (%).**

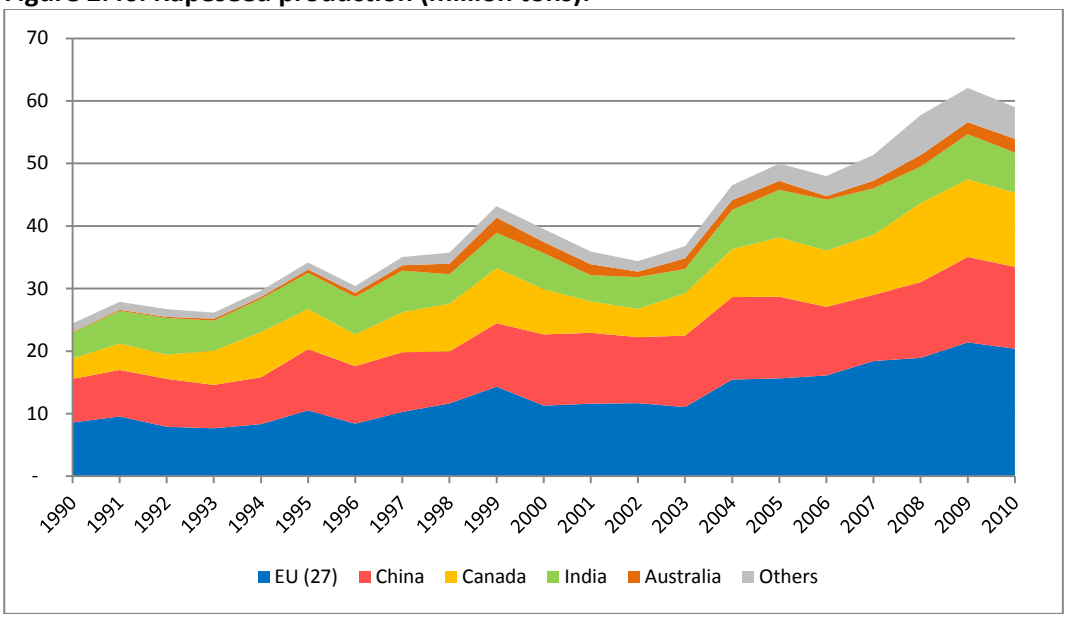



Source: own calculation on FAO data.

### *2.3.1.4 Rapeseed production.*

Rapeseed is the main feedstock for biodiesel production in the European Union, which is also the main producing country of the crop in the world. Similarly to what happens for many other agricultural commodities, also in the case of rapeseed, production is concentrated in relatively few countries. The top-four producers, the EU, China, Canada, and India, represented 86% of the world production in 2010, even though the share of third countries has been increasing in the last 20 years. In 2010 the world rapeseed output was equal to 59 million tons, 5.0% down from 2009 levels. The major producer in the world was the EU (20.4 million tons), followed by China (13.0 million tons), Canada (13 million tons), and India (11.9 million tons). In the last 20 years production more than doubled (from 24 million tons to 59) especially in the EU (+137% with respect to 1990) and Canada (+263%) (Figure 2.40).

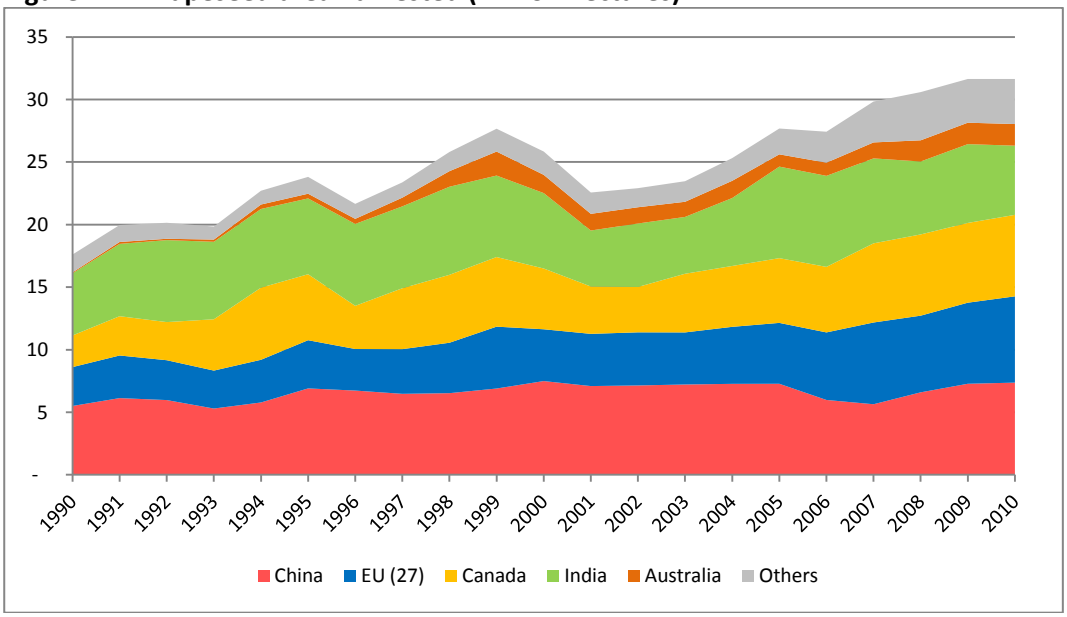
**Figure 2.40. Rapeseed production (million tons).**




Source: own calculation on FAO data.

Also areas harvested expanded even though to a lesser extent. In 2010 more than 31 million hectares were covered with rapeseed crops, 79% more than in 1991. Most of the cropped area is located in China (7.4 million ha), the EU (6.9 million ha), Canada (6.5 million ha), and India (5.5 million ha). Areas harvested, over the last two decades, expanded especially in Canada, which rapidly became one of the most important rapeseed oil suppliers of the EU (Figure 2.41).

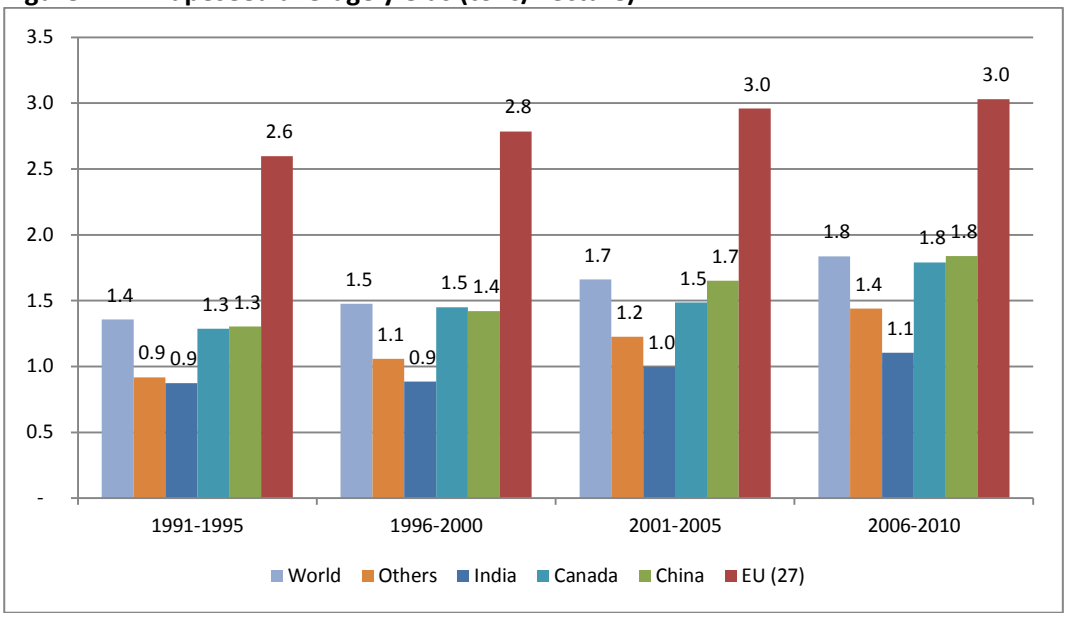
**Figure 2.41. Rapeseed area harvested (million hectares).**




Source: own calculation on FAO data.

Since production increased more than area harvested, also yields increased over time, especially in the European Union, where they are the highest in the world. At the beginning of the 90s, world average yield was 1.4 t/ha, while by the end of the 200s it grew up to 1.8 t/ha. EU yields have been much higher than those of the rest of the world for the whole period (2.6 t/ha in 1991-95 and 3.0 t/ha in 2006-10). While one could expect yields to be significantly lower in China and India it is somewhat surprising to see that also Canadian yields are substantially lower than EU ones, especially in recent years (1.8 t/ha at the end of the 2000s) (Figure 2.42).

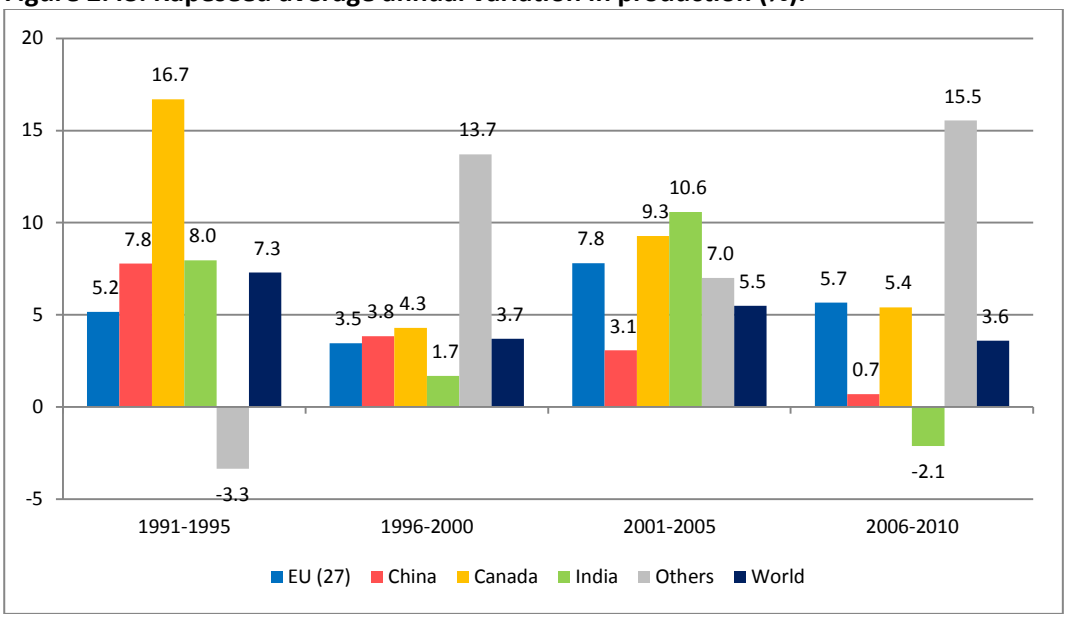
**Figure 2.42. Rapeseed average yields (tons/hectare).**




Source: own calculation on FAO data.

The average annual variation in production did not follow a particular trend during the last 20 years. Even if production increased, the rate at which it grew was neither growing nor declining. At the beginning of the 90s, in average, world production increased by 7.3% per year, while at the end of the 2000s just by 3.6% per year. In the EU the growth rate was 5.2% per year in the 1991-95 period to decline to 3.5 in the second half of the 90s, go up again in the early 2000s (7.8 per year) and decline again in the second half of the 2000s (5.7% per year) (Figure 2.43).

**Figure 2.43. Rapeseed average annual variation in production (%).**



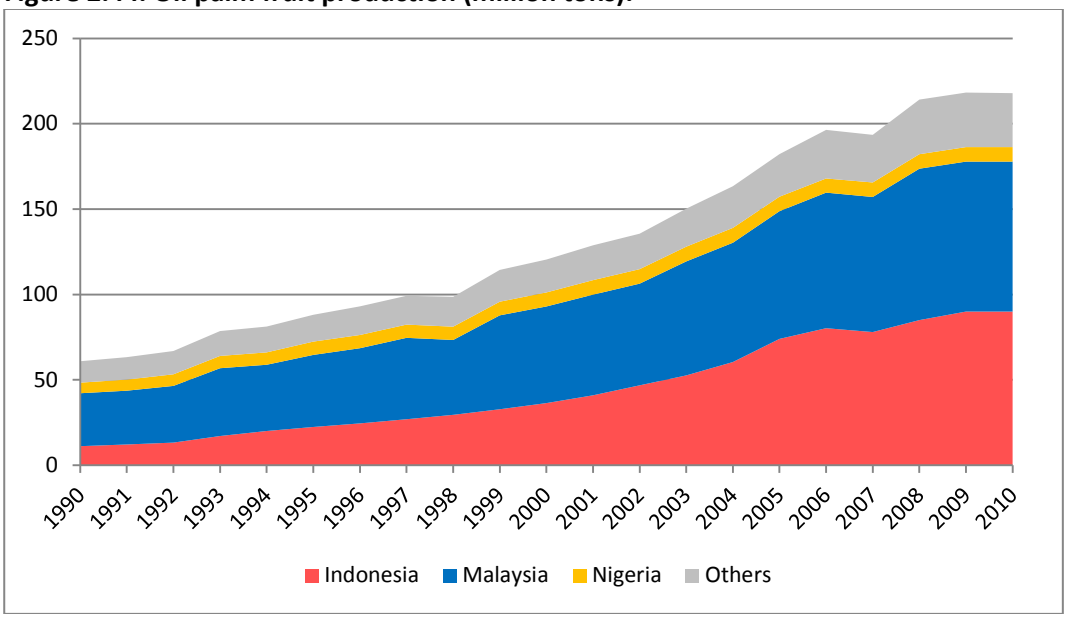

Source: own calculation on FAO data.

### *2.3.1.5 Oil palm fruit production.*

Oil palm production is concentrated in Indonesia and Malaysia, which together account for more than 81% of the world production. In 2010 the world output was equal to 218 million tons of oil palm fruits, 90.0 million of which produced in Indonesia, and 87.8 in Malaysia. Production, in the last two decades increased substantially. In 1990 the world output was just 60.9 million tons, 2.6 times lower than in 2010. In 1990 Malaysia was the major producer in the world (31 million tons) but its production grew in a relatively lower rate than Indonesia's, which is now the leading world producer. Indonesia production was, in 2010, 7 times higher than in 1990, while Malaysia's just 1.8 times higher (Figure 2.44).

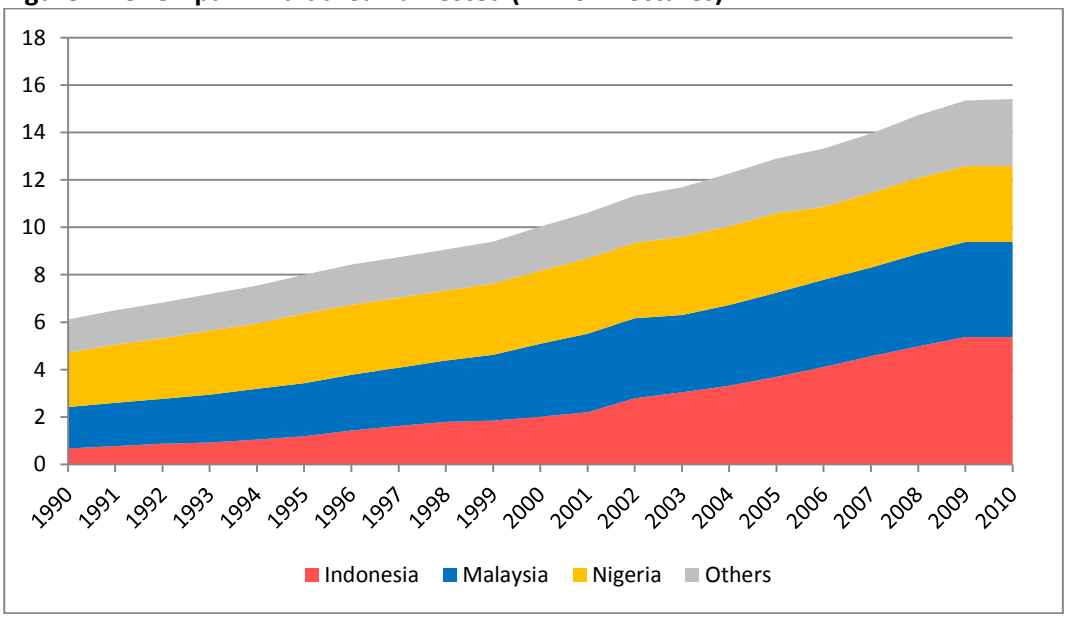
The evolution of area harvested was very similar to that of quantities produced, with Indonesia being the country characterized by the highest increase. In terms of area harvested Malaysia and Indonesia are not the only important countries: if the two Asian countries, in 2010, were characterized, together, by 9.4 million hectares under cultivation, the Nigerian oil palm crop occupied almost 3.2 million ha in the same year. From this it is possible to infer that while oil palm cultivation is very intensive (and export-oriented) in South-East Asia, it is much more extensive in Western Africa, where it is finalized to domestic consumption (Figure 2.45).

**Figure 2.44. Oil palm fruit production (million tons).**




Source: own calculation on FAO data.

**Figure 2.45. Oil palm fruit area harvested (million hectares).**

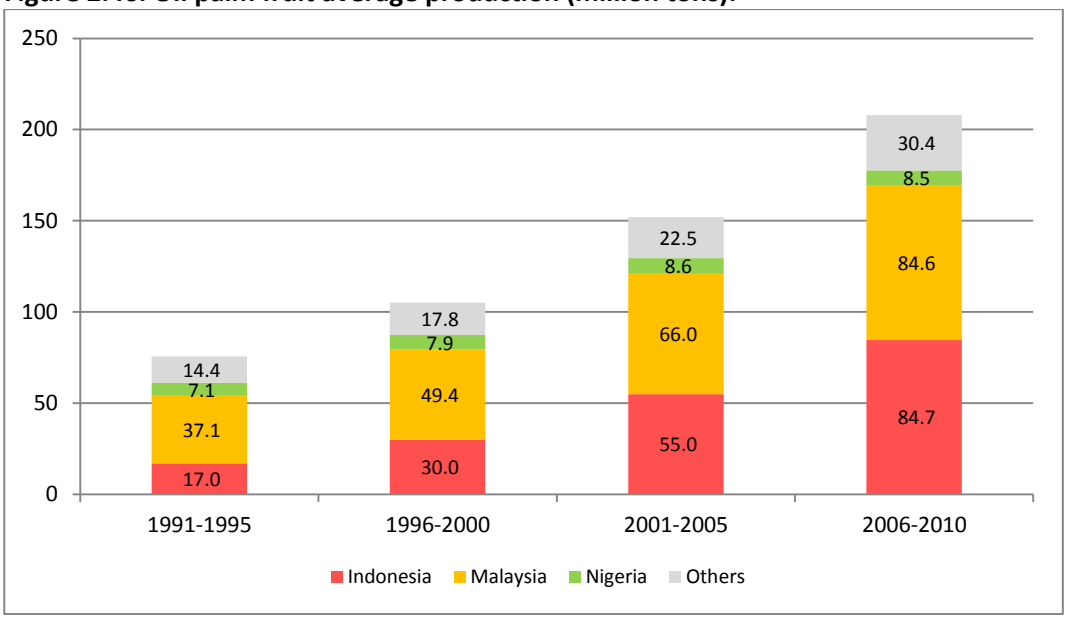



Source: own calculation on FAO data.

While in Nigeria, not affected by biofuel expansion, average production (calculated over 5-year long period from the beginning of the 90s to the end of the 2000s) remained almost constant or slightly increased (8 million tons per year), in Malaysia and especially in Indonesia it increased exponentially to meet the growing demand for palm oil for biodiesel production. In the 1991-95 period the average annual production in Malaysia was 37.1 million tons, and in Indonesia 17.0 million tons. In the second half of the 2000s average production was almost 84 million tons in both countries (Figure 2.46). Such growth in production, explained by the expanding demand for palm oil, might have had serious consequences for the tropical forest and relative ecosystems: in order to create room for the new plantations, large parts of the

rain forest had been logged with a subsequent mobilization of carbon stored in the threes and serious consequences for biodiversity.

**Figure 2.46. Oil palm fruit average production (million tons).**

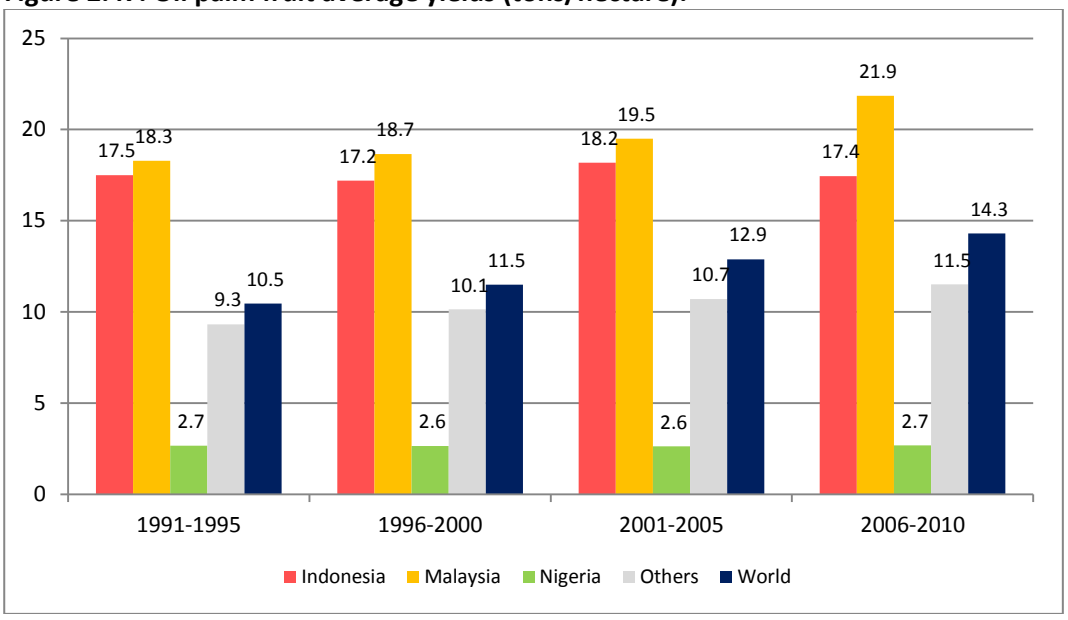



Source: own calculation on FAO data.

Yields had been increasing from 1990 to 2010 in Malaysia, while they remained almost constant in Indonesia, Nigeria and the other producing countries. In the first half of the 1990s average yields were 17.5 t/ha on Indonesia and 18.3 t/ha in Malaysia. By the end of the 2000s they had grown to 21.9 t/ha in Malaysia while remained constant in Indonesia. Yields in Nigeria, the third most important country for are harvested fluctuated around 2.7 t/ha for the whole period (Figure 2.47).

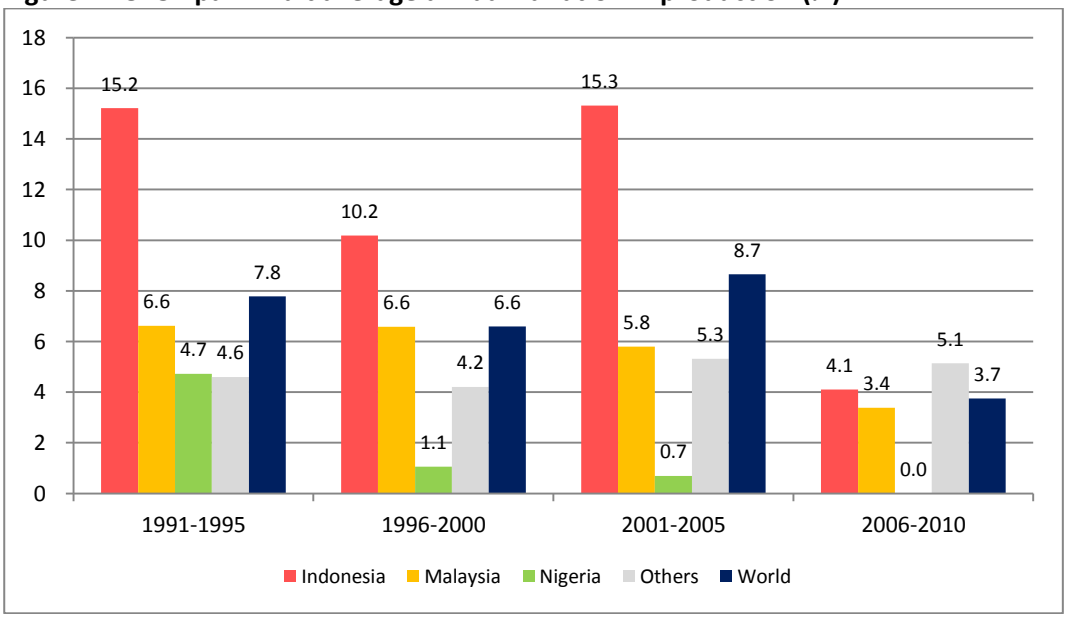
The analysis of the evolution of the average annual variation in production, shows once again the strong increase Indonesian Malaysian output. During the 90s and the first half of the 2000s, Indonesia oil palm fruit production grew at a double-digit rate, especially in the 2001-05 period (+15% per year). Production growth in Malaysia was lower but still significant: around 5-6% per year on average. In the second half of the 2000s production growth slowed down in both countries, with average production growth rates of 4.1%/year for Indonesia and 3.4%/year for Malaysia (Figure 2.48).

**Figure 2.47. Oil palm fruit average yields (tons/hectare).**




Source: own calculation on FAO data.

**Figure 2.48. Oil palm fruit average annual variation in production (%).**




Source: own calculation on FAO data.

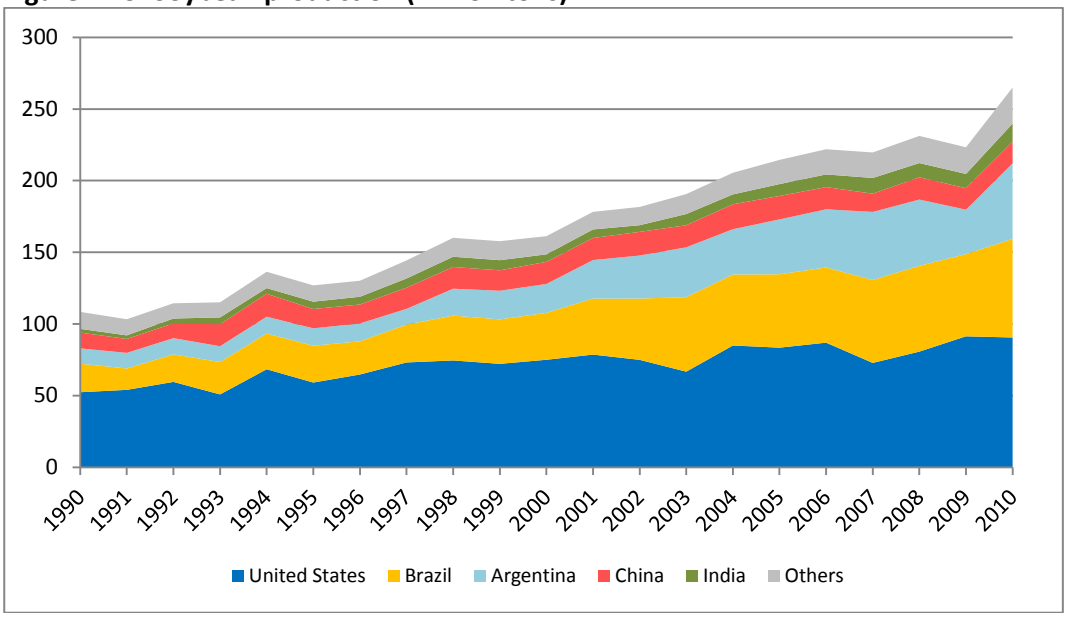
### *2.3.1.6 Soybean production.*

Soybeans are a key agricultural commodity, both for human and animal consumption and therefore, like wheat, it could have been affected (at least indirectly) by biofuel expansion biodiesel, both in Brazil and the US, is produced from soybean oil. Even though biodiesel production in these countries is still not very developed, it might grow in the future since both countries have started implementing policies to favor the development of the biodiesel sector.

In 2010 the world soybean production was about 265 million tons, 18.6% up from 2009 and 1.4 times higher than in 1990. Almost 80% of world production, in 2010, came from either the US, Brazil or

Argentina. The US had been the major soybean producer in the world since 1990 and its output totaled 90.6 million tons in 2010, 34.2% of world production. Brazil, always in 2010, produced 68.8 million tons of soybeans (26.0% of the world output), while Argentina 52.7 million (19.9% of world production). With respect to 1990 the world production increased 2.4 times, with the greatest increases in Latin American countries: while US output expanded by 173%, production in Brazil and Argentina grew by 3.5 and 4.9 times respectively. China's output increased by 1.4 times (15 million tons in 2010), while India's almost quintuplicated, passing from 2.6 million in 1990 to 12.7 million in 2010 (Figure 2.49).

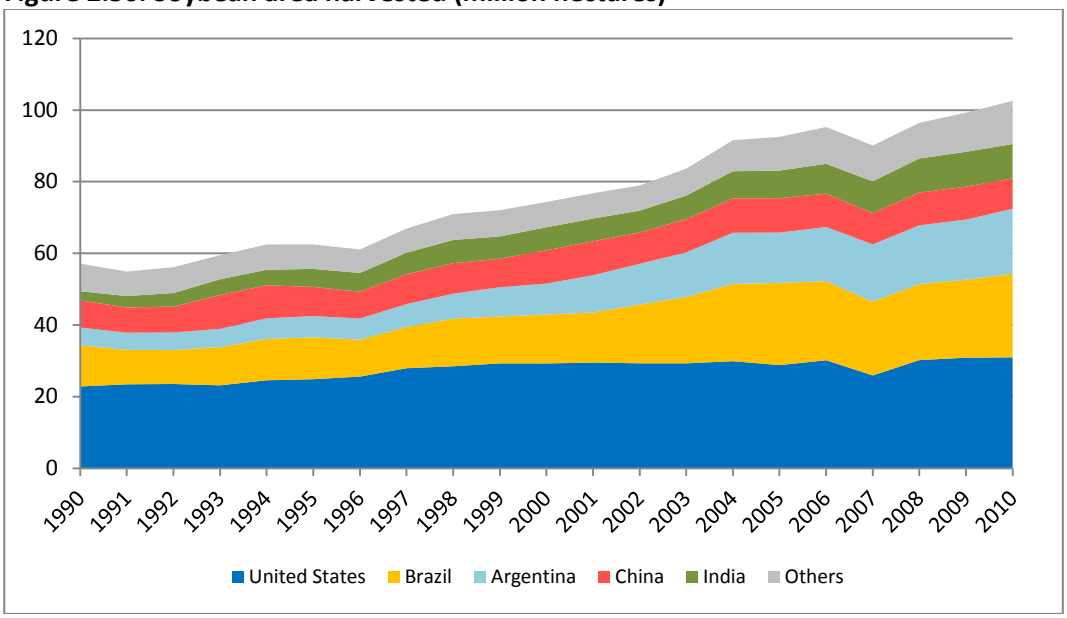
**Figure 2.49. Soybean production (million tons).**




Source: own calculation on FAO data.

The evolution of the area harvested is similar to that of quantities produced. It has been a steadily increase in area harvested during the last two decades, especially in Latina American countries such as Argentina and Brazil. In 2010 total area harvested amounted to 103 million hectares, almost 1.8 times more than in 1990. Most of the area cropped is located in the US (31 million ha, 30% of world total), Brazil (23 million ha, 22.7%), and Argentina (18.1 million ha, 17.7%). With respect to 1990 US area harvested increased by 1.3 times, less than the world average. Conversely, in Brazil and Argentina, area harvested grew 2 and 3.7 times respectively (Figure 2.50).

**Figure 2.50. Soybean area harvested (million hectares)**

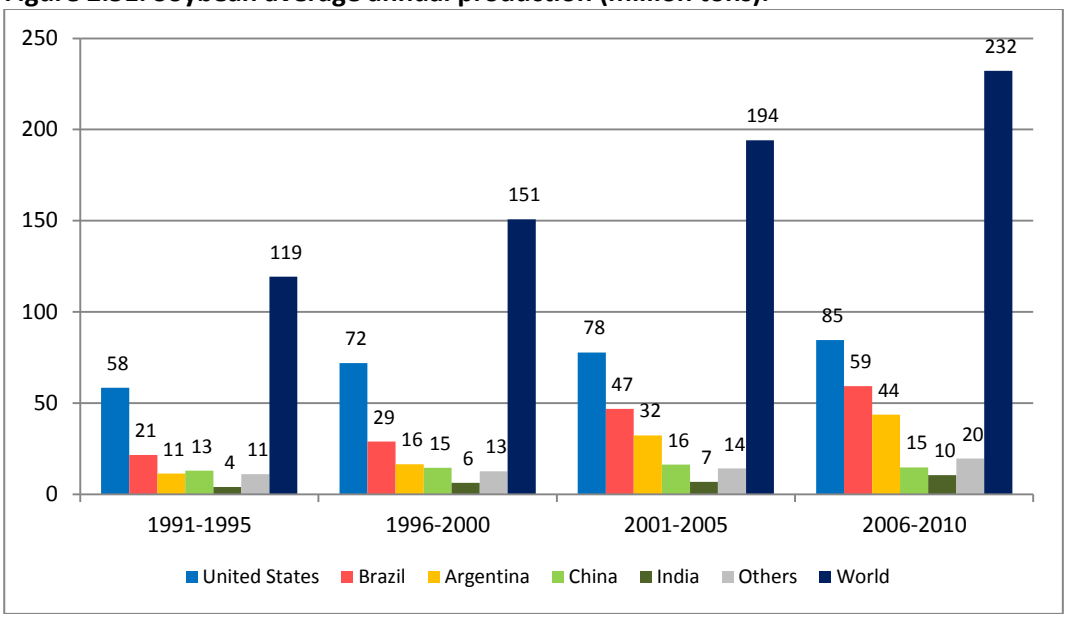



Source: own calculation on FAO data.

Average production has been calculated, similarly to the other commodities, for four five-year-long periods from 1990 to 2010 in order to analyze the evolution of quantities produced net of short-term factors that might have influenced supply like adverse weather events. In 1991-95 the average soybeans production was 119 million tons per year, this quantity has been increasing over time and in 2006-10 it was almost two times higher (232 million tons). Average annual US production increased from 58 million tons in 1991-95 to 85 million tons in 2006-10 (+44.6%). The increase in average production in emerging countries was higher in relative terms. Brazilian average annual production increased from 21 million tons to 47 (+175.9%), Argentinean from 11 to 32 (almost triplicated) and Indian from 4 million tons to 10 (+166.8%). The increase in Chinese average production was much smaller and around 13.8% (Figure 2.51).

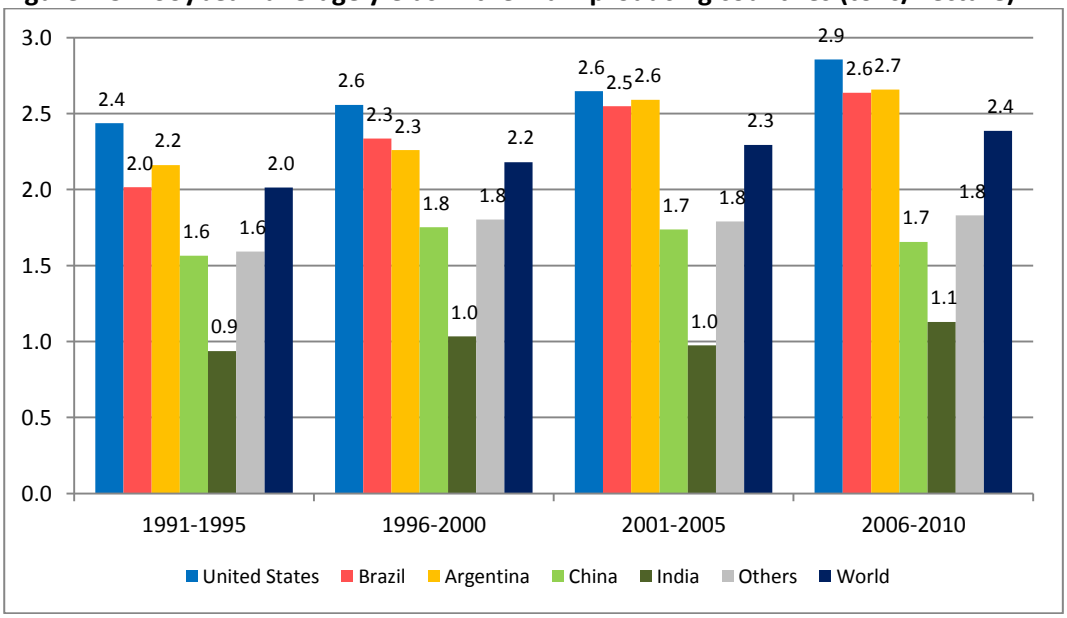
Yields had been increasing in the two decades under examination. In the first half of the 90s (1991-95), the average world soybean yield was about 2 t per ha, while at the end of the 2000s (2006-10) it had grown up to 2.4 t per ha. Yields increased in all major producing countries even though with different magnitude. In the US yields increased by 17.2% from early 90s to late 2000s (from 2.4 to 2.9 t per ha), while in Brazil and Argentina the increase was more substantial: +30.9 and +23.0% respectively. In both Latin American countries, in 2006-10, yields were only slightly lower than US's and equal to 2.6 and 2.7 t per ha respectively. In China and India, characterized by a more extensive agriculture, yields are sensibly lower: in the second half of the 2000s they were respectively 1.7 and 1.1 t per ha (Figure 2.52).

**Figure 2.51. Soybean average annual production (million tons).**




Source: own calculation on FAO data.

**Figure 2.52. Soybean average yields in the main producing countries (tons/hectare).**

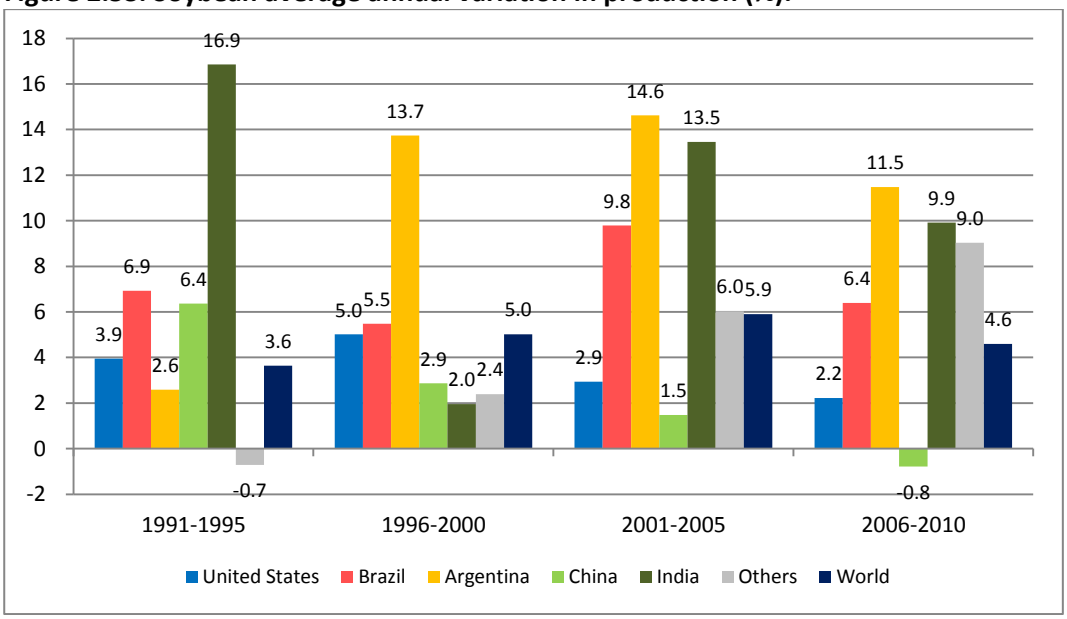



Source: own calculation on FAO data.

The average annual variation in production has been generally positive during the last two decades, meaning that production has been increasing. However, at least in some countries the rate at which production increased had declined during the 2000s. At world level soybean production was growing, on average, by 3.6% per year at the beginning of the 1990s. This rate increased up to 5.9% per year in the first half of the 2000s and then decreased to 4.6% per year. In the US, the most advanced producer, production growth rate had been lower than the world average for the whole period considered, and declining over time, from 3.9% per year in the early 90s to 2.2% per year in the late 2000s. Brazilian and Argentinean production growth rates had been higher and, in the Argentina case, production grew at a double-digit rate

even in the second half of the 2000s when there was a generalized decrease in production increase (Figure 2.53).

**Figure 2.53. Soybean average annual variation in production (%).**



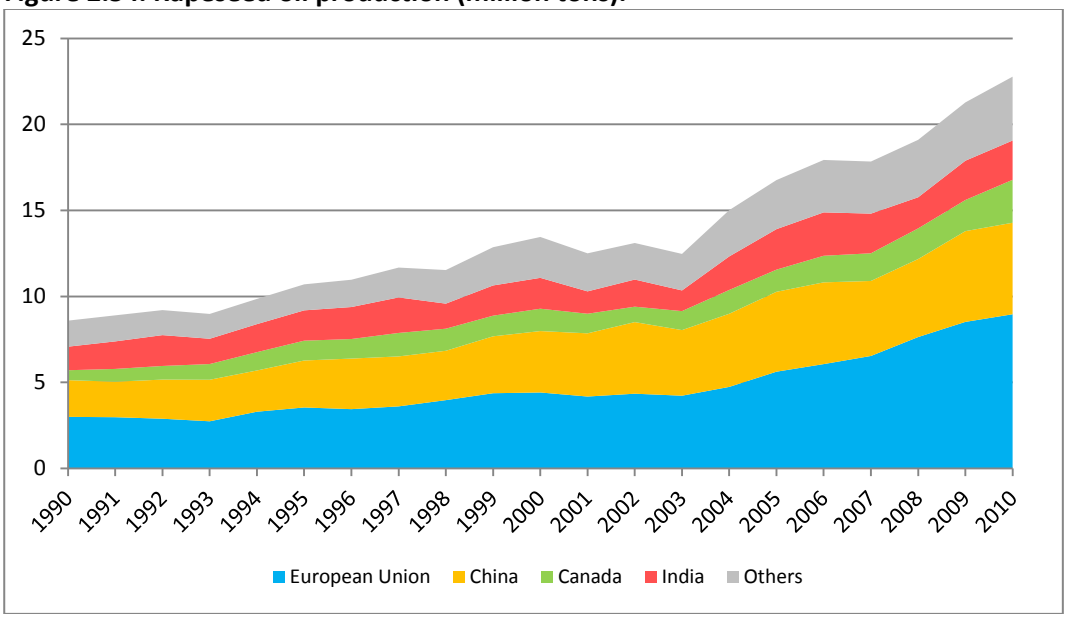

Source: own calculation on FAO data.

### *2.3.1.7 Rapeseed oil production.*

Rapeseed oil is one of the main feedstock used in biodiesel production, especially in the EU, which is also the main producer in the world. In 2010 world rapeseed oil production was equal to about 22.8 million tons a quantity that has been increasing greatly over time. In 1990 world production was just 8.6 million tons, 2.7 times lower than in 2010. The great expansion in world production is due to the strong increase in production in the EU and, to a lesser extent, in China and Canada.

In 2010 EU rapeseed oil production was about 9.0 million tons and represented 39.4% of the world total. China was the second-largest producer with 5.3 million tons in 2010, equal to 23.4% of world output. Canada and India are other two leading producing countries with an output of 2.5 and 2.3 million tons respectively in 2010. The role of other countries is marginal. Rapeseed oil can be used in the food industry but also for biodiesel production. Since the EU imports large quantities of biodiesel from Canada, it is possible to argue that the strong increase in Canadian production could be also traced back biodiesel expansion in the EU. Conversely, the increase in production in both China and India can be explained by the increase in domestic demand (Figure 2.54).

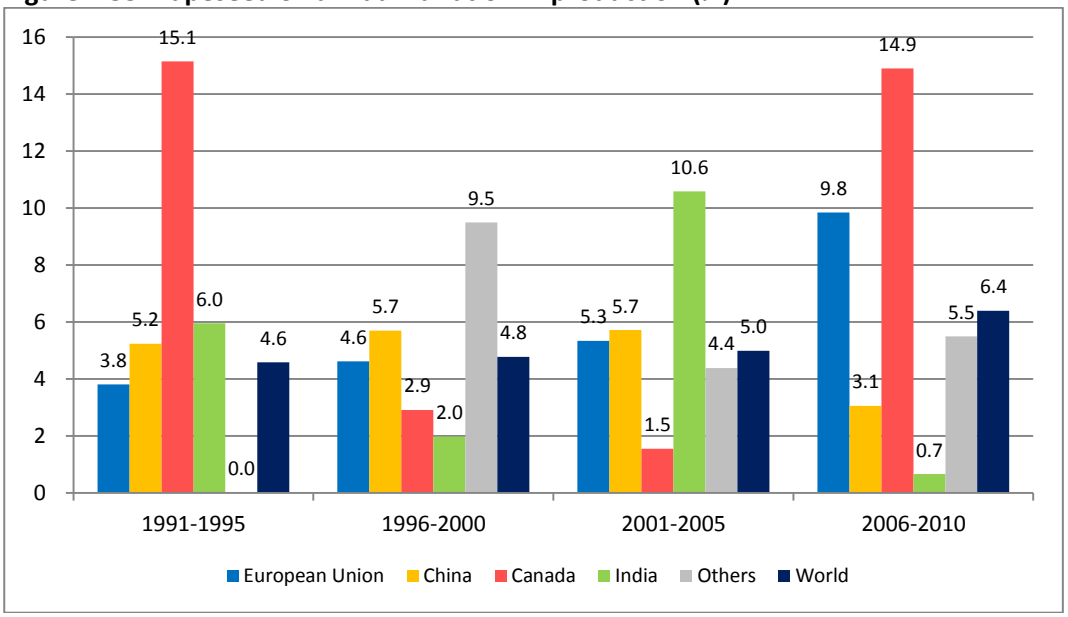
**Figure 2.54. Rapeseed oil production (million tons).**




Source: own calculation on FAO data.

The average annual variation in production had been increasing since 1990, especially in the second half of the 2000s in the EU and Canada, when the production of biodiesel in the EU boomed. On average, in the EU, rapeseed oil production increased by 9.8% per year in the late 2000s and in Canada by 14.9% per year, significantly more than in the previous periods and in the other major producing countries (Figure 2.55).

**Figure 2.55. Rapeseed oil annual variation in production (%).**

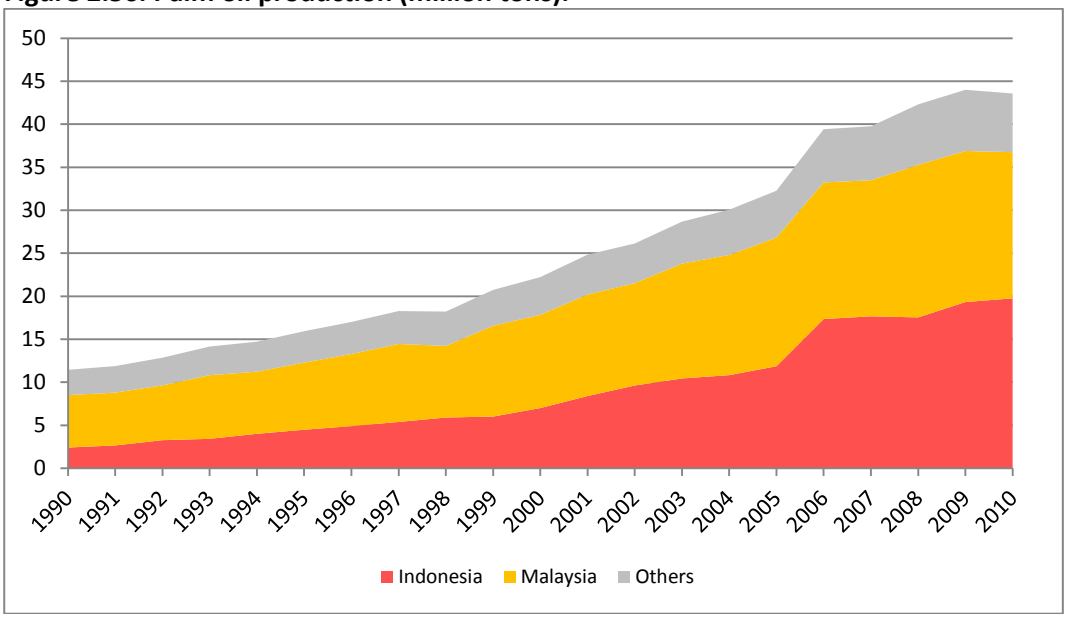



Source: own calculation on FAO data.

### *2.3.1.8 Palm oil production.*

Palm oil production is concentrated in two countries: Indonesia and Malaysia, which together accounted for 84% of world production in 2010. In the same year the world output totaled 43.6 million tons, 19.8 of which produced in Indonesia and 17.0 in Malaysia. Production grew exponentially in the last 20 years: in 1990 it was four times lower than at the end of the 2000s. The expansion can be only partially explained by the increase in demand for food consumption in tropical developing and emerging countries. As a matter of fact production, in Indonesia and Malaysia, started to grow significantly at the beginning of the 2000s when biodiesel production started to expand substantially in the EU. Since the domestic EU rapeseed production is not sufficient to produce all the biodiesel that the EU needs to produce to meet its consumption targets, the EU started to import palm oil, also suitable as biodiesel feedstock. In 20 years the Indonesian production grew more than 8 times, while the Malaysian one by a little less than three times. In both cases, however, the magnitude of the increase has been substantial, especially if compared to that of other producing countries (mainly poor countries in Sub-Saharan Africa) where production increased at way lower rates (Figure 2.56).

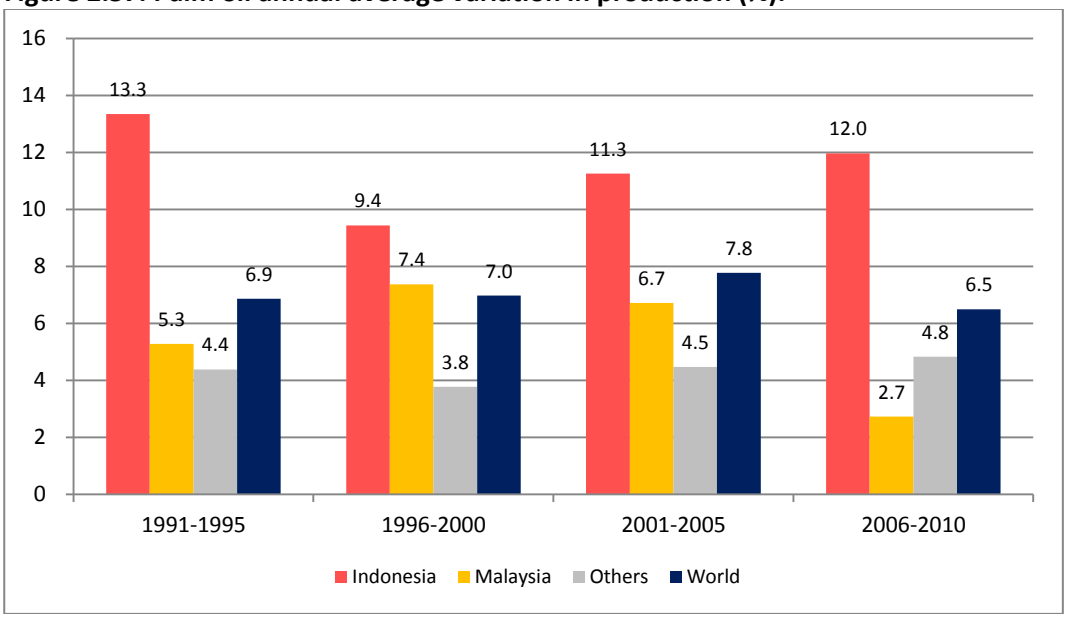
**Figure 2.56. Palm oil production (million tons).**




Source: own calculation on FAO data.

The average annual variation in production had been, in the case of Indonesia, positive and, with exception of the second half of the 90s, increasing at a double-digit rate. In the second half of the 2000s, for example, the Indonesia palm oil production increased, on average, by 12.0% per year. In Malaysia average increases had been much lower and, most importantly, decreasing over time, especially in the second part of the 2000s, when the average variation in production was just +2.7% per year (Figure 2.57).

**Figure 2.57. Palm oil annual average variation in production (%).**




Source: own calculation on FAO data.

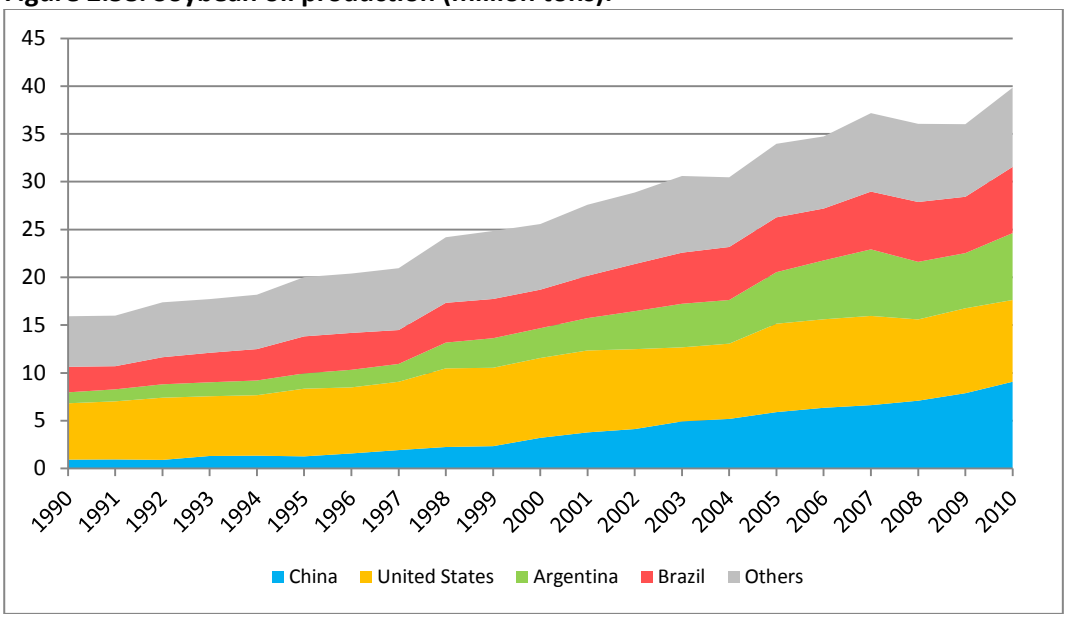
### *2.3.1.9 Soybean oil production.*

In 2010 world soybean oil production was 39.8 million tons, 10.6 up from 2009 levels. Main producing countries were China, United States, Argentina, and Brazil that, together, represented 79.2% of world production, similarly to what happened for soybeans. In the last 20 years world production substantially expanded: in 2010 the world output was 2.5 bigger than in 1990. The country that experienced the greatest expansion in production was China, which output grew 9.9 times during the time span considered (production in 2010 was 9.1 million tons). US production (8.6 million tons), the second-largest producer, grew 1.5 times during the time span analyzed. In 2010 production in Argentina and Brazil was almost the same (7 million tons), however, in the last two decades the Argentinean output grew more than 6 times, while the Brazilian one 2.6 times (Figure 2.58).

Soybean oil is still used mainly for food purposes as the rapid growth of China's output shows (Chinese cuisine makes great use of soybean oil), however countries like Brazil and the US that have started subsidizing the biodiesel sector might have increased their soybean oil production to meet consumption targets.

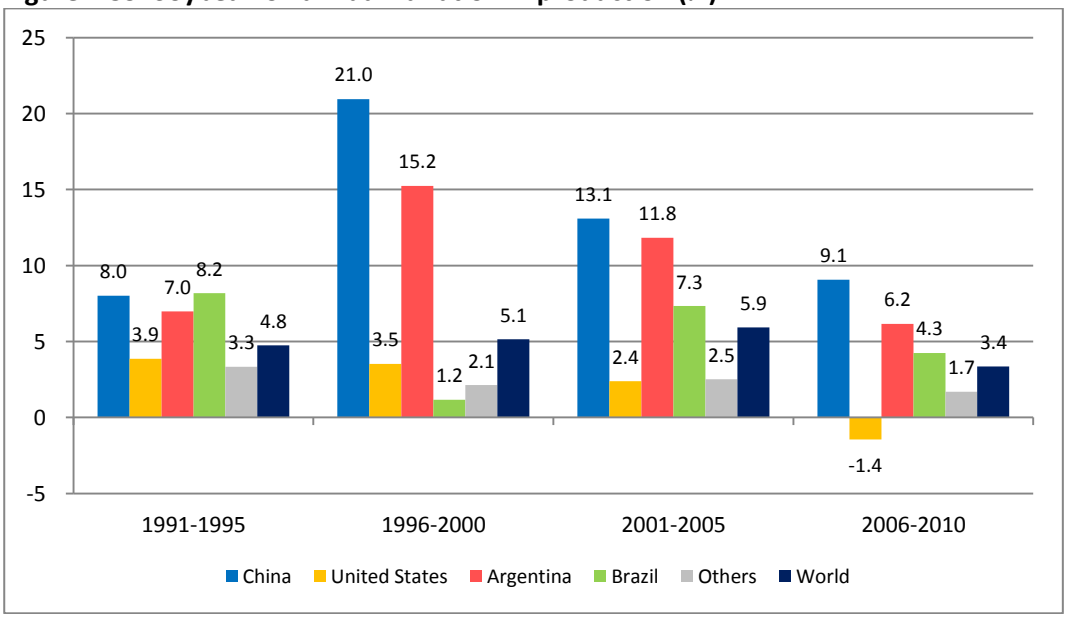
On average, production, at world level, increased at a more rapid rate, at the end of the 90s and at the beginning of the 2000s (+5.1 and +5.9% per year respectively). Chinese production expanded at an increasing rate during the 90s: at the end of the decade Chinese output was growing by 21% per year on average. During the 2000s production kept increasing but at a declining speed. The same happened in Argentina, while the growth rate of US production declined for the whole period and became, during the second half of the 2000s, negative (Figure 2.59).

**Figure 2.58. Soybean oil production (million tons).**




Source: own calculation on FAO data.

**Figure 2.59. Soybean oil annual variation in production (%).**




Source: own calculation on FAO data.

### 2.3.2 Evolution of agricultural and forest area and fertilizer use in the world.

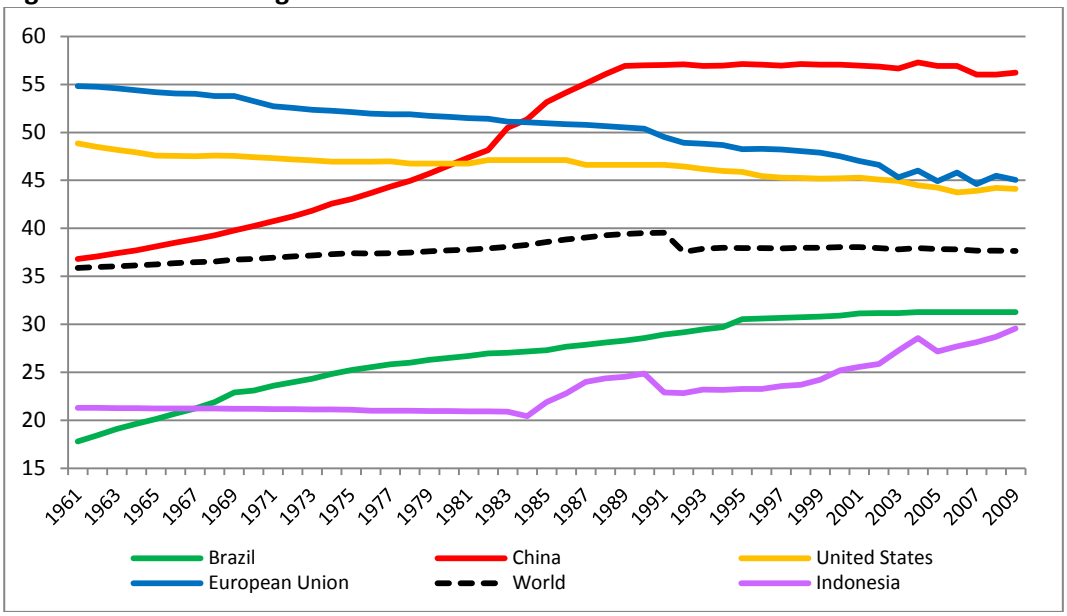
This sub-section is about the evolution of agricultural land, average yields, fertilizers consumption and forest area in the past five decades. It is important to understand how agricultural production has evolved in the last 50 years in order to better understand the possible effects biofuel expansion has been having on the agricultural sector and on the environment worldwide. Data illustrated in this sub-section are from the World Bank World Development Indicators database (World Bank, 2012) and from the Faostat database (FAO, 2012).

On a global scale, the share of agricultural area on total land area has only slightly increased during the last 50 years. It slowly increased (from 38% in 1961 to 40% in 1991) until the early 90s to stabilize around 36% in the last 20 years. The decrease in agricultural land that took place in the early 90s is due to the dismantling of the Soviet Union, following which a big amount of land stopped to be cultivated. However, the pattern was different depending on the country. In developed countries, such as the US and the EU, agricultural land have been declining steadily passing from being more than half of total land in the early 60s to 45% in the late 2000s. In developed countries the agricultural sector has undergone deep changes. Production structure evolved substantially: marginal land was progressively abandoned in favor of more productive land, which has been cropped with increasing intensity. In other words, more is produced in less land, with more inputs by less farmers. In developing countries the picture is much different. In China agricultural land, as a share of total land, increased substantially during the 70s and the first half of the 80s, thanks to the Green Revolution. Since the early 90s the share of agricultural land on total land has been stable around 56%. The increase in Brazil and Indonesia has been constant since the 60s. however, while in Brazil the share of agricultural land on total land grew, in the last 20 years, at a lower rate than before, the increase, in Indonesia has been almost exponential, mainly because of oil palm expansion. In both cases, however, the share of agricultural land is much lower both than in the other countries examined and the world average (almost 30%). The only case in which it is possible that the increase in biofuel production triggered an increase in land area is Indonesia's, where the progressive deforestation is cause of concern because of biodiversity loss and the increase in the amount of carbon released into the atmosphere (Figure 2.60).

From Figure 2.61 it is possible see how the share of agricultural land has been decreasing in the last 20 years, while it increased substantially in developing and least developed countries. It is arguable that such increased would have taken place anyway, however, it is likely that biofuel expansion, in palm oil and sugarcane production countries, contributed to such increase.

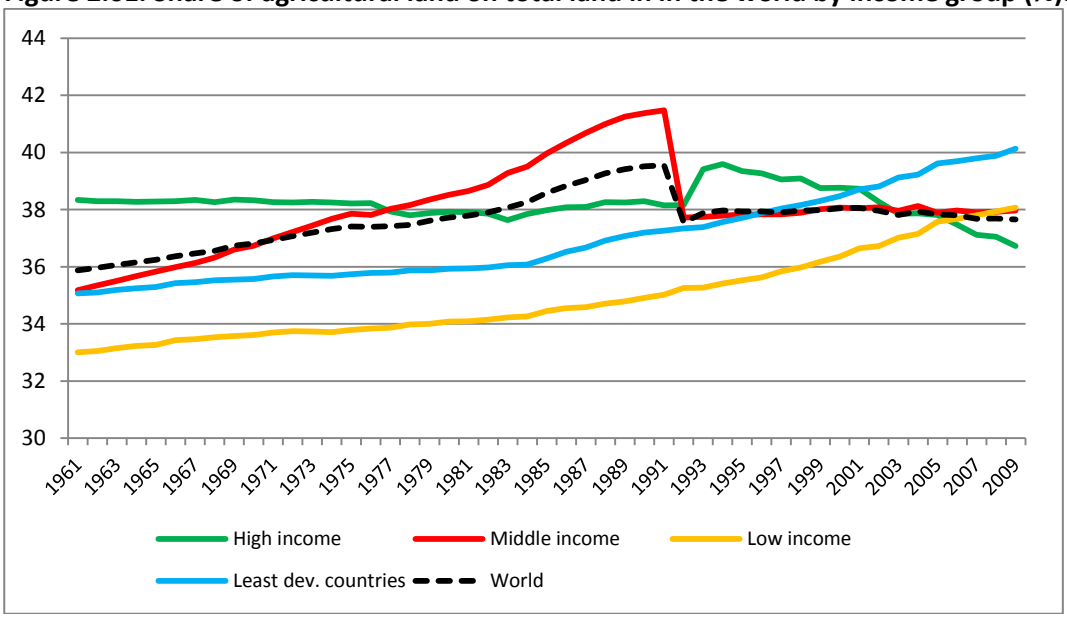
In Indonesia the increase in the share of permanent cropland on total land area has been exponential during the last 25 years and can be better seen in Figure 2.62. This is all due to the great expansion of oil palm plantations. The expansion of permanent cropland area in the South-East Asian country was particularly strong during the 2000s.

**Figure 2.60. Share of agricultural area on total land area in the world and in some selected countries (%)**



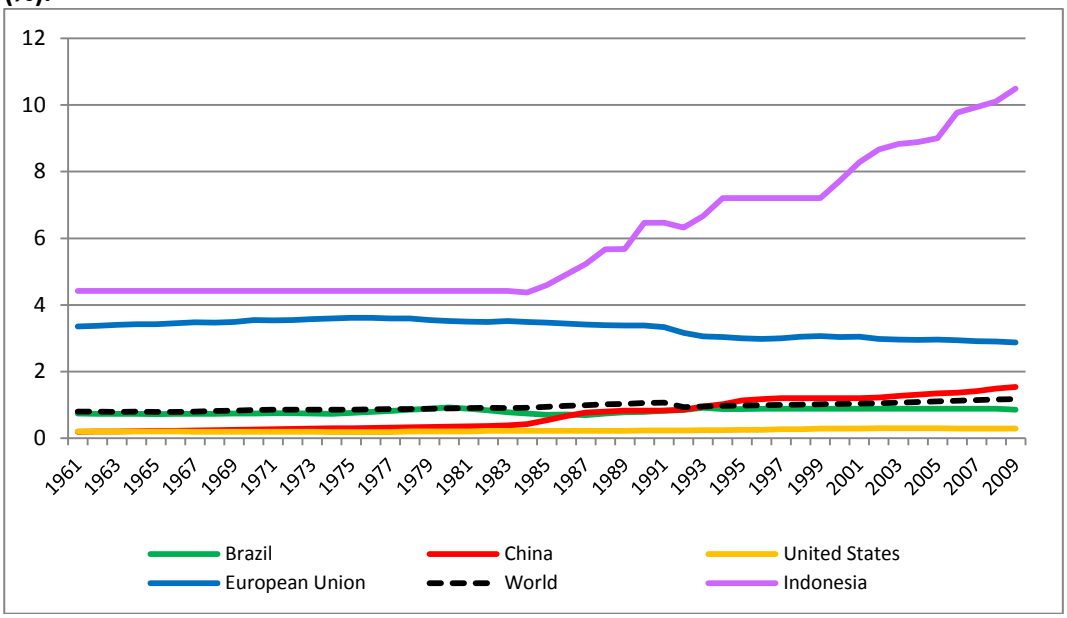

Source: own elaboration on WB data.

**Figure 2.61. Share of agricultural land on total land in in the world by income group (%).**




Source: own elaboration on WB data.

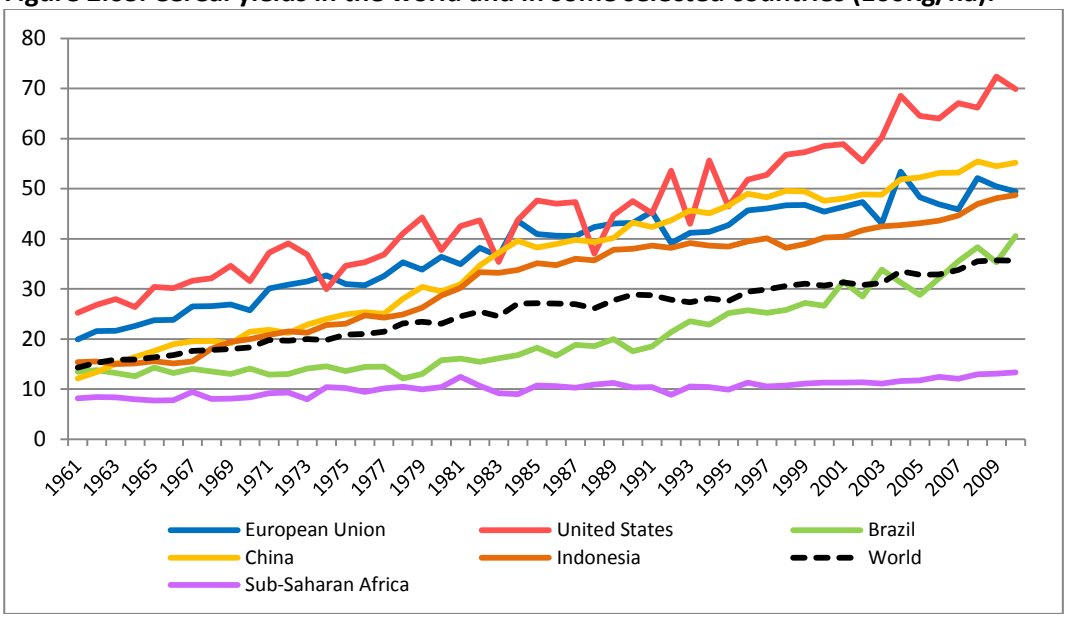
**Figure 2.62. Share of permanent cropland on total land area in the world and some selected countries (%).**




Source: own elaborations on WB data.

During the last 50 years cereal yields have been increasing in the world, even if at a declining rate. Nevertheless, the increase in yields, a proxy for agriculture intensity, varied greatly among countries. Yields, in the US, increased more than 17 times (from 2.5 to 7.0 tons/ha) from 1961 to 2009 and in the EU almost 15 times (from 2.0 to 4.9 tons/ha). The increase, in emerging countries like China and Indonesia was even greater (36 and 22 times respectively) and average cereal yields, in the two Asian countries, in 2009, were comparable to EU's. The increase in cereal yields, in Brazil was also substantial (20 times from 1961 to 2009) but, in the South America country, are significantly lower than in the other major producing countries. As a term of comparison, yields, in Sub-Saharan Africa, increased only a little during the time span considered, indicating how economic growth and political stability are essential factors to increase productivity, also in the agricultural sector.

**Figure 2.63. Cereal yields in the world and in some selected countries (100Kg/ha).**



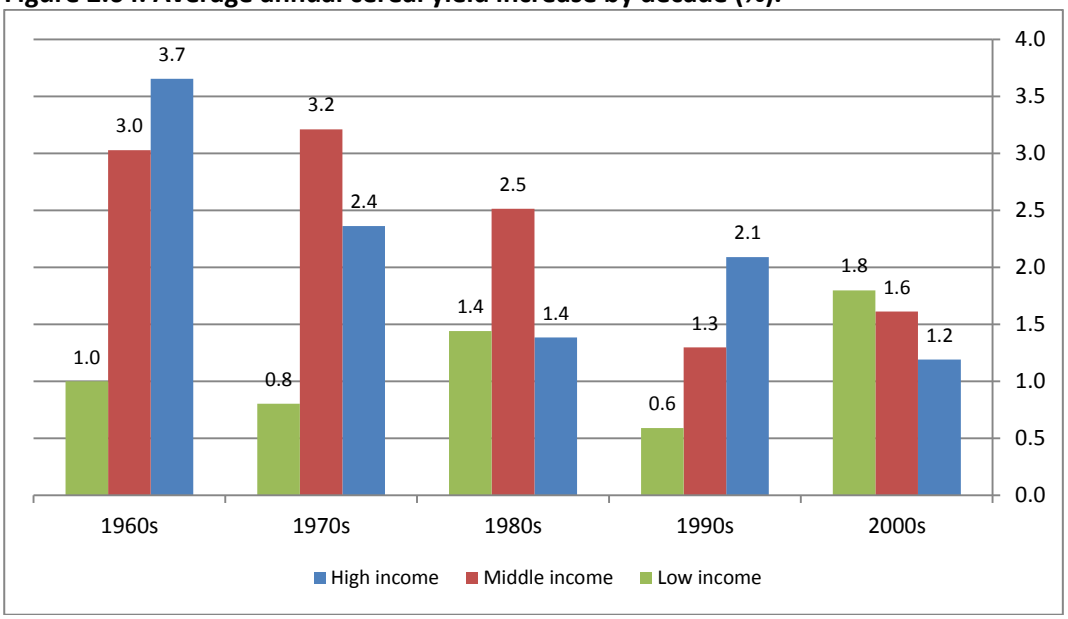

Source: own elaborations on WB data.

The expansion of the biofuel sector in the US and the EU seems that did not affected the rate at which yields increase over time. The rate at which yields increase over time has been declining in the last five decades, especially in developed countries, meaning that we are approaching to the maximum level of productivity obtainable with current production techniques. This is a potential very strong limiting factor not only for first-generation biofuel production but also for food production, especially in a context characterized by a strong demographic expansion and the increase in demand from emerging countries (Figure 2.64).

Forest area, in the world, decreased by 3.3% since 1990 passing from 41.6 to 40.2 million $Km^2$. However the pattern changes quite substantially across countries. In high income countries forest land remained almost constant (around 9.6 million $Km^2$), while in middle and low income countries it decreased by 3.5 and -12.0%. Among the main biofuel producing countries Brazil and Indonesia are the countries that experienced the greatest decline in total forest land: --9.6 and -20.3% from 1990 levels respectively. Conversely forest land increased in the EU (+8.7%) and China (+31.6%), and remained almost constant in the US (+2.6%) and Canada (+0.0%) (Figure 2.65). In relative terms the discrepancy between developing and developed countries is even more striking. The share of forest land on total land area decreased from 68.0 to 61.4% in Brazil and from 65.4 to 52.1% in Indonesia in the last 20 years. Conversely it increased from 32.4 to 33.2% in the US and from 34.6 to 37.5% in the EU (Figure 2.66). This shows how actively enforced environmental policies can affect forest area. The greater awareness towards environment protection governments have in developed countries led to reverse the decreasing trend in forest cover that characterized the first part of the century. Conversely rapid economic development in emerging economies led to the opposite phenomenon. Something that, however, had already happened in developed countries in earlier stages of their development. Finally, it is true that developing countries have low environmental standards but it is

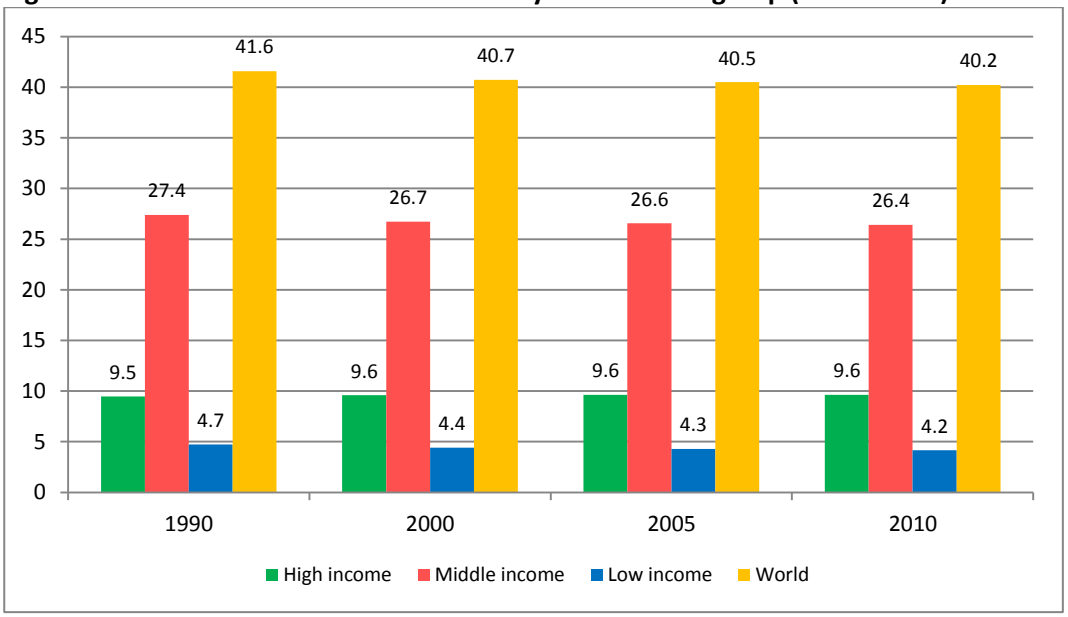
also true that, in some cases, developed countries do little to help them in better preserving nature and biodiversity. A clear example of the "not in my garden" policies undertook by developed countries is represented by the RED directive of the EU that regulates biofuel production in the EU: it allows the production of biofuel within the EU only if feedstock cultivation and production processes meet very strict standards, but it does say anything about the eventuality in which feedstocks come from third countries (like in the case of palm oil), where they are often produced without too many restriction but far from the public opinion's eyes.

**Figure 2.64. Average annual cereal yield increase by decade (%).**



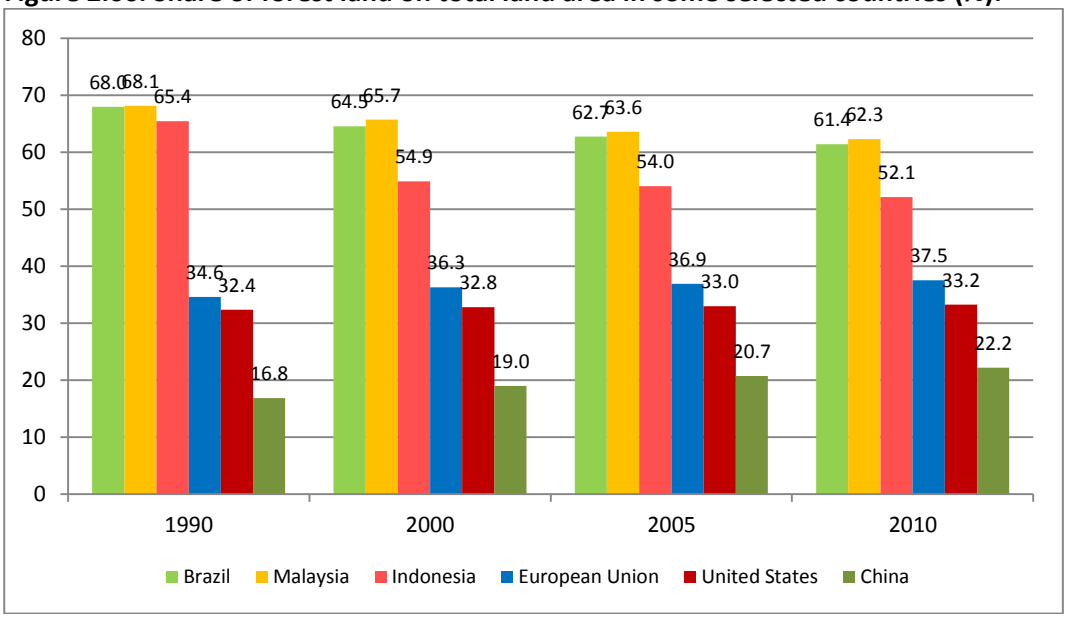

Source: own elaborations on WB data.

**Figure 2.65. Total forest land in the world by income level group (million Km$^2$).**




Source: own elaborations on WB data.

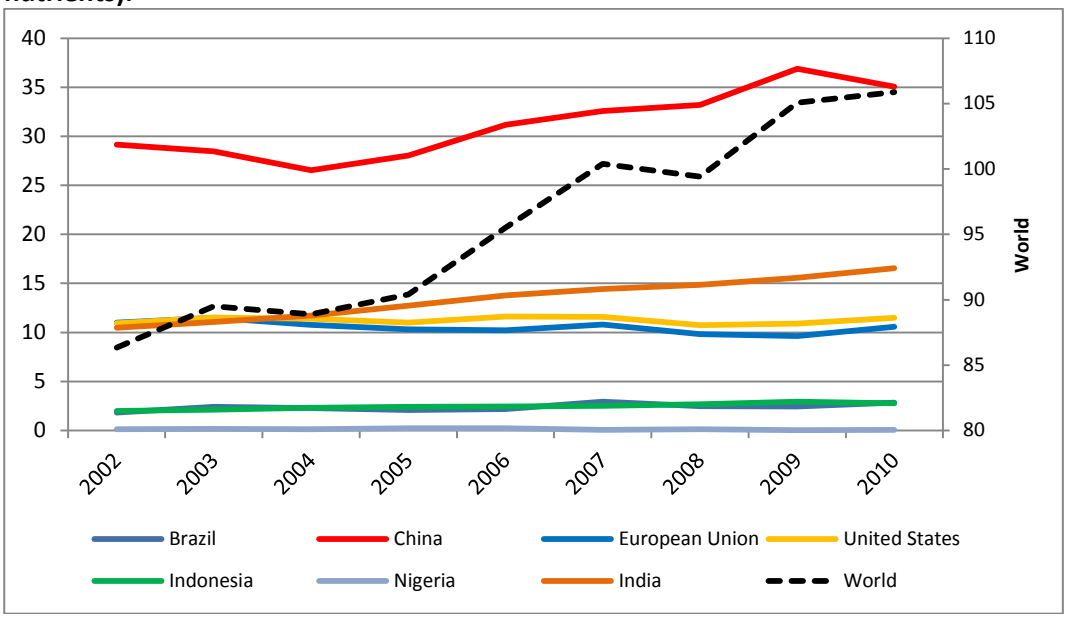
**Figure 2.66. Share of forest land on total land area in some selected countries (%).**




Source: own elaborations on WB data.

In the last decade fertilizer use has been increasing at world level even though changes were quite different across countries and the type of nutrients considered. Nitrogen fertilizers are those which utilization has grown the most, passing from 88 to 105 million tons of nutrients employed (+22%). Nitrogen fertilizers are the most widely used in the world since they are the main fertilizer used in cereal production (FAO, 2006), which are in turn the most widely diffused crop. Nitrogen fertilizers are also those characterized by the worst environmental effects. The main responsible of such strong increase in nitrogen consumption is China and other emerging economies such as India, which use of the fertilizer grew by 20 and 58% respectively. In the US, where corn is the main feedstock for ethanol production, the increase in nitrogen fertilizer consumption with respect to 2002 was much lower (+5%). Nitrogen fertilizer consumption, in the US, decreased in the mid-2000s but it started to grow again after 2007 (+8% from 2008 to 2010), possibly because of increased corn production due to ethanol expansion. In the EU, where cereals are not grown for biofuel production nitrogen fertilizer consumption decreased in the time span considered, declining by almost 4% from 2002 levels. Even though in the US the slight increase in nitrogen fertilizer usage can be attributed to ethanol expansion, this is not the case at world level, where the rise is due to the strong increase in Chinese and Indian cereal (wheat and rice) production, used in the food sector.

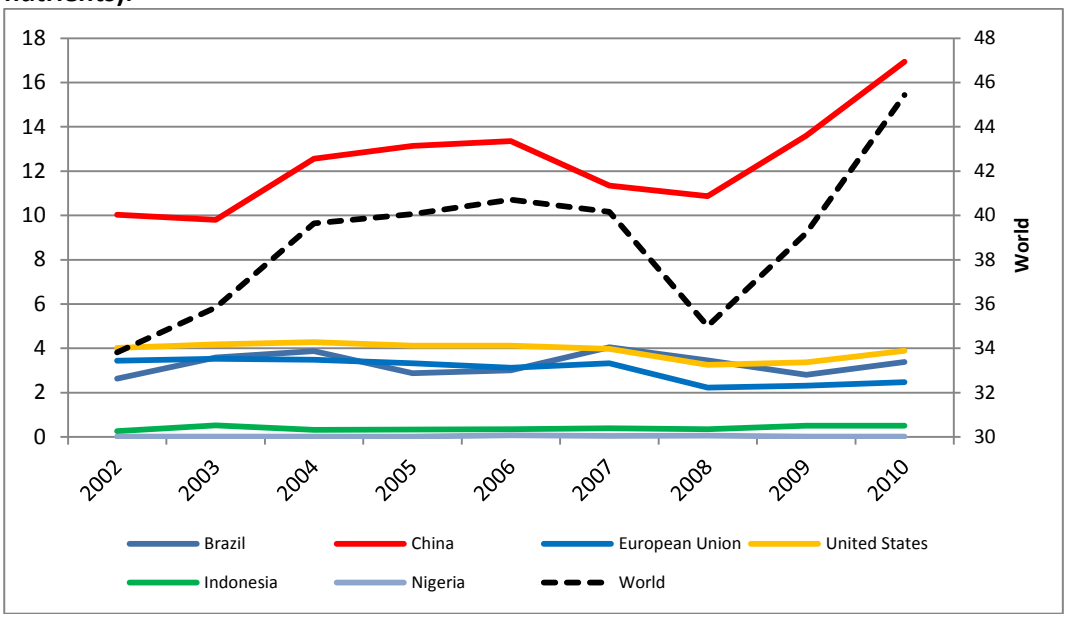
**Figure 2.67. Nitrogen fertilizer consumption in the world and some selected countries (million tons of nutrients).**




Source: own calculations on FAO data.

Phosphate and potash fertilizers are used to a lesser extent than nitrogen fertilizers at world level but they are very important for many crops, especially tropical ones such as sugarcane and oil palm, which are directly interested by ethanol and biodiesel increased production. Phosphate fertilizer consumption increased from 34 to almost 46 million tons of nutrients from 2002 to 2010 (+34.4%) even though not all the years were characterized by an increase in consumption. Similarly to what happens for nitrogen fertilizers, also in the case of phosphorus it is China the leading consumer country and the one that influences the most consumption at international level. Phosphate fertilizer consumption shrank in 2008 because of a strong decrease in Chinese consumption because of the very strong increase in phosphate rock price that took place in that year (+800%) (Figure 2.68).

**Figure 2.68. Phosphate fertilizer consumption in the world and some selected countries (million tons of nutrients).**

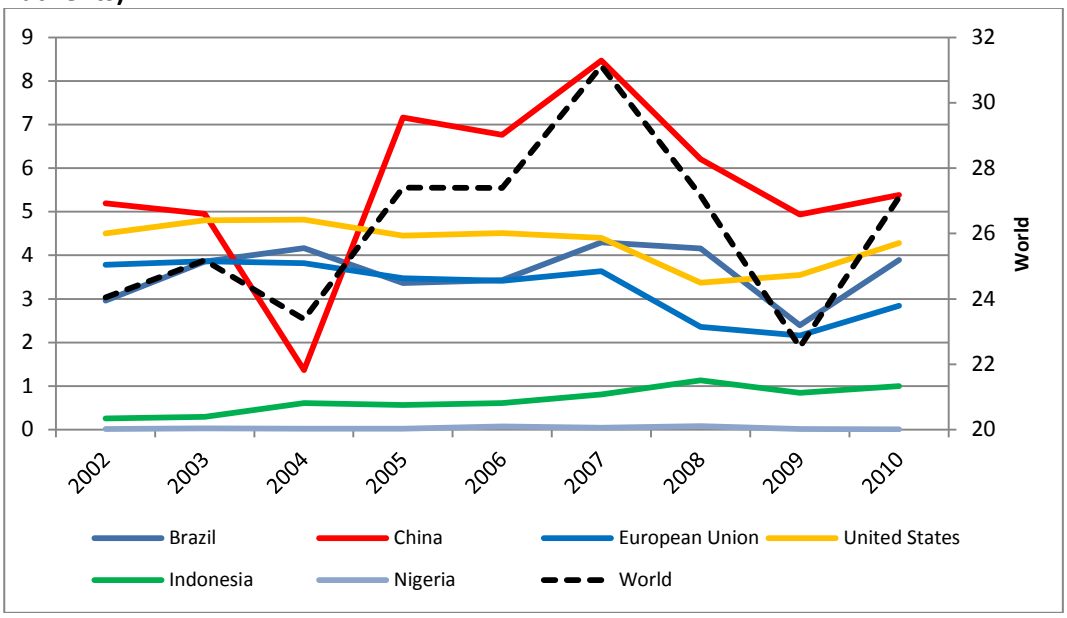



Source: own calculations on FAO data.

Potash fertilizer consumption followed a different trend at world level but still strongly influenced by China's consumption, since the Asian country is the leading world consumer. World consumption peaked in 2007, when it reached 31 million tons of nutrients and then sharply declined to less than 23 million tons by 2009. Consumption increased again in 2010 when it reached 27 million tons. Similarly to what happened in the case of phosphate fertilizers, the substantial decline in consumption was due to a strong price increase. Consumption, in the main biofuel producing countries remained almost stable during the past decade or even declined, like in the case of the EU and the US, mainly because of the strong increase in price that took place in 2008. However, it is important to highlight the significant increase in potash fertilizer consumption in Indonesia, where it has been increasing steadily since 2002 without being affected by the price spike of the end of the 2000s. Indonesian potash fertilizer consumption increased almost four times since 2002 (Figure 2.69. Potash fertilizer consumption in the world and some selected countries (million tons of nutrients).). The reason is the strong expansion of oil palm plantations in turn spurred by increased demand in palm oil for biodiesel production. This is because potash is, by far, the main fertilizer used in oil palm cultivation. Even though when the palm is young it also need significant quantities of nitrogen fertilizers, once it has begun to produce it needs a great quantity of potash since it increases the number of fruit clusters and makes then bigger (FAO, 1990). Even though potash has no known deleterious effects on the quality of natural waters (unlike nitrogen and phosphate) it might indeed create problems on soil fertility. Experiments have shown that in many soils reserves of plant available phosphate and potash can build up over time. Even though it is true that soil enriched with these reserves give larger yields it has also been shown that there are critical values blow which yields decrease substantially but accumulate reserves above these critical values is unnecessary and, most importantly, costly. It might also represent an

environment risk since soil lost by water or wind erosion to streams, rivers or lakes can take its nutrient load with it. Therefore the excessive use of potash in agriculture, even if does not pose any known pollution or health hazard, can represent an economic failure. Even though the use of potash in agriculture is relatively safe, the same cannot be said with respect to potash mining and extraction, which has, like many other minerals, bad consequences on the environment. Moreover an excessive use of both phosphorus and potash must be avoided since there are no known replacements (IFA-UNEP, 1998).

**Figure 2.69. Potash fertilizer consumption in the world and some selected countries (million tons of nutrients).**




Source: own calculations on FAO data.

### 2.3.3 Biofuel and agricultural commodity prices in the US, Brazil and the EU.

This subsection analyzes international agricultural commodity prices in the last decades and compares their evolution with that of biofuels and crude oil prices. The analysis of the variables shows a clear interdependency between oil, biofuels and agricultural commodity prices, especially in the last ten years. A more formal analysis of such relations is provided in chapter 6.

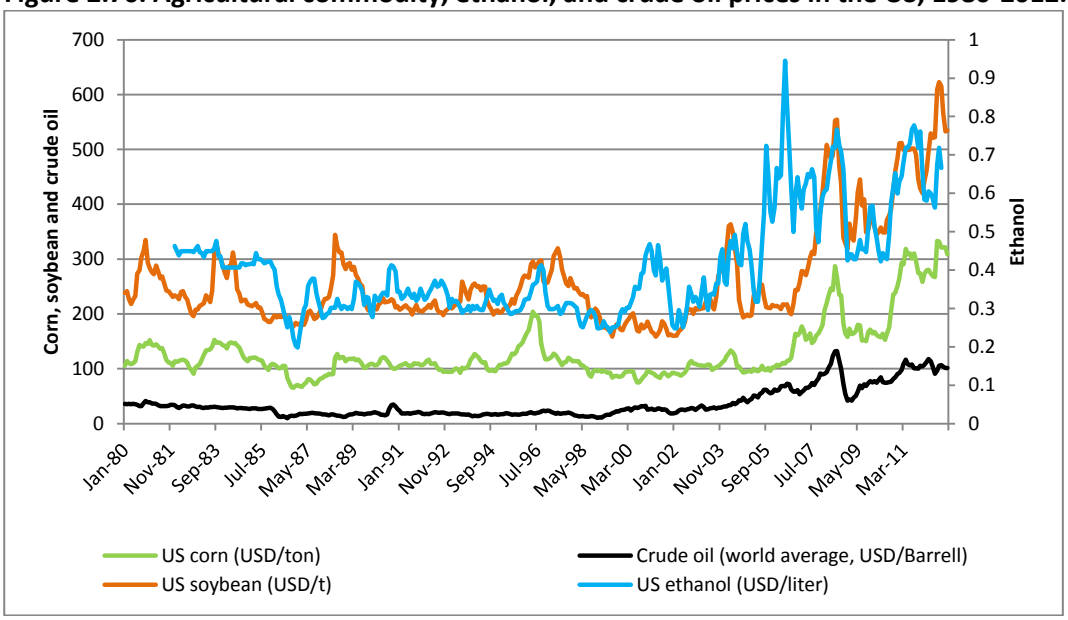
Prices taken under consideration are those for major crops in the US, Brazil and the EU. In the case of the US prices considered are corn, Hard-Red wheat and soybean fob prices at the Gulf of Mexico, which are also the reference international prices for such commodities. In the case of the US also the price of soybean oil (future price at Chicago Board of Trade) and the prices of ethanol and biodiesel have been examined. Agricultural commodity prices are from the IMF Commodity prices database (IMF, 2012), while those of ethanol and biodiesel are provided by the United States Department for Agriculture (USDA, 2012).

In the case of Brazil commodities considered are crystalized sugar (São Paulo), soybean (Paraná), corn (national average) and anhydrous ethanol (São Paulo). All Brazilian prices are from the Center for

Advanced Studies in Applied Economics (CEPEA, 2012). In the case of the EU, prices examined are those of biodiesel, wheat, corn and rapeseed oil. EU rapeseed oil price, world average crude oil price, Malaysian palm oil export price and the international sugar price are from the IMF database, while average EU wheat and corn prices are from the European Commission. German biodiesel prices (representative of the EU) are from Busse et al. (2012). Unfortunately German biodiesel prices are available only up to 2008. All prices are monthly figures.

Figure 2.70 shows the evolution of corn and soybean prices in the US during the last 30 years and compares it to that of corn-based ethanol and crude oil.

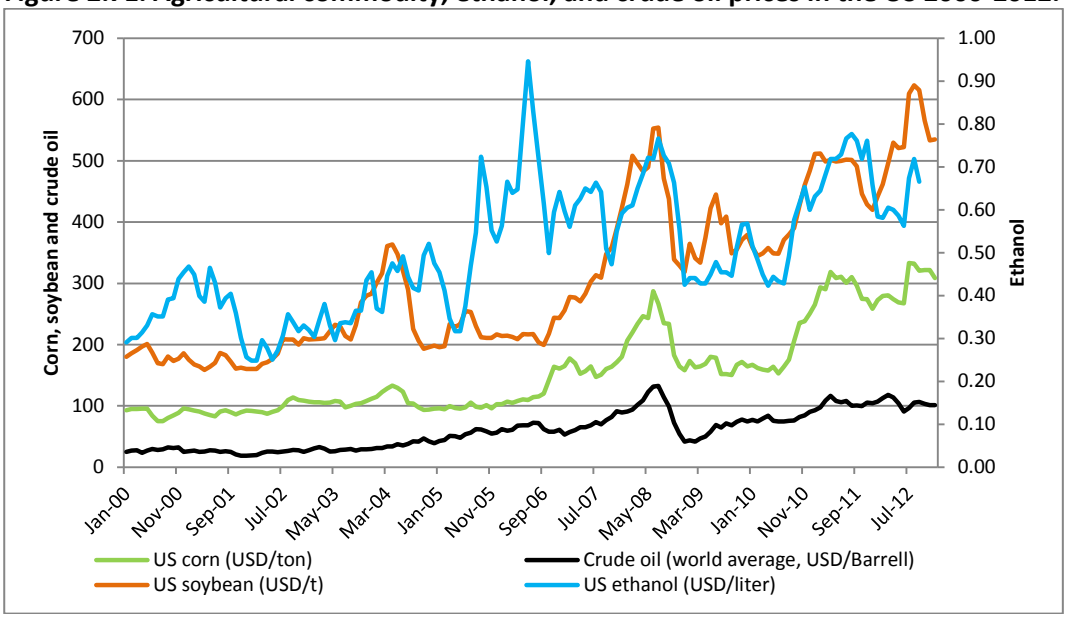
**Figure 2.70. Agricultural commodity, ethanol, and crude oil prices in the US, 1980-2012.**




Source: own elaboration on IMF and USDA data.

The first thing that one can see by looking at the graph is that prices of all commodities have fluctuated around a certain mean value from the early 80s until the late 90s. since prices are in nominal terms, this means that, taking inflation into account, prices have, in real terms, declined. However, at the beginning of the 2000s, something changed. Prices started to increase following similar paths. This happened because of many reasons: increased world demand, stagnant supply, increase in financial transactions, bad weather. However, the role of the strong increase in ethanol production was probably relevant. In the US ethanol is produced from corn (42% of the US corn crops was used in ethanol production in 2011) and the great expansion in ethanol production that took place in the last decade inevitably had a significant impact on corn market (Figure 2.71). Prices of the two major US crops, corn and soybeans, have been moving together with ethanol and crude oil prices especially after 2006-07, period in which the RFS2 was implemented. The hypothesis that policy-induced biofuel expansion created a new link between energy and agricultural prices, seems to be supported by the data, which before was limited and related to the cost of some energy-intensive agricultural inputs.

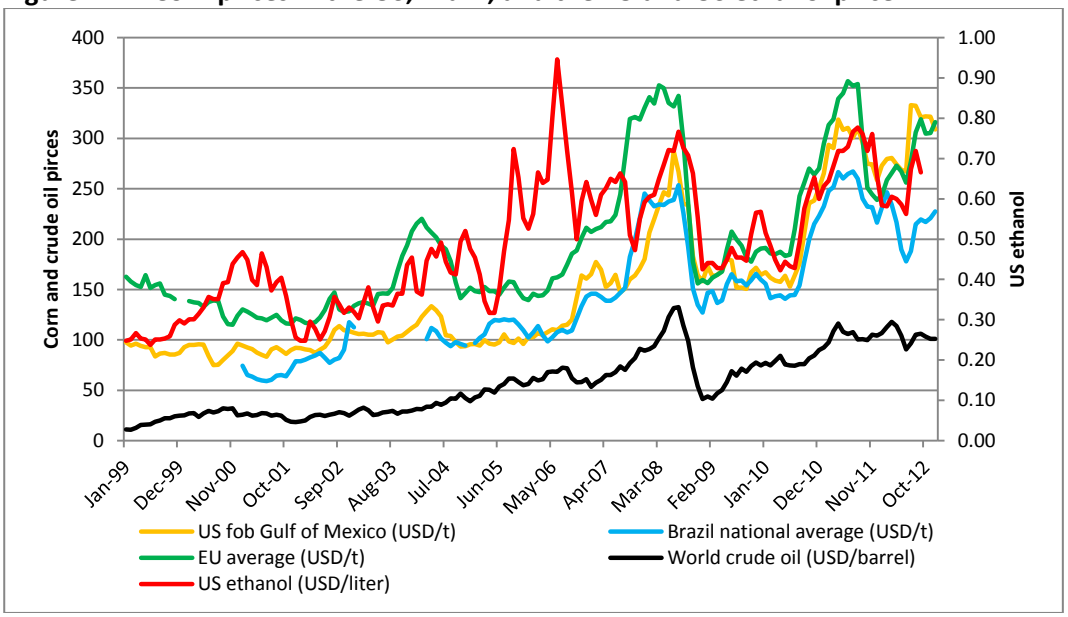
**Figure 2.71. Agricultural commodity, ethanol, and crude oil prices in the US 2000-2012.**




Source: own elaboration on IMF and USDA data.

Since the fob Gulf of Mexico US price, in the case of corn, can be considered representative of the world price, it is likely that ethanol expansion not only created a link between US corn and ethanol prices, but also between corn prices in other countries and US ethanol price. This can be seen in Figure 2.72

**Figure 2.72. Corn prices in the US, Brazil, and the EU and US ethanol price.**

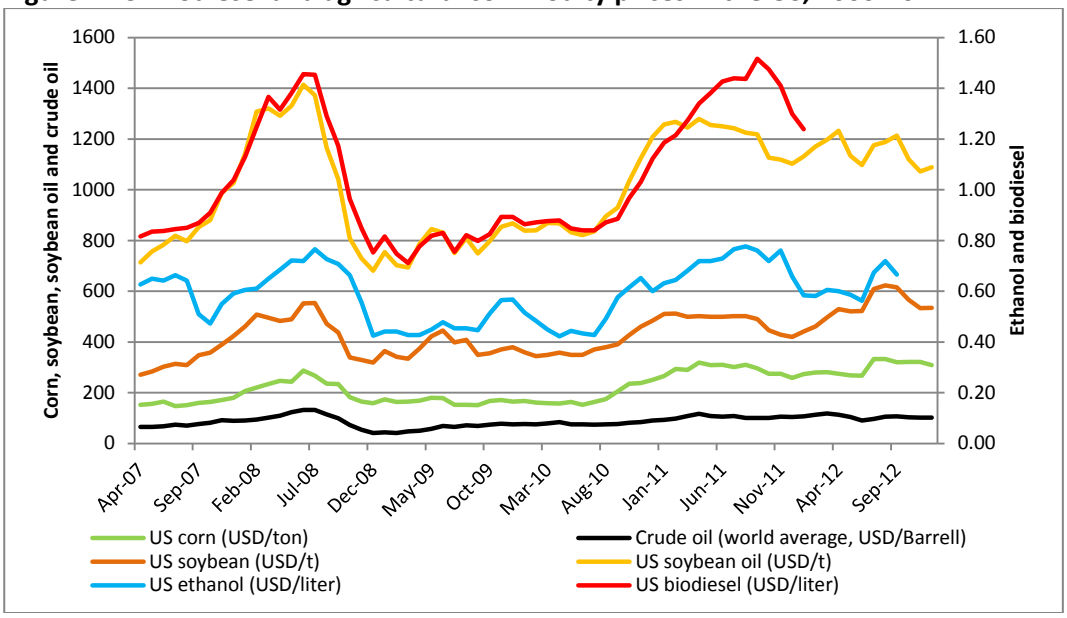



Source: own elaboration on IMF, EU Commission, CEPEA and USDA data.

Corn prices, especially after the first price bubble, that of 2007-08, started to follow the same trend. This due to the progressive globalization of world markets and, at least, in the case of the EU, the progressive reduction of the protectionist measures of the Common Agriculture Policy.

Also in the case of biodiesel it is possible to detect a high degree of integration between agricultural and energy markets. Even though the biodiesel sector, in the US, is still relatively small, biodiesel and soybean oil (from which biodiesel is produced in the US) prices followed almost the same trend in the last decade, meaning that also in the biodiesel sector, the relationship with agricultural prices is strong. In this case, however, the relationship is much stronger with the price of the processed product (soybean oil) than with that of the agricultural raw material (Figure 2.73).

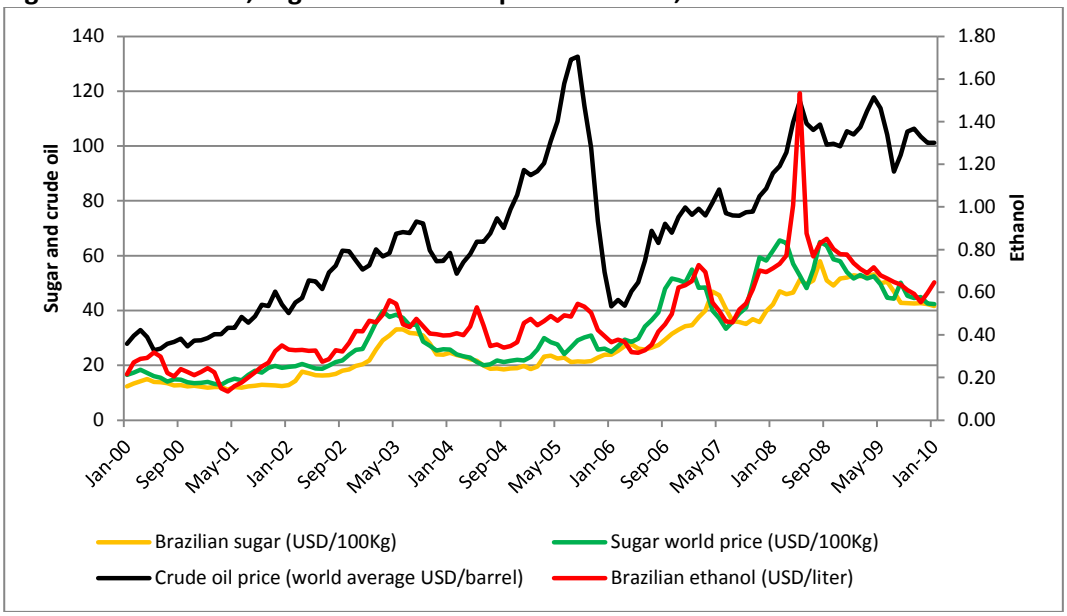
**Figure 2.73. Biodiesel and agricultural commodity prices in the US, 2000-2012.**




Source: own elaboration on IMF and USDA data.

In Brazil ethanol has been produced from sugarcane since the early 70s, therefore the relationship between ethanol and sugar prices is very tight. Nevertheless, starting from the mid-2000s, also the relationship between ethanol, sugar and crude oil prices seems to have strengthened (Figure 2.74).

**Figure 2.74. Ethanol, sugar and crude oil prices in Brazil, 2000-2012.**

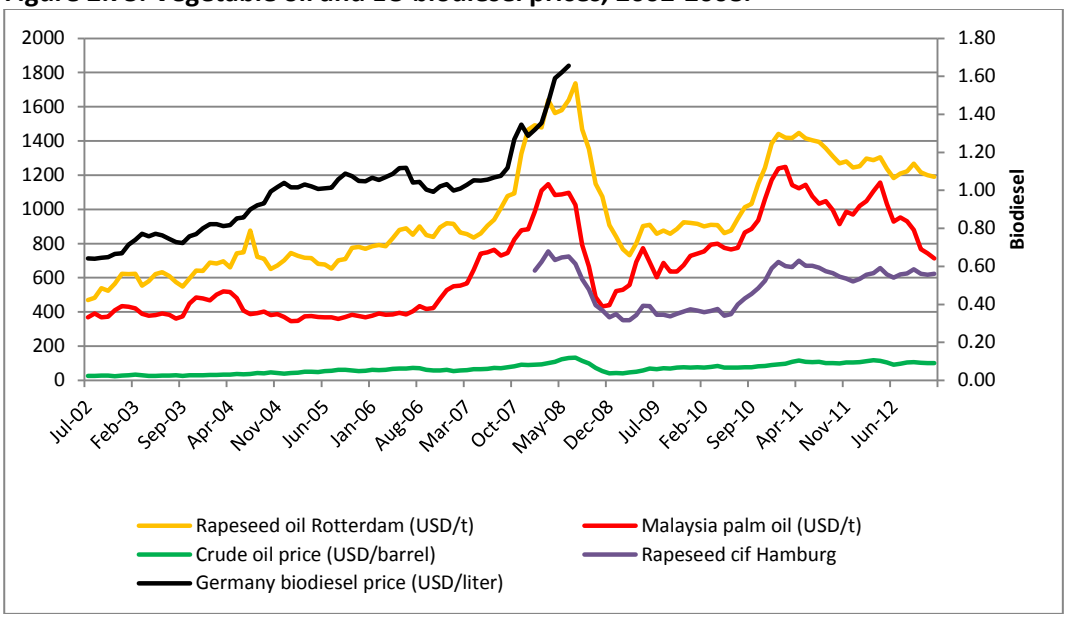



Source: own elaboration on IMF and CEPEA data.

Ethanol production do not only have repercussions on the Brazilian sugar market, but also on the world one, since Brazil is the major producer and major exporter of the commodity in the world. the strong increase in sugar price that took place in the second half of the 2000s (prices reached record-high levels) might be traced back, amongst the other things, to ethanol expansion in Brazil but also in the US, which has been the main destination market for Brazilian ethanol for years.

In the EU the main biofuel is biodiesel, which is produced from domestically produced rapeseed oil and (in increasing percentages) imported palm oil. Even though, due to data availability problems it has been possible to examine the evolution of biodiesel and EU commodity prices only up to 2008, it has been nevertheless possible to detect a certain degree of co-movement (Figure 2.75).

**Figure 2.75. Vegetable oil and EU biodiesel prices, 2002-2008.**

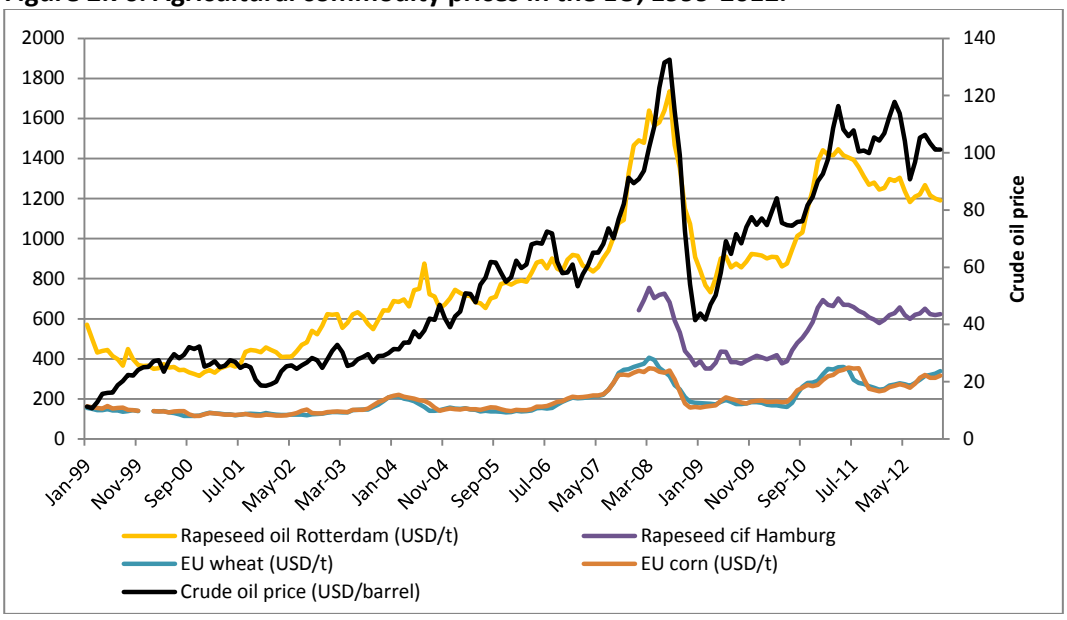



Source: own elaboration on IMF, EU Commission and Busse et al.(2012) data.

Biodiesel price, in Germany clearly follows the same path of that of domestically produced rapeseed oil (Hamburg cif price) and that of Malaysian palm oil, which has been increasingly used in biodiesel production in the EU in recent years. Also in this case, both biodiesel and vegetable oil prices started to grow substantially in 2006-07. Even though more recent data on biodiesel prices are not available it is reasonable to think that, similarly to what happened in the US in the case of ethanol and corn prices, the link between vegetable oil and biodiesel prices, in the EU has been tightening in recent years, especially in the case of imported palm oil.

Also in the European Union it is possible to detect, like in the US, an increasing degree of co-movement between energy and agricultural prices in the last decade, especially after 2006, which can be considered as the beginning of a new period characterized by high commodity prices, higher volatility and closer relationships between prices for different agricultural commodities (Figure 2.76).

**Figure 2.76. Agricultural commodity prices in the EU, 1999-2012.**




Source: own elaborations on EU Commission and IMF prices.

### 2.3.4 Final considerations.

In the last decade world production of main feedstocks used in biofuel production (corn, sugar cane, and to a lesser extent vegetable oils) has increased, especially if compared to other major agricultural commodities like wheat. Very often it is argued that the main driver of agricultural production is the growth in demand from emerging countries where a higher number of people has increased their disposable income and started to consume more food, especially of animal origin. However, also other factors play a role and biofuel expansion is one of them. While wheat production has increased only slightly in the last two decades, despite the strong increase in demand from emerging economies, corn and sugarcane production have increased substantially, especially in the second half of the 2000s. Both wheat and corn are widely used for human consumption and animal feed and both of them have experienced a period of price increase, however, only the latter is used in biofuel production. Average annual corn production increased from 518 million tons/year in 1990-95 to almost 800 million tons/year in the late 2000s, while average wheat production increased by a much lesser extent. Also sugarcane production increased substantially, especially in Brazil, where it is employed in ethanol production, while in other major producing countries it remained almost constant. In the same time frame, harvested area, both in case of corn and sugar cane, increased less than production (however, in absolute terms the area increase, in the case of sugar cane, was nevertheless significant), meaning a progressive intensification of agriculture. It means that more is produced using the same area implying a greater amount of inputs (fertilizers and herbicides, for example), with possible negative consequences for the environment. In the case of palm oil, which has been increasingly used for biodiesel production in the EU, the expansion, both in terms of production and area harvested was dramatic. Production in Indonesia (the major palm oil fruit producer)

increased 7 times in the last 20 years, while in Malaysia almost doubled. The expansion in production also meant an strong increase in area harvested, at the expenses of the biodiversity-rich rain forest. Also rapeseed production, another popular biodiesel feedstock in the EU, increased significantly, especially in the EU and in Canada, where also area harvested expanded, even if to a lesser extent. The expansion in rapeseed area in the EU (and to a lesser extent in Canada) is less alarming since, environmental regulations are much more strict (and enforced) than in developing countries. In the last 20 years, agriculture area remained almost constant or even declined in developed countries, while forest area slightly increased. In developing countries, conversely, agricultural area expanded greatly in the last 20 years, mostly at the expenses of forest land, with negative consequences in terms of biodiversity loss and GHG emissions.

Even though global fertilizer consumption has been increasing in the last decade it is hard to say whether such increase was due to biofuel expansion or other factors such as the increase in the demand for food. Fertilizer consumption has increased especially in emerging countries, such as China, were environmental regulations are less strict than in developed countries and the need of increasing domestic production more pressing. Nevertheless, oil palm expansion in South-East Asian countries, mainly driven by biodiesel production increase in the EU, did significantly increase potash fertilizer consumption.

Finally, biofuel expansion, together with several other factors, such as increased world demand, increased financial transactions, bad weather, has been having significant consequences on agricultural commodity prices, especially in the US. Prices, especially after 2006, started to move together, showing a higher degree of interrelationship than in the past. In the last decade also the link between crude oil and agricultural prices has been tightening, possibly because of policy-induced biofuel expansion.

# 3 Biofuel policies in the world.

Currently, commercially available biofuels are almost entirely produced from food crops: sugarcane, sugar beet, corn, and oil seeds, therefore policies encouraging biofuel production have repercussions also on the markets of goods related with biofuel production (Sorda, Banse, & Kemfert, 2010). A recent report issued by the Join Research Center of the European Commission in Seville (2010) provides an extensive overview of current policy actions promoted by countries across the world to foster both biofuel production and consumption. The main reasons behind countries' decision of subsidize "green energy" production are the will (or the need) to reduce dependence on fossil fuels (energy security), to reduce greenhouse gasses emissions (climate change mitigation), and to increase demand for certain agricultural products that suffer from production surplus (support to farmers' income).

Each of these three reasons has been criticized. Energy security, for example, could be achieved not only encouraging biofuel use but also through other forms of domestically produced renewable energy such as solar and wind power. The contribution of biofuels in reducing greenhouse gas (GHG) emissions has been contested as well. Currently biofuels are mainly produced from agricultural commodities such as corn (ethanol) and rapeseed or palm oil (biodiesel). Farmers can be induced, by higher commodity prices, to put more land under cultivation or to make their production processes more intensive. This may result in an increase of carbon emissions from the agriculture sector that can eventually offset the greenhouse gas emission reduction obtained from an increase in biofuel consumption. Finally, it is true that an increased demand for food and non-food agricultural products can raise farmers' income, however this might come at the expenses of food consumer worldwide and the environment. People, especially those living in low-income countries, might face substantially higher food prices or food shortages in a similar way to what happened in 2008 (*Tortilla Riots*). Concerns over high food prices, for example, convinced countries like China to stop or reduce their support to first-generation biofuels and to increase their subsidies to 2$^{nd}$ generation ones (Sorda, Banse, & Kemfert, 2010). Biofuel policies, making an upward pressure on agricultural prices, can also undermine the environment since they encourage the expansion of agricultural areas at the expenses of rainforests and wilderness (direct and indirect land use changes).

It is important to fully understand policies issued by the major biofuel producer and consumer countries because their decisions can have a substantial impact on world markets of both bio-energy and agricultural products. The following sections present the current and, when available, planned biofuel policies across the world.

## 3.1 Biofuel policies in the United States.

The US government started subsiding the ethanol industry since the early 70s, mainly under the form of tax incentives. Starting from the 80s, ethanol has been used as a gasoline additive: even if it has a

lower heat content than regular gasoline, it is characterized by a higher octane level and can therefore be used to increase engine performances. All vehicles can accommodate up to 10% ethanol (E10 blend level) without any modification to the engine system (Saunders, Kaye-Blake, Marshall, Greenhalgh, & Aragao Pereira de, 2009).

The three key components of the current US ethanol policy were until December 201!: tax credits, tariffs, and blending mandates, however tax credit, with were in place both at federal and state level, were abolished in January 2012.

The US government started imposing the consumption of given biofuel volumes with the Renewable Fuel Standards (RFS1) in the *Energy Policy Act* of 2005. The original target was to employ 4 billion gallons of renewables in transport fuel by 2006. The rationale behind the US policy was to reduce the country's dependency from oil. In 2007 the *Energy Independence and Security Act* was passed, which set the target of reducing gasoline consumption by 20% in the next decade. One year later the *Biomass Program* was implemented that set the target of decreasing gasoline consumption by 30% when compared to 2004 levels by 2030, and to gradually substitute corn-based ethanol with cellulosic ethanol (Sorda, Banse, & Kemfert, 2010). Today, US ethanol is mainly derived from corn, which production employs almost 40% of domestic corn supply.

Until Fall 2010, the US government mandated the blending of gasoline with ethanol in a 10% blend. The US Environmental Protection Agency (EPA) raised the 10% limit up to 15% on October 13$^{th}$ 2010. However the E15 fuel (E15 meaning that it contains 15% of ethanol) can be used only to cars and light trucks sold since 2007 because in older cars it might damage the engine. Nevertheless, vehicles sold between 2001 and 2006 will be subject to further testing. This decision raised many objections from both gasoline blenders (who now will require separate storage and distribution infrastructure) and drivers that could undertake legal actions if they believe the new fuel had damaged their cars. The final decision is the result of a political compromise since ethanol producers and the strong farmer lobbies in the Mid-West have been exerting pressure on the EPA to raise the limit. In particular the ethanol industry has been stressing the point that the former E10 standard was the cause of the so-called "blend wall", which was preventing the achievement of the usage targets for biofuels set by the renewable fuel standard bill. In fact, the law mandates that the use of biofuels must rise from 2010's 12 billion gallons (9% of total petrol consumption) to 13.2 billion in 2012 and 36 billion in 2022 (Financial Times - Web Edition, 2010).

In July 2010 the *Renewable Fuel Standard (RFS2)* was passed by the Senate, which set a 36-billion gallons consumption target to be reached by 2022. This objective can be reached only by increasing the consumption of second-generation biofuels from 2010's 0.1 billion gallons (estimate) to 21 billion in 2022 (Sorda, Banse, & Kemfert, 2010). This shows how the US is pushing towards the technological development of the current production system. At the beginning of 2010 the Department of Energy allocated more than 80 million dollars for a new national program dedicated to biofuel research, both committed to the

development of new types of biofuels and to improve the existing infrastructure (The New York Times - Web Edition, 2010). Research into second-generation biofuels is important not only because of food implications but also because the development of new technologies (*e.g.* cellulosic biomass from feedstocks like stalks, leaves, grasses, and trees) can allow higher ethanol yields requiring less intensive management (and therefore fossil fuel consumption in the production process) than corn-based production. Moreover, the fact that the US corn production is concentrated in the Mid-West states implies that also ethanol must be produced in that relatively restricted area. If new technologies become available it will be possible to produce ethanol also in places closer to the areas of major consumption (the Coasts) reducing transportation costs and their externalities (pollution).

The RFS2 also requires second-generation biofuels[8] to reduce GHG emissions by at least 50% (60% for cellulosic biofuels), while standard biofuels by 20% (this restriction applies only to fuel from facilities built after December 2007).

In addition to mandates, also tax credits to biofuel producers were in place until December 2011, and they resulted the most important source of financial support to the ethanol sector during the last few years. The *Volumetric Ethanol Excise tax Credit* (VEETC) was enacted in 2004 and was due to expire at the end of 2010 but it was eventually extended for an extra year. The credit was awarded to gasoline blenders who could use either domestically produced or imported fuel without any quantity limit, independently of the price of gasoline, and to both domestically produced and imported ethanol. Blenders could claim US$0.51 per gallon of ethanol used. In 2010 the tax credit cost 5 billion dollars to the US government. The total cost for taxpayers was however even greater: if also local and state subsidies are taken into account the bill reached 11 billion dollars (Sorda, Banse, & Kemfert, 2010).

The tax credit is available also for biodiesel, in this case the subsidy amounts to US$1 per gallon for biodiesel produced from virgin oils or fats, and US$0.50 per gallon for recycled oils. Total cost for the collectivity was 1.4 billion dollars in 2008.

Tariffs on imported ethanol are composed of a 2.5% *ad valorem* tariff and a 54 cent per gallon specific tariff. Combined, these two measures, amount roughly to a 60 cents per gallon or at an *ad valorem* equivalent of 25%. Since the tax credit is applicable also to foreign ethanol used in blended fuel, the tariff has been put in place to offset the credit that US blenders would receive for imported ethanol and to encourage the use of domestic product. NAFTA (North American Free Trade Agreement) members can export ethanol to the US on a duty-free basis. Duty-free imports are allowed also from Caribbean countries belonging to the CBERA (Caribbean Basin Initiative) but only if their exports are less than 7% of the domestic production (Sorda, Banse, & Kemfert, 2010). The import tariff was established to compensate for a legislative void, that is the fact that the blending subsidy is not restricted to ethanol domestically

[8] In its original definition the EPA calls second-generation biofuels as “advanced biofuels”, which include: biomass-based diesel, cellulosic biofuels, and non-cellulosic advanced biofuel.

produced. The tariff, however, similarly to all trade-impeding measures, distorts world markets, raise the domestic consumer price, and harm foreign producers with lower production costs than American ones (especially Brazil's) that could potentially benefit from selling their ethanol in the US market.

The RFS2 requires also that transportation fuel sold or introduced into commerce in the US must contain minimum specified volumes of renewable fuel, advanced biofuel, cellulosic biofuel, and biomass-based diesel. The minimum volume of total renewable fuels to be used domestically will have to rise from 12.95 billion gallons in 2010to 36 billion gallons by 2022, with an increasing share of cellulosic biofuels (Yanom, Blandford, & Surry, 2010). However, doubts have recently been raised on the actual capability of the US biofuel production system to meet the target regarding second-generation cellulosic biofuels. Under the RSD2 targets, production of cellulosic biofuels should have reached 500 million gallons in 2012 but so far the output is almost zero since no one seems to have hit on a "commercially successful recipe" (New York Times, 2012). So far the US Environmental Protection Agency (EPA) could only repeatedly waive nearly all of the cellulosic requirements. Refiners have been complaining because they are required to use a fuel that does not exist or face fines. This happens because even though the EPA waived most of the cellulosic requirements it kept, at least for 2012, a 2.75 billion-gallon quota of "advance" biofuels in general, which includes Brazilian sugarcane ethanol (considered therefore an advanced biofuel) and biodiesel from soybean oil. The problem is going to worsen in 2013 is the EPA will waive again the cellulosic requirements but keep intact the overall 2.75 billion quota for advanced biofuels. In 2013 the cellulosic quota was supposed to grow to 1 billion gallons and if it will be waived, other "advanced" biofuels will have to make up the difference.

Beyond Federal measures, many US States have developed additional incentive schemes to spur ethanol production and consumption. These measures include producer payments, property or business tax exemptions, market mandates, public fleet requirements, and incentive programs for investment in alternative fuel vehicles and fueling facilities.

## 3.2 Biofuel policies in Canada.

Almost 70% of Canadian ethanol is produced from corn, while the remaining 30% from wheat. Biodiesel is from animal fats like tallow grease, yellow grease (used oil from deep fryers), and canola (rapeseed oil). Canada, similarly to the US, mandates the blending or regular gasoline with ethanol. The *Environmental Protection Act Bill C-33* established that gasoline must contain 5% of renewable fuels in 2010 and that diesel and heating oil 2% by 2012. It has been estimated that, in order to meet these targets, at least 1.9 billion liters of ethanol should be produced at current gasoline sale trends. To achieve also the diesel and heating oil target an additional 520 million liters of ethanol must be either produced or imported (Sorda, Banse, & Kemfert, 2010).

Federal mandates are not the only policy in place to support ethanol production. Ethanol manufacturers have been enjoying a CAN$0.10/liter incentive rate since April 2008 thanks to the *EcoENERGY for Biofuels Program*. Starting from January 2011, however, the incentive rate started to decline by CAN$0.01 per year until it will reach CAN$0.04 in 2015 and 2016. A similar incentive exists also for biodiesel producers. In this case the incentive rate is CAN$0.20, also declining in the next few years until it reaches CAN$0.06 in 2016.

Several found schemes are also in place to expand biofuel production through an increase of production capacity (new infrastructure). Similarly to what happens in the US, also in Canada local government (provinces) integrate Federal measures with their own policies. Finally, trade protection is much lower than that of the US and the EU. Renewable fuels from NAFTA countries can be imported duty-free, while there is an import tariff of CAN$0.05 per liter on Brazil ethanol (Sorda, Banse, & Kemfert, 2010).

## 3.3 Biofuel policies in the European Union.

The European Union's targets set by the Directive 2009/28/EC (Renewable Energy Directive, RED) concerning renewable energy are finalized to reducing GHG emissions, improve the security of energy supply, promote technological development and innovation, and provide new employment opportunities and rural development, especially in rural areas (The European Parliament, 2009). In practice, the EU targets to obtain 20% of its total energy consumption from renewable energy sources by 2020. The targets for the four largest economies of Europe: Germany, France, UK, and Italy, are 18, 23, 15, and 17% respectively. These targets are set by the European Commission (EC) depending on the current situation and potential for growth in different MS (USDA, 2012a). By the same year the share of renewable energy in the transport sector must reach at least 10% (this target is obligatory for all Member States).

Biofuels used to reach the 10% target must meet certain sustainability criteria (which have been nevertheless heavily criticizes, see section 4.2.2), including reducing GHG emissions by at least 35% compared to fossil fuels. From 2017 the reduction must be 50% and at least 60% for new installations (USDA, 2012a). Second-generation biofuels (made from lingo-cellulosic, non-food cellulosic, waste and residue materials) will count double towards the goal. Member States can meet the target increasing the use of hydrogen from renewable sources, or that of biofuels, either produced with first or second-generation techniques. However, the EU's reference legislation regarding biofuels emphasizes the fact that the expansion in biofuel use must be done using only "sustainable" biofuels, that is those generating net and clear GHG savings and that do not have a negative impact on both biodiversity and land use (European Commission, 2010).

The Fuel Quality Directive (FQD, Directive 98/70/EC as amended by Directive 2009/30/EC) complements the RED and mirrors some of the RED's content such as the sustainability criteria. The FQD regulate the properties of biofuels and fuel additives in addition to the amount of such products that can

be blended into fossil fuels. A key requirement is that all fuel suppliers (oil companies) must meet a 6% cut over 2010 GHG emission levels by 2020 across all fuel categories supplied to the market. This is designed to be consistent with the 10% use of biofuels and to move demand towards biofuels with higher GHG emission savings. The FQR also limits ethanol blends to 10%, when ethanol is used as oxygenate. The FQR supports a duel grade system of E5 for older vehicles and E10 for newer vehicles. This due grade permits continued growth in ethanol use even though the overall gasoline market is shrinking. For biodiesel a B7 standard already exists, which permits EU biodiesel growth rate to exceed that of regular biodiesel in the next future. There is work in progress to set a higher blend limit for heavy and even light-duty trucks. Fuel specifications for biodiesel place limits on the use of palm oil and soy oil as feedstock for biodiesel (USDA, 2012a).

Sustainability criteria have to be met by all biofuel whether produced within the EU or imported. The sustainability criteria include minimum GHG savings (35% less than fossil counterparts until 2016, 50% from 2017), not being produced from feedstock grown on land with high biodiversity value such as primary forests and highly biodiverse grasslands; not being produced on land with high carbon stocks such as wetlands or continuously forested areas and not being produced on peat lands. Other sustainability criteria refer to soil, water, air quality and social criteria such as the impact on consumers of higher food prices and inherence to International Labor Organization conventions. The agricultural raw materials produced within the EU must be produced in accordance with the minimum requirements for good agricultural and environmental conditions that are established in the common rules for direct support schemes under the common agricultural policy (USDA, 2012a).

The European Commission states that biofuels produced from renewable sources may play a key role, in the future, as an alternative to fossil fuel energy sources (mainly oil) especially in the transport sector, which account for more than 20% of total European GHG emission. Biofuels are important also because they help diversifying fuel sources, which is a key target of the EU for the future, when it is likely that oil will become more scarce. In this framework the Biomass action plan, adopted in 2005, imply an increasing cooperation with developing countries for biofuel use promotion and sustainable production.

The EU's Joint Research Center (JRC) define GHG emissions savings for different raw materials and supply pathways. The calculated GHG emissions for cultivation, processing, transport, and distribution for different raw materials sand then estimated GHG emissions. Net carbon emissions from indirect land use changes are not included (and this is matter of controversy). Under the RED is possible to attribute higher GHG savings than the default ones presenting proper documentation and Lice Cycle Analysis procedures (values are provided in the annexes of the RED). Currently the EU is evaluating different methodologies to calculate GHG emissions from indirect land use changes but it still unknown when and if the GHG emission calculation methodology will be updated. The RED required MS to submit National Renewable Energy

Action Plans (NREAPs) by June 30, 2010. These plans provide detailed roadmaps of how each MS expects to reach its legally binding 2020 target (USDA-1, 2012).

Currently only 20 Member States have notified the Commission full transposition of the RED. The Commission is also examining the sustainability criteria of each Member State's legislation. The possibility for certain biofuels of receiving double credit based on what feedstock are being used have so far been introduced in nine Member States: Austria, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, and the U.K. The use of double counting biofuels is limited but growing, in particular the consumption of biofuels produced from waste fats (USDA-1, 2012).

The RED stipulates that by December 31, 2014, the Commission shall present a report on some of the details in the RED. These include: a review of the minimum GHG emission saving thresholds, the cost efficiency of the measures implemented to reach the 10 percent target, the impact of biofuel production on the availability of foodstuffs at affordable prices and an assessment of the feasibility of reaching the 10 percent target while ensuring the sustainability of biofuels production in the Community and in third countries. On the basis of this report the Commission will propose to modify the RED to address such aspects as the minimum GHG savings if it deems appropriate (USDA-1, 2012).

Four broad groups of biofuel policy types can be identified in the European Union: budgetary support, consumption targets, trade measures, and measures to stimulate productivity and efficiency improvements (European Commission - Joint Research Center, 2010).

Until 2008, at the Union level, the *budgetary support* was provided by the Common Agriculture Policy (CAP). It consisted in two measures, a direct and an indirect one. The latter was the set-aside premium (established in 1993): farmers would grow non-food crops (largely for liquid fuel production) on land under the set-aside scheme. The former was an energy crop aid of €45 per hectare with a ceiling of 1.5 million hectares. This measure was introduced in 2004 and modified in 2006 with the raise of the ceiling up to 2 million hectares. Both the set-aside and crop aid were stopped with the CAP "health-check" in 2008. Many Member States use tax exemptions or reductions to stimulate biofuel consumption but can do it only obeying to the guidelines given by the EU Directive 2003/96/EC. Currently Member states using tax reductions (some also impose a quota on the quantity eligible) for both ethanol and biodiesel are: Belgium, Bulgaria, Cyprus, Denmark, Estonia, Hungary, Latvia, and Sweden, while Malta and Portugal for biodiesel only (European Commission - Joint Research Center, 2010).

*Consumption targets* are set on an individual basis by Member States. In most cases they consist in blending mandates. The German biofuel policy, for example, except for tax exemptions for high-blend biofuels, is almost exclusively made up by blending mandates. Countries using only blending targets for both ethanol and biodiesel are the Czech Republic, Finland, Ireland, Luxembourg, and the Netherlands, while Italy uses them for ethanol only. A mix of taxes and mandates has been chosen by Austria, Germany, France, Lithuania, Poland, Romania, Slovakia, Estonia, United Kingdom, and Greece. Even if tax exemptions

and blending mandates have the common target of promoting biofuel diffusion they differ in who bears the costs. Tax exemptions are founded by the government, while compulsory blending falls on fuel supplier and then on final consumers.

*Efficiency-enhancing measures* are meant to stimulate research and technological development, promote investment in production capacity and in the development of dual and flexi-fuel vehicles, facilitate the establishment of distribution networks for biofuels, formulate product quality standards, and to provide information to consumers. These measures, hard to quantify, are implemented at Member State level (European Commission - Joint Research Center, 2010).

Within the European Union the two largest biodiesel producing countries are France and Germany, which both have their own subsidy policies in addition to EU ones. The French government mandates the blending of bioethanol and biodiesel and grants fiscal incentives. Some quotas of biofuel production can benefit from tax rebates. These quotas (for a six-year period) are assigned through public tenders open also to foreign producers. Tax rebates are revised annually and have been decreasing since they were established and were phased-out in 2011. Despite the progressive incentive reduction, France's biofuel production have been increasing in recent years.

Similarly to France, also Germany has implemented its own policies to subsidize the biofuel sector. The sustainability decree on biofuels, promulgated in 2009, which acknowledges the directions established by the RED and states that biofuels must be produced from feedstocks which production does not affect primary forests, highly biodiverse grasslands, protected territories, and carbon-rich areas. Germany has also proposed the adoption of hydrotreated vegetable oils (HVO) to the EU, which is currently reviewing the request. Tax exemptions were abolished in 2007 in Germany (because they were too costly for the government) and replaced with quota obligations and tax rebates (Sorda, Banse, & Kemfert, 2010).

The European Union protects its biofuel producers by imposing a MFN tariff of €0.192 per liter on imported undenatured ethanol, €0.102 per liter on denatured ethanol, and of 6.5% on ethanol-gasoline blends and on biodiesel. These *trade measures* are undertaken to increase the domestic price above the world market price and therefore favor domestic producer over foreign. European transport users are negatively affected by such a policy because they must face higher prices than they would in absence of impediments to trade. Nevertheless, even with the MFN tariff in place, Brazilian ethanol remains highly competitive with EU ethanol. This is important because it is not stated anywhere that the 2020 mandatory targets must be achieved relying only on domestic production (European Union, 2009). In 2011 almost a fifth of the domestic use of biofuels was imported from outside the EU (USDA, 2012a).

In the future, to ensure a sustainable production of biofuels, the Commission intends to introduce sugar for the production of bioethanol in CAP aid schemes. Moreover, it will study the possibility of using cereals from existing intervention schemes into biofuels, promote information campaigns for farmers and forest operators, as well as explore the possibility of using by-products and waste as energy sources.

The Commission also wants to create separate custom codes for biofuels and to pursue a balanced approach to trade negotiations with ethanol-producing countries. Moreover, measures to support developing countries with potential for biofuel production, will be implemented, in particular in those countries more affected by the EU sugar reform (which set minimum prices for sugar to be sold in the UE, therefore harming producers in third countries). Similarly to the US, also the EU supports research and innovation, especially to improve production processes and reduce production costs. The main measures are included in the Seventh Framework Program for Research and Development and focus especially on 2$^{nd}$ generation biofuels (European Union, 2008).

## 3.4 Biofuel policies in Argentina.

Argentina started to subsidize biofuels in 2007 mainly to diversify the energy supply, reduce the environmental impact and promote rural development. The program focuses on conventional biofuels since Argentina already has a large biodiesel industry based on soybean oil and a rapidly increasing ethanol industry based sugarcane and grains. Starting from January 2010 gasoline and diesel sold in Argentina must contain 5% of biofuel. Prices for ethanol and biodiesel sold into the domestic market are established by law. Biofuel producers do not enjoy tax incentives if they sell their products abroad. Conversely, if producers sell in the domestic market can ask for the reimbursement of the value added tax. In addition the government assures that all biofuel will be purchased for the 15-year period that the biofuel law will be in place. However the incentives are not guaranteed (they are renewed annually) and prices are set by the government.

Argentinean biodiesel is produced from soybean, and major plants are located in the Rosario area. Argentina is still a small player in the world biofuel market but its production is growing rapidly. Ethanol production is much more limited and is linked to the sugar industry.

Biofuel produced in Argentina, despite the domestic incentives, is almost entirely exported because it enjoys more favorable export tariffs (15% effective levy) than the raw materials (soybean and soybean oil) form which it is produced. However, the new, stricter EU standards for biofuels (minimum of 35% reduction in GHG emissions) might represent a constraint for Argentinean exports in coming years. The fact that Spain banned imports of biodiesel from extra-EU countries might negatively affect the Argentinean biodiesel industry in the coming years.

## 3.5 Biofuel policies in Brazil.

Brazil has the most advanced biofuel program in the world. Ethanol policies have been implemented in Brazil for the first time in the early 70s to provide a stable internal demand for sugar cane excess production, to limit energy supply constraints, and to offset fluctuations of the international sugar

price. At the same time the government made agreements with car manufacturers to produce vehicles able to run on ethanol. By 1985, 96% of cars sold in Brazil were ethanol powered (Sorda, Banse, & Kemfert, 2010). However the oil price decline of the late 80s and early 90s and the over-valuation of the Brazilian currency made ethanol production not profitable anymore. As a consequence, in 1993 the government mandated the blending of gasoline with 22% of ethanol. Today blending obligations for ethanol are up to 20-25% for gasoline and the government has recently put in place blending mandates also for biodiesel in order to reach 5% in 2013: a target similar to that of the European Union (Al-Riffai, Dimaranan, & Laborde, 2010). These policy targets are reached through tax reduction or exemptions, which vary according to the size of the agro-producers and the development level of the Brazilian region where the producers are located.

Brazil's production benefits also from the Common External Tariff (CET) issued by the Mercosur trade agreement. The CET implies import duties for both ethanol (20%) and biodiesel (14%). The removal of these measures has been under discussion at WTO level. Brazil does not issue any non-tariff barrier on ethanol imports, while the tariff on biodiesel is set at 14%.

Ethanol has been becoming more and more popular in Brazil during the last decade thanks to both rising oil prices and the introduction of flex-fuel vehicles. In 2006 flex-fuel cars accounted for 83% of total automobile sales and are expected to make up 27% of Brazil car fleet in 2010 and 43% in 2015.

Sugar and ethanol production in Brazil have very close interdependencies: almost 50% of sugar cane supply is used in ethanol production. Both industries play a very important role in the Brazilian economy. Together they account for 3.5% of GDP and employ more than 3.6 million people. Brazilian ethanol is also the most competitive – relative to production costs – biofuel in the world. It costs US$0.23 to produce one liter of ethanol in Brazil, while in the US it requires US$0.29 (Sorda, Banse, & Kemfert, 2010). These production costs mean that ethanol is competitive only if oil price is above US$30 per barrel. Since second-generation biofuels have a per liter production cost of around US$0.37, the oil must cost at least US$42 per barrel to make them competitive.

Brazilian ethanol is competitive because the production feedstock, sugarcane, is cheap, the mills use a sugar cane by product (bagasse) to satisfy their energy needs, and because years of government support allowed large technological development in the field.

Currently the Brazilian government, even if gives preferential treatment to the ethanol industry over gasoline producers (the fuel VAT is generally lower for ethanol than for fossil fuels), does not give any direct subsidy to the renewable sector, which is booming mainly thanks to foreign investments, especially from the US and the EU (Sorda, Banse, & Kemfert, 2010). Investments do not involve only distillation plants but also sugar cane production. Investors are attracted by the low price of raw material and by the high level of integration in the supply chain.

Recently Brazil has also started incentivizing the production and use of biodiesel. The *National Program in Biodiesel Production and Usage*, inaugurated in 2005, requires that 2% of petrol-based diesel is replaced by biodiesel by 2012, and 5% 2013 onwards. The President Dilma Rousseff is currently evaluating the possibility of increasing such percentage to 10% by 2020. Since the government also mandated a 5% blending share in 2009, it is possible that the 5% target will be reached ahead of schedule. In 2009 Brazil's biodiesel production was 1.5 billion liters, however the total output capacity of installed facilities reaches 4 billion liters. Biodiesel is mainly produced from soybean in Brazil, even if some plants run on castor bean, palm oil and jathropa. Biodiesel is subsidized because, unlike ethanol, it is not cost-competitive. Two are the support schemes in place. The first is government actions where the National Petroleum Agency buys given quantities of biodiesel to assure that supply targets are met. The second consists in tax exemptions, which vary according to plant location and the provenance of feedstock: a minimum quantity must be purchased from family farmers. Depending on these two variables, tax incentives range from 73 to 100% of the existing levy (Sorda, Banse, & Kemfert, 2010).

Finally it is worth mentioning that the Brazilian government is considering the possibility of starting making ethanol also from corn in states, like Mato Grosso, where there is an excess supply of grains. Even if ethanol has become the main fuel for Brazilian cars, it is still struggling to compete in areas located far from the cane-growing states of the South-East. Starting making ethanol form corn in remote areas would improve farmers' income since for them it is not economically feasible to export since they are located too far from the ports (Reuters, 2010).

## 3.6 Biofuel policies in China.

China's policies focus especially on ethanol since the country is a net-importer of vegetable oil. In 2002 the government launched the *Ethanol Promotion Program* in order to reduce corn excessive stocks. In 2004, the National Development and Reform Commission (NDRC) initiated the *State Scheme of Extensive Pilot Projects on Bioethanol Gasoline for Automobiles* (SSEPP) with which the government controlled both production and distribution of ethanol. In 2006, some pilot projects implemented in five provinces and 27 cities reached the 10% blending target. Later the same year the NDRC proposed to set a 6.6 billion-liter-target for 2010 but the proposal was rejected by the State Council because of high food prices.

In 2007 the NDRC launched the *Medium and Long Term Development Plan for Renewable Energy*, which establishes that renewable energy's share of total primary energy consumption must rise to 10% by 2010 and to 15% by 2020. Of course, biofuels will play a key role to reach these targets. Ethanol production is projected to reach 2 million tons by 2010 and 10 million tons by 2020. Also biodiesel consumption targets were established: 200,000 tons by 2010 and 2 million tons by 2020.

The government is fully committed in meeting these objectives without affecting food prices. To do so it does not allow factories to employ corn in ethanol production but instead encourages the

employment of crops such as cassava, sorghum, and sweet potatoes. These restrictions, however, reduce the potential of Chinese production, which is nevertheless forecasted to reach 1.7 million tons is 2009.

The government also controls ethanol price, which is maintained at a level that would make production not economically feasible without external financial assistance. In 2007 producers were granted a US$200 per ton subsidy, which was replaced in 2008 by payments based on the evaluation of individual plant's performance. In addition ethanol producers does not have to pay the 5% consumption tax and the 17% VAT. Also intermediate inputs like grains and fertilizers are granted financial assistance.

Similarly to what happens in both the US and the EU, also in China research on second-generation biofuels is supported. The subsidy is about US$438/ha for jathropa plantations, and US$394 for cassava. No direct subsidies are given for biodiesel.

## 3.7 Biofuel policies in India.

India ambitious biofuel objectives were set in 2008 by the *National Policy on Biofuels*. By 2017 diesel and gasoline will have to be blended with biodiesel and ethanol respectively. These targets are made difficult to be achieved by the fact that biodiesel must be produced by non-edible oil seeds cultivated in marginal lands. However, in order to support farmers, a minimum support price (MSP) for oil seeds destined to biodiesel production has been put in place. Similarly also a minimum price for ethanol is being implemented.

In 2003 the government started a project (*National Mission on Biodiesel*) finalized to plant jathropa on 11.2 million hectares of wasteland by 2012. However it was not successful because biofuel production costs rapidly surpassed purchasing price.

The Indian government also provides fiscal incentives under the form of the exemption from the central excise tax. However, many regional governments have maintained the state excise duties. Tax incentives are not granted for ethanol even if the government subsidize loans for sugar mills building and ethanol production units.

## 3.8 Biofuel policies in Indonesia.

In 2008 the Indonesian government established mandatory levels of biofuel consumption. Biofuel must reach 2.5% of total energy consumption by 2010 and 20% by 2025. The ethanol component of gasoline must be of 3% by 2010 increasing to 15% by 2025. Later these targets were reformulated and raised to 10% of biofuel share by 2010. The Indonesian Ministry of Energy and Mineral Resources (MEMR) and Parliament reached an agreement to provide biofuel subsidies at 3,000 rupiah per liter for biodiesel, and 3,500 rupiah per liter for ethanol in 2013. Moreover Indonesia coal and mineral mining companies are required to consume 2% of biofuels in their total fuel consumption starting from July 2012 (USDA, 2012b).

Biofuel blending policies, however, have been hampered by high feedstock prices. In 2006, Pertamina, the state-owned oil and fuel distribution company and only biofuel supplier started selling a gasoline blended with 5% biodiesel (B5), however in 2009 it was forced to reduce the blend to 1% due to higher palm oil prices. Petramina, starting from February 2012 started blending conventional diesel with 7.5% biodiesel.

New production facilities are under construction for both biodiesel and ethanol. In 2010 biodiesel production capacity was more than 4 million tons per year. Ethanol capacity was much lower, but the new facilities under construction will make it possible to reach higher outputs. In 2011 almost 90% of Indonesian biodiesel production was exported. Most of biodiesel goes to the EU. In 2011 39% of total EU biodiesel imports came from Indonesia (USDA, 2012b).

The government provides fuel subsidies for almost 15 billion dollars, which are used to allow the selling of ethanol and biofuel blends at the same price of standard gasoline. Of course this imply heavy losses for Petramina, which account for about 40 million dollars per year (Sorda, Banse, & Kemfert, 2010).

## 3.9 Biofuel policies in Malaysia.

Malaysia is one of the greatest palm oil producers in the world, and this gives the country a big competitive advantage in biodiesel production. The government first intervened in 2005 with the *National Biofuel Policy* (NBP) that introduced a 5% biodiesel blending (B5) mandate, which, however has been implemented only recently. At the moment biofuel production in Malaysia is not economically viable yet, mainly because of high palm oil prices, which make for palm oil producers (that are also biofuel manufactures) more convenient to directly sell palm oil instead than further processing it. The Malaysian biodiesel sector is suffering from competition from neighboring Indonesia. As a result Malaysian exports have substantially decreased in recent years (USDA, 2012c).

Malaysia produces two types of biodiesel: envodiesel and palm methyl esters (PME) biodiesel. The latter is the result of the blending of regular diesel with raw palm oil and is used only domestically, despite car manufacturers discourage its use. The former is exported and represents the largest share of total biodiesel production (75%). In 2007 Malaysia exported slightly less than 100,000 tons of PME biodiesel.

Producers can be eligible for financial support through two aid schemes: the *Pioneer Status* (PS) and the *Incentive Tax Allowance* (ITA). The first provides a 70%-tax reduction on the statutory income obtained from biodiesel production for 5 years. The second is for companies with high investment costs in equipment and machinery: allowances spent for fixed assets can be detracted from taxable income for a 5-year period.

Trade restriction measures are not present. Exports of processed palm oil or biodiesel are duty-free, while crude palm oil exports are taxed.

It is important to highlight the fact that also oil is subsidized in Malaysia. Domestic users pay a price that is lower than the international price. This implies a large expenditure for the local government that decided to promote biofuel use to lower the budget spent on fossil fuel subsidies.

Malaysia, similarly to Indonesia, takes advantage of subsidies in place in the EU and the US since large part of the domestic production is exported to these markets.

## 3.10 Biofuel policies in Thailand.

Thailand's biofuel policy incentivizes both biodiesel through mandatory blending and ethanol consumption through tax exemptions that allow ethanol blends to be cheaper than regular gasoline.

Ethanol is produced from sugar cane and molasses but tapioca-based production is expanding. Gasoline blended with ethanol is called "gasohol", which has contributed to a significant decrease of standard gasoline and currently accounts for nearly 50% of total gasoline consumption. Gasohol is exempted from the excise tax and this allows ethanol blends to be 10-15% cheaper than regular gasoline. The government is active in further promoting biofuel production, especially through the diffusion of E20 and E85 blends as well as of flex-fuel vehicles. E20 and E85 blends will be substantially cheaper than regular gasoline (-20 and -50% respectively) thanks to excise duty exemptions and additional state subsidy from the *State Oil Found*.

Biodiesel with 2% methyl ester content has completely replaced regular diesel in the whole country in 2008. A B5 blend should started to be enforced in 2011. Additionally the government set up the *Committee on Biofuel Development and promotion* (CBDP) in order to increase domestic palm oil production, the main biodiesel feedstock, of which currently Thailand is a net-importer (Sorda, Banse, & Kemfert, 2010).

The Government has new 10-year Alternative Energy Development Plan (2012-2021) to replace its old 15-year plan (2008-2022) which has fallen short of achieving its short-term targets, particularly in ethanol consumption. The new plan leaves the ethanol consumption target unchanged at 9.0 million liters/day by 2021 which is still a challenge as current consumption is around 1.1 million liters/day. Meanwhile, the biodiesel consumption target is revised up from 4.5 million liters/day to 5.97 million liters/day by 2021while current production capacity is at 1.62 million liters/day (USDA, 2012d).

## 3.11 Biofuel policies in Australia.

Australia started subsidizing the biofuel sector in 2001 when set a non-binding target of 350 million liters to be reached by 2010. In 2006 two Australian states set two even more stricter targets: New South Wales a 10% binding share of ethanol in gasoline by 2011, and Queensland a 5% one.

Australia's biofuel production is still small: in 2007 it was 83 million liter for ethanol and 77 million for biodiesel. Despite these small figures, biofuels are highly subsidized if compared to other industries. The most important policy is the tax rebate, which has been established to offset the fuel excise duty of A$0.38143 per liter of both ethanol and biodiesel until 2011. In July 2011 the tax rebate for ethanol was abolished even though the excise was lowered to A$0.125. the *Energy Grant–Cleaner Fuel*, however, kept guaranteeing an alternative subsidy for ethanol: A$0.1 per liter decreasing by A$0.025 per year until 2015. Biodiesel underwent a similar treatment when the excise duty dropped to A$0.191 per liter in 2011 and the *Energy Grant–Cleaner Fuel* program introduced a A$0.153 per liter subsidy, also decreasing until 2015 when it will be eliminated.

On June 22, 2010 Australia's Customs and Border Protection Service launched concurrent dumping and countervailing duty investigations into U.S. exports of pure biodiesel and biodiesel blends. Following this investigation, Australian customs published a dumping notice and a countervailing notice. This decision was appealed, however, the appeal was unsuccessful and the decision to impose measures upheld. According to official trade statistics, imports of biodiesel continue despite the recently introduced protective trade measures. Industry sources suggest that the importation of biodiesel will likely continue unabated (USDA, 2012e).

# 4 Biofuels sustainability.

This chapter contains an extensive literature review on the environmental, social and economic sustainability of biofuel production in the world. Biofuels, especially biodiesel, at current oil prices, would not be competitive with fossil fuels if government support policies were not in place. However, these policies might also have some unintended effects on land use patterns, GHG emissions, and agricultural commodity prices (European Commission - Joint Research Center, 2010). Not only first-generation biofuels are likely not to significantly reduce GHG emissions, they are also likely to have undesirable side-effects such as increase in food prices, indirect land use changes, and negative effects on rural communities, especially in developing countries. The fear that biofuels, especially first-generation ones, are just making the situation worse, has now reached policy-makers in many countries.

Biofuels started to be massively subsidized (and therefore produced) at the beginning of the 2000s (except than for Brazil, where bioethanol has been used in the transport sector since the mid-70s). They, in the aftermath of the signing of the Kyoto protocol, were considerate "green" alternatives to fossil fuels, that is a carbon-neutral and potentially infinite source of energy. Even the former US president George W. Bush, not famous for being an environmentalist, a few years ago declared that "*the most efficient and quick way to replace oil is the expansion of the ethanol sector, which can also represent an opportunity of development for rural areas while respecting the environment.*" In the last decade, thanks to policies implemented by the US and the EU, biofuel production grew exponentially and it has been predicted that, at current expansion rates, biofuels could represent 7% of total fuels used in the transport sector by 2030.

However, in the same time frame, many problems linked to the production of biofuels started to surface. Some researchers are questioning the common belief that biofuels are, in fact, contributing in lowering GHG emissions, while others started to point out the fact that their diffusion is having negative effects on food production and on agricultural and food prices. Recently also concerns on farmers' working conditions in developing countries (where the raw materials for some biofuels are produced) have been raised. Furthermore, according to some studies, biofuels would have negative consequences on ecosystems and biodiversity as well. Biofuel production can, in some circumstances, encourage deforestation (especially in tropical countries), land use changes (from traditional crops to those suitable for biofuel production) and reduce water availability.

Concerns on the real effectiveness of biofuels fueled the debate at international level, especially in a framework of increasing world demand for agricultural commodities. Some governments, concerned over the potential negative consequences of biofuel production, started to subsidize research on second-generation biofuels, produced from non-food crops, and characterized by more efficient production technologies. Feedstock for these fuels is produced from crops that require small amounts of water and fertilizers to be grown and that are suitable for cultivation in poor soils and marginal land. However,

second-generation biofuels are still under development and none of them is currently ready for commercial production. In the US, even though the Federal government is trying to promote research on second-generation biofuels, has to face the opposition from the powerful “ethanol-lobbies”, which have massively invested on corn-based ethanol plants and now need time to return from their investment. Corn is cropped in a very intensive way in the US, with a high amount of fertilizers, pesticides and mechanical labor. In other words, in the US, subsidizing the ethanol sector translates in incentivizing intensive (and polluting) corn production.

Also in Brazil ethanol is the most popular biodiesel, but is obtained from sugarcane. Even if sugarcane production is less problematic than corn production it can still create problems to the environment. Sugarcane plantations are located along the Atlantic coast and their current strong expansion is taking place at the expenses of the *cerrado*, the tropical savanna usually used as grazing land, which, in turn, expands at the expenses of the Amazons.

In the EU policies are mostly in favor of biodiesel, which is produced from vegetable oils. The most commonly used ones are rapeseed and palm oil. The problem here is that most of the palm oil used for biofuel production in Europe is imported from tropical countries such as Indonesia and Malaysia, where a massive action of deforestation is taking place to create room for oil palm plantations. Deforestation is carried out by the means of fire, a method that releases into the atmosphere high amounts of carbon. The problem is exacerbated by the fact that soils, in South-East Asia, are very rich in peat.

In recent years many studies have questioned the real capability of biofuels in reducing GHG emissions and some have even started providing evidence in favor of the hypothesis that they are, in fact, increasing them. Biofuels’ carbon balance is measured through life-cycle assessment (LCA) methodologies, which take into account not only emissions generated while burning biofuels, but also those produced by feedstock cultivation, biofuel production and transportation to distribution sites. When all these aspects are taken into account, one may come to the surprising conclusion that biofuels pollute more than fossil fuels. For example, an increase in the amount of nitrogen in the cropping phase may lead to an increase in nitrogen oxide, one of the most powerful greenhouse gasses. The increase in demand for agricultural raw materials, due to biofuel production and other factors, can translate into an increase in cropped land, potentially at the expenses of forest or other biodiversity-rich land. These land-use changes (LUC), specifically from forest to arable land, also increase GHG emissions because, by logging the forest, one releases in the atmosphere a great amount of carbon, previously stocked in the trees.

During the 20th European Biomass Congress, held in Milan in June 2012, the debate on the real biofuels’ GHG reduction capacity was the main point in the agenda. Even though many speakers (included the EU commissioners for climate and energy) still considered biofuels effective in mitigating climate change, many others did not agree. Some recent studies not only show that biofuels do not reduce carbon emission but contribute worsening the situation. Biofuels, when used (burned) emit the exact same

amount of GHG than fossil fuels but they are considered “carbon-neutral” because plants used for their production, while growing, are assumed to absorb the same amount of carbon that will be eventually released when using the fuel. If a hectare of forest is logged down to create room for crops to be used for biofuel production, the emission increase due to the forest clearing must be accounted for separately as “carbon emission increase due to land use change.” This method, however, is correct only if it is applied on a world scale. Nonetheless, rules, under, the Kyoto protocol, are different. The protocol fixes a upper limit to emissions but only for a limited number of countries and in an incomplete way: in the case of iLUC there is no counting mechanism on a world scale.

During the conference it has been pointed out that biofuels are not as “clean” as the man from the street could think. Biofuel production factors are not infinite since water and earth are limited resources. In 2012, agriculture (both for food and non-food production) used up to 75% of total vegetated land and 70% of freshwater resources. Furthermore, the rapid diffusion of intensive cropping systems has massively increased the use of chemical fertilizers that (we will see in section 5.4 that this is not always true), in turn, substantially raised nitrogen levels in the ground, creating serious environmental damage. Intensive agriculture already has bad consequences on the environment, and a further increase in its intensity is not something to hope for.

The fact that plants are used to produce biofuels instead than food does not mean that, while growing, they will absorb more $CO_2$ that they would do if used for food production. In other words, it is possible to reduce emissions only if, to produce biofuels, no additional land is put under cultivation. This can be achieved either by reducing food consumption (unlikely, since emerging economies, such as India and China, are increasing their wealth and therefore their food demand) or producing more (also unlikely since annual yield growth has been steadily declining since the Green Revolution). It is possible to produce more also putting under cultivation areas that previously were not used for agricultural production but agriculture land expansion should not take place at the expenses of “carbon sinks” such as forests. Increasing yields without increasing pollution and GHG emissions is not easy since it implies an increase in the amount of fertilizers (characterized by a declining marginal utility), which are typically characterized by energy-intensive production processes. Also increasing cropped areas is not easy and often implies deforestation, which means a rise in GHG emissions (mobilization of the carbon stored in the trees). Some scientists point out that substituting fossil fuels with biofuels would result in less carbon mobilized from underground (fossil) reserves and therefore a decrease in GHG emission. However, this is true only if this “carbon emissions saving” is greater than the increase in GHG emissions due to indirect land use changes (iLUC). But, also in this case, it is extremely difficult to quantify the amount of carbon “saving” consequent to a decrease in fossil fuel consumption, supposed that it will actually occur (not very likely because of rapid economic growth in emerging countries).

Put in another way, current generation biofuels can reduce GHG emissions only if crops are managed in a way that allows the growth of the right amount of additional biomass that will absorb the carbon released with biofuel combustion. An alternative is the use of waste or crop residues as feedstock. This material, if not re-used in biofuel production, would release GHG anyways while decomposing. In this way it could be even achieved a reduction in GHG emissions. Nevertheless, biofuels production techniques that use waste and residues as feedstock cannot be produced at a large scale yet.

In some cases countries implementing biofuel policies do not compute GHG balances in the correct way. The case of the EU is amongst the most evident ones. The EU directive 2003/87/EC caps total emissions from the industrial sector and power plants but completely ignores emissions from biomass combustion and those caused by iLUC, especially in third countries (but due to EU policies). Furthermore the EU directive 2009/28/EC, which sets a 20% consumption goal of biofuels on total fuel used in the transport sector to be achieved by 2020 explicitly (and erroneously) considers emissions from biomass to be null, independently from the biomass used. Even if the EU directive says that LCA must be used to compute GHG emissions, the methodology proposed (analyzed in detail in section 4.2.2) does not take into account the emissions released by vehicles and does not verify whether biomass used for biofuel production is generated in surplus with respect to that used for food production. In this way it is assumed that plants, while growing, counterbalance emissions from biofuel combustion, without verifying that there is, in fact, additional biomass growing than in the "no-biofuel" scenario or that waste or crop residues are used as feedstock. iLUC do not only increase $CO_2$ emissions but also jeopardize ecosystems and contribute in decreasing biodiversity. Potential effects are huge. It has been estimated that, if the EU will reach its 2020 consumption targets, iLUC would be between 4.7 and 7.9 million hectares, an area more or less as big as Ireland. This would mean, instead than a decrease, an emission increase quantifiable in 31.3-64.6 million tons of $CO_2$ equivalent (Global Subsidy Initiative, 2012).

Biofuel production is potentially dangerous not only for its effects on GHG emissions and iLUC but also for its consequences on water availability. Some crops used in biofuel consumption, such as sugarcane, need great amounts of water to grow, especially in tropical and sub-tropical climates. This means that countries that already suffer from water scarcity, such as China and India and many African countries, may experience a further worsening of water availability due to increased biofuel production. This, in turn, might translate into lower food production and higher food prices.

Subsidies to the biofuel sector are justified also by the fact that feedstock production may increase investment in agriculture, increase farm income, create new jobs, and promote development in rural areas, especially in developing countries. However it is very unlikely to happen since poor farmers in developing countries benefit from biofuels since most of the land, in those countries, is in the hands of big multinational companies, which intercept all revenues. The Brazilian government acknowledged this fact by learning from its previous mistakes. In the 70s when the *Proálcol* program was launched to promote

ethanol production, it supported the creation of large-scale production plants and plantations belonging to the "sugarcane aristocracy" at the expenses of smallholders in rural areas, which were forced to start working, often in poor conditions, as cane-cutters in big industrial plantations. The Lula government tried not to make the same mistake while developing the new Brazilian biodiesel development plan, in which preferential access to the feedstock market is granted for small farmers located in marginal areas.

A study from de Vries et al. (2010) compares the ecological sustainability of biofuel production from several major crops that are also used for food or feed production based on current production techniques in major production areas. They compare biofuels on the basis of nine sustainability indicators focused on resource use efficiency, soil quality, net energy production, and GHG emission. Disregarding, however, socio-economic aspects, biodiversity and land use changes. Biofuel produced from oil palm (South East Asia), sugarcane (Brazil) and sweet sorghum (China) appear to be the most sustainable since these crops make the most efficient use of land, water, nitrogen, and energy produced. One of the hypothesis of the study is, however, that there is no land use change and GHG emissions are lower if compared to fossil fuels. These results show how misleading sustainability analyses can be if some aspect are not taken into account or treated in detail. Oil palm cultivation, for example, is one of the most damaging crops in terms of consequences on the environment, since for its cultivation large portions of tropical forest are logged down with very negative consequences in terms of biodiversity and GHG emissions.

Scarlat and Dallemand (2011) review the last developments on the main alternative approaches for the sustainability certification of biofuels and bioenergy. They detect a lack of harmonization across different initiatives worldwide to enhance sustainability of major crops used as biofuel feedstock. Many approaches have significantly different requirements and might lead to inconsistent schemes. It is needed an effort to increase coordination and integration to develop common frameworks, definitions (e.g. what is "forest land"?, What is "high conservation land?") and methodologies (GHG emission calculation *in primis*). If sustainability criteria are clearly defined then there is less ambiguity in their interpretation and it is easier to enforce them. Another risk is that the same, well-developed, criteria will not be interpreted in the same way in different countries or might not be applied with the same rigor. Even well-designed sustainability certification schemes are nevertheless probably not able to avoid certain indirect effects like the impact on food availability and iLUC. iLUC often have an international dimension, across markers and countries in fields often regulated by different policies. Water-related issues (both regarding water quality and availability) need to be included in sustainability criteria and also for the conversion phase. Certification schemes include all agricultural production and processing for all end-uses (not only for fuel but also for food, fodder, fiber, *etc.*). Considering the high complexity, uncertainty and lack of scientific agreement on the iLUC effects of biofuels, iLUC should not be included in certification schemes but, rather, addressed by other mechanisms. Land use changes can be limited through the implementation of land use plans and a reliable enforcement plans, which are difficult to implement in developing countries. Monitoring should be

done through remote sensing and regular field surveys. The EU experience in the field of use of high-resolution satellite imagery for control and implementation of the CAP can be relevant.

Furthermore, biofuel policies are not for free. They cost money and the strong financial crisis that has interested many countries around the world may force governments to put an end to most of them. Biofuel policies cost over 22 billion dollars to governments worldwide in 2010, an amount hardly justifiable in periods of crisis given that real effectiveness of biofuels in reducing GHG emission is, at least, controversial. In the US, the Congress voted in favor of eliminating tax exemptions for ethanol producers for an annual saving of 6 billion dollars, starting from January 2012. However, reducing biofuel policies is not always easy, even in periods of crisis since in many cases strong initial investments were made, which need to be amortized and that are a deterrent to policy reduction. In many countries policies are "paid" directly by consumers since they are related to consumption and blending mandates. In the case of blending mandates the cost are sustained by a multitude of consumers (who often ignore it) and the pressure on government (to cease the policies) they can exert is much lower than that of biofuel lobbies.

This chapter is organized as follows. Section 4.1 is on the effects of biofuel expansion on food production and food prices, section 4.2 is about the environmental sustainability of biofuel production, section 4.3 deals with the implications of biofuel expansion for developing countries and section 4.4 summarizes and concludes.

## 4.1 Biofuels and food production.

The role biofuels play with respect to GHG emissions is just one side of the coin. The other is their impact on agricultural prices, which have reached record levels in the last five years. Between 2007 and 2009 biofuel production absorbed 20% of total sugarcane consumption, 4% of total oilseed, cereals and sugar beet. Figures that have probably increased thereafter. The FAO, in a report dated 2011, emphasized that blending mandates increase inelasticity of demand and price volatility. The report suggests G20 countries to abolish all measures favoring biofuel production. As an alternative the FAO proposes that governments, at least, adopt more flexible policies that could be adapted in order to limit negative effects when agricultural prices are particularly high. The increase in demand for agricultural commodities (due to both biofuels and higher food consumption in developing countries) faces a rigid supply, especially in the short period, therefore causing price increases. Even though the factors that exert an upward pressure on prices are many – low stocks, exceptional weather and increase in financial transactions – the role played by biofuels is all but marginal. The first price bubble (2006-08) took place when both the US and the EU introduced blending mandates, triggering a quick and strong increase in biofuel production. In 2009 prices declined, mainly because of the financial crisis, but started to go up again in 2010 due to bad weather conditions in many key production countries. Many government agencies and independent researchers have explored this topic. It is acknowledged that biofuels do have an effect on agricultural prices but the

magnitude of such effect is controversial: depending on the country and the methodology adopted, the price increase due to biofuels ranges between 12 and 75% of the total price increase (Global Subsidy Initiative - International Institute for Sustainable Development, 2012).

This section gives a partial and far to be exhaustive literature review on recent efforts to investigate biofuel policy impacts on agricultural markets in most cases using either partial and general equilibrium models, those commonly used for policy planning by international agencies and governments. Even though partial and general equilibrium models have been so far the main tool used by researchers and analysts to investigate the impact of biofuel policies, the literature is rich also in contributions using different methodologies, such as econometric techniques (price transmission) or systems of simultaneous equations or literature reviews. This section examines also official publications issued by international organizations. What can be inferred from the literature is that the magnitude of the impacts of biofuels on food prices is very much sensitive to the models used to assess those impacts. Partial equilibrium (which model the agricultural and the biofuel sector in isolation) models ignore the interactions with other sectors of the economy and usually find higher impacts on food prices. On the other hand, general equilibrium models, which account for interactions across sectors, usually find smaller impacts (Timilsina & Shrestha, 2011). To facilitate the reader, in the following subsections works assessing the impact of biofuel expansion on agricultural and food prices are organized on the basis of the methodology used to analyze the problem.

### 4.1.1 Works based on partial and general equilibrium models.

One of the most recent and complete paper focusing on the impacts of biofuel policies on agricultural markets is the one published by the Join Research Center (Institute for Prospective Technological Studies) of the European Union in June 2010. The paper assesses the impact of the EU's Renewable Energy Directive (EC/2009/28) on European agricultural production and on land allocation worldwide. The directive under scrutiny sets an overall binding target of 20% for the share of UE energy needs to be produced from renewables such as biomass, hydro, wind, and solar power. The issue at stake is to understand whether it is true that an increased biofuel consumption will lead to a reduction in greenhouse gas emissions, after global land usage implications are taken into account. The study measures the impacts of EU biofuel policies on agricultural production, trade, and land use within and outside the EU, up to year 2020 using three partial equilibrium models: AGLINK-COSIMO, ESIM, and CAPRI. These models are scientifically acknowledged tools for simulating policy changes. The AGLINK-COSIMO is a global, dynamic-recursive, partial equilibrium model, which covers 39 agricultural primary and processed commodities and 52 countries or regions. The model also includes biofuel modules for the EU, Canada, USA, and Brazil. The ESIM (European Simulation Model) is a comparative-static, partial equilibrium, net-trade multi-country model of the agricultural sector. Countries individually represented are the EU member states, Turkey, and the USA. Other countries are aggregated in the rest-of-the-world group. The ESIM

models demand and supply of biofuels and distinguishes some byproducts such as gluten feed (from wheat and corn), and oilseed meals (rapeseed, sunflower seed, and soybeans). The CAPRI model is a comparative-static, spatial, partial equilibrium model designed to model agricultural commodity markets worldwide, with a very detailed representation of the EU. It is made up by two interlinked modules: the supply module (formed by regional NUTS-2 level mathematical program modules), which focus only on European producers, and the market module, which is a global, spatial multi-commodity model with more than 50 commodities and 60 countries. The area of both arable and grass land is set exogenously.

Each model simulated two scenarios: the baseline and the counterfactual. The first assumes that the EU's target for energy use in the transport sector is achieved using both 1$^{st}$ and 2$^{nd}$ generation biofuels in the ratio 70:30. The second assumes that there is no mandatory target for the biofuel share of total transport fuel, and no tax exemptions or other fiscal stimuli for biofuels. Both scenarios use the same exogenous trends regarding population, incomes, transport fuel demand, and crop yields.

The three models yielded different results, partially because of their different design. However, all models agree on the fact that EU's biofuel production in 2020 will be much higher, that the EU will remain a net-exporter of wheat, and that impacts on livestock production are negligible. Nevertheless, the authors conclude pointing out that more detailed analysis is needed to assess to what extent EU's energy independence may be improved by its biofuel policies, especially when reliance on imported feedstocks is taken into account. The increased EU's demand for biofuels will push biofuel prices up, especially those for biodiesel feedstocks. Significant changes in cropping patters will also occur in the EU. Cereals will shift away from Central Europe to the North-Eastern, North-Western, and Southern areas. Conversely, in central areas oilseed production will increase. Finally biofuel by-products are forecasted to reduce pressure on crop supplies and arable area coming from the higher demand for biofuel feedstock, since they can be used as animal feed. The JRC paper is an example of analysis carried out using large, data and software-intensive models.

Wallace and Farzad (2008) used a simpler partial equilibrium approach to examine the profitability of a typical US ethanol producer with and without the ethanol subsidy for different combination of corn-crude oil prices. The authors conclude that we are in a new era, characterized by a tight long-term connection between crude oil and corn prices. Since this linkage exists between oil and corn, it is possible to expect it will exist also between crude oil and other commodities. The model consists in two integrated markets: corn an gasoline. The supply side of the corn market consists of identical corn producers, who produce using a short-run Cobb-Douglas production function and sell their products in a competitive market. The input of corn producers is a composite input that covers all inputs such as: seed, fertilizers, chemicals, fuel, electricity, *etc*. The demand side of the corn market consists of 3 users: domestic users that use corn for feed and food, foreign users, and ethanol producers. Domestic and foreign demand are modeled with constant price elasticity functions. The foreign demand for corn is more elastic than the

domestic demand. The demand of the ethanol industry for corn is a function of the demand for ethanol. The gasoline market has 2 groups of producers: gasoline and ethanol producers. It is assumed that ethanol is a substitute of gasoline. Both gasoline and ethanol producers produce according to the short-run Cobb-Douglas production functions. The variable input in gasoline production is crude oil, while for ethanol production is corn. Both groups of producers are price takes in product and input markets. Demand is modeled with a constant price elasticity demand function. The constant parameter of this function can change due to changes in income and population. The gasoline industry is assumed as well-established (and operating at long-run equilibrium), while the ethanol industry is assumed expanding. New ethanol producers enter the market when there are profits. It is assumed there is no physical limit to ethanol production, only economic ones. The model is calibrated to the 2006 data. Elasticities are taken from existing literature. Endogenous variables are gasoline supply, demand, and price: ethanol supply, demand, and price; corn price and production; corn use for ethanol, domestic use, and exports, DDGs supply and price, land used for corn, and the price of composite input for corn. Exogenous variables are: crude oil price, corn yield, ethanol conversion rate, ethanol subsidy level and policy mechanisms, and gasoline demand shock (due to non-price variables like population and income. The model is solved by market clearing conditions that corn supply equals the sum of corn demands and that ethanol production expands to the point of zero profit. The model is simulated over a range of oil prices and with and without demand shocks. The results conform to expectations and depict well the expected strong linkage in the future between crude oil prices and corn prices and production. Target year is 2020.

Tokgoz et al., (2007) use a multi-product, multi-country deterministic partial equilibrium model (the partial equilibrium model of the Center for Agricultural and Rural Development of the Iowa University) to project US ethanol production and its impacts on planted acreage, crop prices, livestock production and prices, trade, and retail food costs in the US, under the assumption that tax credits and trade policies are maintained. The results indicate that increased US ethanol production will cause long-run crop prices to increase. Also livestock farmgate prices will increase, as a response to higher feed costs. Retail meat, egg, and dairy prices will go up as well. The authors also simulated the effect of a drought, combined with a large mandate for continued ethanol production. In this scenario crop prices would increase sharply, while livestock production would drop and food prices increase. In any of the scenarios simulated second-generation biofuels become economically viable. This is because even if higher energy prices will drive switchgrass ethanol and biodiesel, they will also increase the price of corn-based ethanol. So as long as farmers can choose between soybeans for biodiesel, switchgrass for ethanol, and corn for ethanol, they will choose to grow corn. In this study the authors introduced DDG (distilled dried grains, a byproduct of ethanol production, which can be used as animal feed) in the model. They enter the rations of ruminant animals replacing, to some extent, corn and soybeans used for ethanol production. With more expensive DDG world poultry and swine producers continue to purchase corn and soybean meal and thus soybean

area increase rather than decrease. Increasing soybean prices cause South American soybean area to increase, as the US reduces its soybean production.

More recently Babcock, Barr, and Carriquiry (2010) applied the same model of Tokgoz et al. (2007), to examine the consequences on the US ethanol industry, corn producers, taxpayers, fuel blenders, and fuel consumers of the elimination of the current US biofuel policy. The estimates were obtained using a new stochastic model that calculates market-clearing prices for US ethanol, Brazilian ethanol, and US corn. The model is stochastic because market-clearing prices are calculated for 5,000 random draws of corn yields and wholesale gasoline prices. The model assumes that the strong growth in flex-fuel vehicles in Brazil continues and that intermediate ethanol blends with few restrictions are implemented in US markets by 2014. The last assumption seems justified since the US Department of Energy recently allowed a 15% blend of gasoline with ethanol. With these assumption, the US ethanol production is forecasted to reach 15 billion gallons in 2014 and Brazilian ethanol production to increase by at least 45% by 2014. The projected strong demand for ethanol in Brazil, combined with a saturated US ethanol market means that the elimination of the US ethanol import tariff will have no impact. The elimination of the tax credit would also have a modest impact: US ethanol production would in fact decrease by only 0.7 billion gallons. However this drop in ethanol production would still cause corn prices to drop by 23 cents per bushel and ethanol prices by 12 cent per gallon. If the tax credit is eliminated, taxpayers will save more than US$6 billion. If the impact of a change in US ethanol policy is assessed in 2014, the outcome would likely to be different since Brazil would have the chance to respond. The South American country would improve its ability to export in response to trade liberalization by the US. However the magnitude of the impact will depend on the ability of Brazilian producers to meet the strongly increasing domestic demand.

Also the International Food and Policy Research Center (Bouet, Dimaranan, & Valin, 2010) tried to assess the impact of high biofuel production on feed and food production. However, they do not only focused on agricultural production implications, but also on the real environmental effects of a higher use of first-generation biofuels. The authors argue that the relocation of production due to a higher biofuel demand can increase deforestation and therefore release significant volumes of carbon into the atmosphere. The authors used the trade policy model MIRAGE 7, based on the GTAP 7 database. Also in this case researchers modified the existing model to explicitly capture the role of different types of biofuel feedstock crops, energy demand, and carbon emissions. The authors measure the environmental cost of different land conversions due to biofuels in the carbon budget, taking into account both direct and indirect carbon dioxide emissions related to land use change. In this framework the paper assesses the impact of both US and EU biofuel policies (with special attention paid to ethanol) with and without trade liberalization. According to the model, biofuel policies significantly worsen the total carbon balance, in other words, the increased carbon emissions needed to increase biofuel production offset the carbon savings yielded by a greater biofuel use for transportation. Ethanol trade liberalization can limit the carbon

emission increase because, in free trade, both the EU and the USA would import large quantities of biofuel from Brazil, where production costs are lower. In Brazil ethanol is produced from sugarcane a relatively emission-saving feedstock. However, an increased demand for Brazilian (and other developing countries') ethanol can eventually increase deforestation and worsen the carbon balance even more.

An example of general equilibrium model (CGE) applied to the biofuel sector is given by Golub et al. (2008) who used a CGE model with explicit biofuel, land, and energy markets to estimate the effects of biofuel policies on a broad range of input and output markets. In particular the authors link their CGE model (a modified version of the GTAP model) to a forward looking model of the forest sector in order to measure the changes in land use and in forest carbon stocks. The model also includes biofuel by-products that can be used for livestock feed. An increase in the share of renewable fuels in total liquid fuels in both the EU and US would trigger increases in cropland for grains, oil seeds, and sugar cane, with decreases in grazing land, forest lands, and other croplands. The growth in US biofuels would also yield a 5.85 million tons of carbon equivalent (MMTCE) emission increase. If also the EU is taken into account, emissions would increase by 13.45 MMTCE.

Bhattacharya et al. (2009) use a relatively simple multi-market displacement model to assess the interdependence between ethanol production, ethanol by-products, and meat production in the US. The models considers six markets: beef, pork, poultry, corn, ethanol, and ethanol by products. Equilibrium displacement models have the peculiarity that supply and demand functions are not assumed to have a particular functional form. Total differentiation of supply and demand equations is performed and changes in both endogenous and exogenous variables are expressed in proportionate terms or as ratios of proportionate changes (elasticities). In this paper policies are not taken into account. Ethanol is produced from corn that can also be used as animal feed, like ethanol by-products. The authors found that a 10% shift in ethanol demand raises corn price by 4.5%, which in turn leads to a decline in corn demand by 4.05% for cattle, 2.38% for hogs, and 8.5% for chicken. By-products supply increases by 5.7% and its price declines by 3.96%. Since by-products are cheaper, their use in the cattle and hog sector increases respectively by 9.5 and 3.11%.

Saunders et al. (2009) use a partial equilibrium model of international trade to quantify the price and farmgate income effects of US biofuel policies on New Zealand's agricultural sector. They found that even if US policies do affect corn prices, their consequences on livestock prices and production are small. They also conclude that the New Zealand's pasture-based livestock sector benefits from an increased ethanol production since it can benefit from higher selling prices but does not face the same input cost increases competitor countries like US and EU face. The authors used a modified version of the Lincoln Trade Environmental Model (LTEM), which is an agricultural multi-country, multi-commodity model specifically made to assess the impact of domestic and trade agricultural policies. The model can also be

extended to quantify the linkages between the agricultural sector and the environment. A detailed description of the model is given in Catagay and Saunders (2003).

Babcock (2010) evaluates of the consequences of the abolishment of the US ethanol tax credit (45%) and ethanol import tariff (54%). The study was performed at the end of 2010, with high corn prices due to Summer drought in the US and a wheat export ban issued by Russia. It was estimated that if the two policy measures would not be extended (as it, in fact, happened), the livestock sector would be better off thanks to reduced corn demand. Corn is the most important factor in determining the cost of feeding livestock (it also affects the price of other feeding cereals and that of soybeans since they compete for land). The two policy measures affect corn prices only if ethanol production is higher than the mandated level (the US mandates the blending of regular gasoline with ethanol), in this case the removal would cause production to decline to the mandated level. Whether the mandate is binging or not depends on the price of gasoline: if it moves higher, the tax credit stimulates production beyond mandated levels and the price of corn increases. So the removal of the tax credit would lower feed costs only if ethanol production is higher than mandated levels. In the scenario in which tax credit and import tariff are allowed to expire, and the mandate is kept in place, the US ethanol production drops by 600 million gallons (average of all runs) and ethanol imports increase by 120 million gallons. The price of corn decreases by 6.8%. With no mandate, the US ethanol production would decline by another 1.7 billion gallons. The 7% drop in corn price due to the removal of the tax credit and the import tariff would help livestock farmers but corn price would stay high because of the mandate, only if the mandate is removed corn prices would fall significantly. In 2012 the US government removed the tax credit but kept the blending mandate and the price of corn did not change significantly because of this decision.

Miljkovic, Shaik, and Braun (2012) develop a comparative statics theoretical model to analyze the direct and indirect effect of ethanol policy on livestock production in the Unites States. The model is made up by a one-input and two-output ethanol model and a two-input and one-output livestock model. Corn is the sole input for the ethanol model and a joint input in the livestock model, with distillers' grains (DG) being the other one. Outputs of the ethanol model are ethanol and DG. Ethanol and DG are produced from corn in semi-fixed proportions, while livestock production utilizes corn and DG as feed. Corn and DG are feed substitutes. Ethanol policy increases the demand for ethanol, which, in turn, increases the demand for corn. The increased production for ethanol increases DG production, so livestock farmers have to face an increased competition for corn but have also at their disposal a greater supply of DG [this does not happen in other countries also affected by US policies]. So lower DG prices (due to increases demand) could increase cattle production and therefore decrease cattle prices, but higher corn prices have the opposite effect. Results show that the inclusion of the Renewable Fuels Standard (RFS) by the US increased corn supply (through increased cropped area), therefore it is possible that the RFS indirectly affected cattle quantity through the corn equation. Reduced forms of the three structural equations were used to assess

the direct impact of the RFS on cattle production: all variables dealing with price were not significant but the dummy representing the RFS was, in fact, positive and significant. The RFS increased the production of DF, which in turn allowed cattle production to increase. DG can, therefore, mitigate the negative effects of the RFS on the livestock sector in the US. In third countries this mitigating effect does not exist.

Timilsina, Mevel and Shrestha (2011) investigate, through a CGE model, the impact of oil price on biofuel expansion and on food supply. The base year is 2009. A 65% increase in oil price in 2020 from 2009 levels (65 USD/barrel) would trigger an increase in biofuel global penetration from 2.4 to 5.4%. Penetration would be 9% if oil price increases by 150% in the same time-frame. A 9% increase is higher than that would be caused by current consumption mandates worldwide. The study also shows how global food output decreases due to an oil price increase. The drop is small in major biofuel countries since biofuel expansion partially offsets the negative impacts of the oil price increase on agricultural outputs. However, an increase in oil price would reduce world food supply through direct impacts and the diversion of food commodities towards the production of biofuels. The model explicitly models biofuels (3 types of ethanol and biodiesel) and has a detailed land-use section. It also represent various petroleum products explicitly. This is important: ethanol competes with gasoline, while biodiesel with diesel. The functional form used is CES. CET functions are used to represent the supply behavior. The social accounting matrix (SAM) is from the GTAP database. Elasticity parameters are taken from the literature. Brazil, India, Malaysia, Russia, and the US are the countries that would experience high levels of penetration. However results are very sensitive to the elasticity of substitution between fossil fuels and biofuels used in the model. An increase in oil price leads to a reduction in agricultural output (-1.5% in 2020 if oil prices increases by 150% from 2009 levels). The loss would be, however, greater in case biofuels were not produced at all. The study finds significant reallocation of land supply from rice, pasture and forests towards production of biofuels feedstocks. The study also finds that a 25% increase in oil price from the baseline would reduce global food supply (including processed food) by 0.7% by 2020. In some countries (China, India, Southeast Asia, and Eastern Europe) food supply is forecasted to decrease by 3.5-6.1%.

Andrade de Sa, Palmer and Engel (2010) investigate the direct and indirect impacts of ethanol production on land use, deforestation and food production. In particular it analyzes how an exogenous increase in ethanol price affects input allocation (land and labor) between sectors (energy and food). Three potential effects are analyzed separately. First, the effect of direct competition for land between rival uses increases deforestation and decreases food production. If the relative marginal profitability of the energy crop sector increases (e.g. due to an increase in ethanol price) a reallocation of land (previously used for food production or forest) occurs. Second, the indirect displacement of food production across regions, caused by a change in food price, increases deforestation and reduces total output of the food sector. This effect is often called, in the literature, indirect land use changes. Increasing profitability of one agricultural sector can displace other agricultural activities to marginal land or forests. However, deforestation occurs

only if the energy crop is produced, at least partially, in the non-forested region and the displaced activity has to be such that national production affects the output price. If this does not occur, then the price of the potentially displaced good does not vary, leaving its profitability unchanged and, instead than a displacement of production, just a direct reallocation of land between the two activities occurs. The size of displacement depends on how sensitive the food price is to a decrease in the quantity produced. This effect implies that governments and decision makers should promote ethanol production through policy instruments that ensure that the displacement of food production is guided towards idle land. For countries with little idle land, ethanol production should not be considered a desirable GHG mitigation strategy. The third effects is about labor mobility between sectors and regions. It tends to decrease both food production and deforestation. The overall impact of ethanol production on food production is negative, while the impact on deforestation is ambiguous since ethanol expansion can both increase deforestation through the land market or reduce it through the labor market. The model is only relevant where forests are vulnerable to deforestation, with weak property rights to forest land and where crops can only be grown under certain conditions.

Babcock and Fabiosa (2011) try to "rewrite" history in a computer model to estimate the impact of the "troika" of US ethanol subsidies (tax exemptions, tariffs, and mandates) had on agricultural markets. They are a discordant voice since according to their estimates, biofuel expansion would have occurred also in absence of government subsidies. They compare historical prices to those produced by a CGE model in which government incentives to the ethanol market were removed. The study finds out that the general pattern of corn prices that we saw in the historical period (price spike in 2008 and sharp decline in 2009) would have occurred also without ethanol subsidies and even if ethanol production would have not expanded at all. Furthermore, investors' fervor for corn ethanol in 2005, 2006, and 2007 would have occurred without subsidies because of the combination of low corn prices, MTBE phasing-out, and high oil prices. Thus, ethanol production would have expanded quite rapidly even without subsidies. The paper also estimates that 8% of the increase in corn price (from 2006 to 2009) was due to ethanol subsidies and 28% to the expansion of the corn ethanol industry. In total, subsidies and market forces accounted for 36% of the average increase saw in corn prices from 2006 to 2009. The authors point out that ethanol production increased because of favorable market conditions (high ethanol prices and low corn prices) and not because of subsidies. Therefore, ethanol subsidies are not responsible for high corn prices or food inflation.

In a working paper Link et al. (2008) use a partial equilibrium model (EUFASOM) to investigate the potentials of biofuel production in Europe in the near future and the effects of expanded biofuel production on food production. The model focuses on Europe and describes resource allocation for the agricultural and forestry sectors over a specified number of optimization periods. Land is allocated to maximize marginal profitability of all endogenous agricultural and forestry land uses. The model output consists of equilibrium market prices of goods, yields, and trade quantities of the goods covered in the

model. The original model has been modified to incorporate data on European biofuel production and potentials. Simulations extend until 2030. Results show that there is a shift in agricultural production depending on the production targets of biofuels. For moderate production targets it is more efficient to produce biodiesel and therefore grow large amounts of rapeseed and other oilseeds like sunflower. This leads to an expansion of the rapeseed area, especially in Central Europe (Germany). If it is desired to produce large amounts of biofuels, then it is necessary to focus more in the production of ethanol, which would lead to an increase in the production of wheat and sugar beet. In this case the expansion of ethanol feedstock would occur in the whole Europe. However it is sugar beet production that is particularly enhanced since wheat can be easily importer from third countries. In conjunction with an increase in biofuel production, agricultural production decreases but prices do not increase since food supply remains stable thanks to imports from other regions of the world.

Tyner and Taheripour (2008) state that agricultural markets have always been quite integrated as well as markets for different energy products. However, only recently, energy and agricultural markets have started to be closely correlated. Energy and agricultural policies have historically been evaluated apart but this cannot be done anymore. In 2002 just 10% of US corn went into the ethanol industry, by 2008, the percentage increased to 40%. This study develops an integrated partial equilibrium model to study energy and agricultural markets and to provide hints for new policies. In particular, the model is built to analyze economic impacts of four alternative policies that can be implemented in promoting ethanol production; fixed subsides per gallon of ethanol, no subsidy, a variable subsidy linked to the oil price, and a renewable fuel standard (consumption mandate). The model is calibrated on 2006 data and elasticities are taken from the literature. Corn prices vary dramatically in all scenarios, but especially in the case of consumption mandates. Consequently, also corn production is heavily affected. Furthermore, when corn use for ethanol increases, corn exports decrease. Even though there are some declines in domestic use, it is exports that takes the biggest hit [with strong implications for food net-importing countries]. The authors conclude that the world has entered a new era of close interdependence between energy and agricultural markets, regardless of the policy in place, even if impacts differ among policies. We must incorporate the new energy-agriculture linkage in our future policy analyses.

McPhail and Babcock (2012) measure the impact of US ethanol policies on price volatility with a stochastic, structural, partial equilibrium model. The effect of policies on commodity markets has been a concern for long time. Increased biofuel production spurred by biofuel policies have brought new players to old markets. The model simulates the US corn-ethanol-energy complex. Risk is also modeled: corn yield is assumed to follow a beta distribution (parameters are calibrated to historical yield data) and crude oil price is modeled as the geometric brownian motion proposed by Brennan and Schwartz, based on arbitrage pricing theory. Both the theoretical and the empirical model suggest that current US ethanol policies decrease the price elasticity of demand for both commodities, and therefore increase price variability.

Hence, policies actions that result in maintaining or changing current mandates and/or the blend wall should account for their effect on the price elasticity of demand and price volatility for corn and gasoline markets. The market for renewable identification numbers (RINs, a 38-digit number that allows the EPA to track production, movement, and use of renewable fuel to meet the RFS levels. Every year each obligated party must submit enough RINs to the EPA to meet or exceed its renewable fuel obligation, RVO, that is the percentage of renewable fuel the RFS mandates to consume times the volume of gasoline or diesel it produced or imported) can be used for current and subsequent year's obligations. When the RINs carried over from previous year are many, than the impact of the RFS on price volatility is reduced. In the case of ethanol produced from corn, rollover and deficit can help alleviate pressure from a short crop in corn. Additional advanced biofuels, such as sugarcane ethanol from Brazil could be imported over their mandated quantities or additional biodiesel could be produced to cover the overall mandate. When there are additional advanced biofuels over mandated quantities the impact of the RFS on price volatility will be smaller.

Kretschmer et al. (2009) employ a CGE model to assess the economic impacts of the EU climate package, including the target of 10% of transport fuel from biofuels by 2020. Results show that the EU emission targets alone lead to only minor increases in biofuel production and therefore additional subsidies are necessary to reach the 10% biofuel target. The increased EU biofuel demand also affects trade patterns, especially for the EU and Brazil. Also agriculture prices are forecasted to increase, providing some ground for the concerns expressed in the food vs. fuel debate. EU agricultural prices are forecasted to increase by up to 7% by 2020.

Ciaian and Kancs (2011a) study the price linkages between the food, energy and bioenergy markets using a vertically integrated multi-input, multi-output market model that allows to derive testable hypothesis, which the authors test by applying time-series analytical mechanisms to nine major traded food commodity prices along with the average world oil price. They use 939 weekly observations from January 1993 to December 2010. The authors consider two price transmission channels, a direct biofuel channel and an indirect one through inputs. The paper shows how the impact of fuel price on agricultural prices is stronger with biofuel production than without it. Moreover the interdependencies between the energy and the food markets increase over time. These findings are important for policy-makers since they explain the role of biofuel (and biofuel policies) in determining agricultural prices. According to the same results, the biofuel channel is a more important driver of agricultural price changes rather than the input channel. Furthermore, it can be affirmed that biofuel production has an impact on food prices, and that this impact is higher stronger than that of higher energy costs in agriculture. These results are in contrast with some statements made by the EU and US policy executives that try to play down the role of bioenergy policy spillovers to the food and energy prices.

Nonhebel (2012) compares the need for biofuel and the needs for food and feed on global scale and builds and uses a simple model to estimate present and near future global needs for food, livestock, feed, and energy. The paper distinguishes between developing, transition, and developed countries. Developing countries need extra-food for their population, transition economies need extra feed for the livestock industry and developed countries need to reduce their GHG emission and for doing so they produce biofuels from biomass. The extra need of biomass for biofuels (1,100 MT) turns out to be larger than the extra need for food and feed (800 MT each). Since developed countries are net food exporters and supply many food insecure countries in Asia and Africa, the increased need of biomass for energy is likely to reduce these export and, consequently, affect food security in many countries. The model is limited because it considers just two different types of diets and one type of renewable energy. The economies considered are only 3. However, the results are still interesting because give an idea of the order of magnitude of the problem.

### 4.1.2 Works based on econometric techniques.

Onour and Sergi (2011) estimate volatility transmission between food commodity prices of wheat and corn, and input prices of crude oil and fertilizers. Prices used are monthly figures from January 1992 to February 2011. Corn is used to assess the impact of a change in demand for biofuel on food commodity markets. Results show that volatility in the corn market, due to biofuel production, is transmitted to the wheat market. Furthermore while volatility in wheat and corn market is influenced by shocks (unexpected news) in the oil market, the effect of crude oil price changes on corn and wheat markets in insignificant. Impulse-response analysis suggests that shocks in oil markets have a permanent effect on food commodity price changes and that volatility in fertilizer markets transmit to wheat and corn markets. Therefore, shocks in the oil market have a direct effect and an indirect one, through the fertilizer market, on food commodity markets. In turn, volatility in fertilizer markets is influenced by volatility in food commodity prices and oil prices. Fertilizer markets are also affected by own-shocks and shocks in oil markets.

Ciaian and Kancs (2011b) study the interdependencies between energy, bioenergy, and food prices. The authors test the theoretical hypothesis that the price of crude oil and agricultural commodities are interdependent, also in the case in which commodities are not directly used in bioenergy production. Data used are weekly prices from January 1994 to December 2008 (segmenting the sample in 3 periods to account for structural breaks). Through a partial equilibrium model, the authors show that the impact of fuel price on agricultural commodities is stronger with than without biofuel production. Then, they apply time-series mechanism to nine major agricultural commodity prices from 1994 to 2008, with structural breaks. The time-series analysis has the objective of identifying the indirect input channel and the direct biofuel channel of price transmission. The interdependencies between the fuel and the agricultural prices is expected to be stronger in the third period due to expansion biofuels in this period. Empirical findings

confirm the *a priori* hypothesis that energy prices affect agricultural prices and that this interdependence increases over time (cointegration detected between oil price and all nine commodity prices considered only in the third period, 2004-2008). The long-run price transmission elasticity between oil and commodity prices ranges between 0.05 and 0.30.

Gilbert (2008) tries to disentangle the factors responsible for the strong increase in food prices that took place in recent years. Usually the causes of commodity prices are investigated adopting an additive framework in which the total impact is the sum of price responses of a set of supply and demand shocks. This approach is not useful to analyze major booms such as those of 1972-74 and 2005-08 in which a large number of prices rise together. When demand shocks simultaneously impact a number of markets, supply elasticities tend to be lower than when shocks are market-specific. Furthermore supply elasticities may themselves depend on macroeconomic and financial factors. So the behavior of markets in boom episodes is different from behavior under normal conditions and it is likely that there is a multiplicative interaction of macroeconomic and financial factors with market shocks which undermine the additive analysis. Granger non-causality tests show that world GDP growth and monetary expansions are determinants of changes in world agricultural prices. The major demand shock experienced by the agricultural sector recently arose from the demand for grains and oilseeds as biofuel feedstocks. Commodities that did not experience the shock, like coffee and cocoa (not even indirectly through land reallocation) did not experience major price rises. The author argue that the price raises in grains and oilseeds is a consequence of growth in China and other Asian economies together with relaxed monetary policy over the preceding years. The resulting boom in metal and energy prices both raised production costs and the responsiveness of agricultural supply. Agricultural future markets might have played a role but speculative bubbles, the authors point out, probably persists only for short periods of time. However the focus should be on commodity investors, not on speculators. Nowadays commodities are seen as an asset class and the activity is sufficiently large to move prices. Index-based investors (who invest over a wide range of commodity futures) may have generalized price increases across markets and price correlations.

Balcombe (2009) employs two econometric methods to explore the nature and causes of volatility in agricultural price commodity over time. The first method decomposes each of the price series into components and volatility for each of these components is examined. In this way one can answer the question on whether volatility in each price series is predictable and/or dependent on shocks, yields, export concentration, the volatility of other prices, exchange rates and interest rates. This approach uses monthly data. The second approach consists in a panel regression where volatility is explained by a number of keys variables and it is used with annual data. The study finds a strong evidence that there is persistent volatility in agricultural series. In nearly all the series examined there is evidence that the series is a function of the past volatility of the series. Also a certain degree of transmission of volatility across commodities has been detected. Stocks and yield data also appeared to be significant determinants of the volatility of agricultural

commodity prices. Oil price volatility has a positive impact on commodity price volatility. This is likely to arise through the impact of energy prices on the cost of production and the alternative use of some crops for biofuel production. Consequently one would expect the link between oil price volatility and agricultural prices to continue or strengthen as the biofuel sector grows. Also the exchange rate was found to influence volatility.

According to Yano, Blandford and Surry (2010) the key components of the US biofuel policy are tax credits [abolished in January 2012], tariffs, and mandates (RFS). The tax credit used to encourage ethanol production beyond the RFS minimum requirements. Once the "blend wall" is reached – in absence of foreign demand – there will be downward pressure on the consumer ethanol price and the price of mixed fuel. The tax credit generated little or no additional consumer demand for ethanol and simply encouraged Americans to consume more fuel because the overall price of fuel will be lower. Ethanol and corn producers did not obtain any additional benefit from the tax credit since the demand is constrained. So, in presence of low world ethanol prices or tariffs issued by third countries (that inhibit US exports) the tax credit had perverse consequences: lower fuel prices and increased consumption of fossil fuels. With the blend wall more US ethanol would become available for export because domestic price would drop in absence of trade. In this context ethanol refineries and blenders would have an incentive to produce blended fuel for export in order to use up additional supplies of ethanol and collect the tax credit. In that case the tax credit acts like an export subsidy for blended ethanol. This already happened with US biodiesel. The biodiesel industry used the blenders' credit to subsidize exports of up to 80% of its production (based on imported biodiesel from Asia and South America) to Europe, until the EU Commission imposed antidumping duties in March 2009. The tax credit was removed but tariffs and blending mandates stayed. If world ethanol price falls because of downward price adjustments in the world sugar markets, then US tariffs will become important for sustaining the domestic ethanol industry in absence of the tax credit. Conversely, if the objective is to replace fossil fuel use in the US with renewable fuels, regardless of their provenance, tariff protection should be eliminated. Also the RFS should be revisited in light of the evolution of transportation fuel demand in the US. If the mandated volume exceeds feasible domestic consumption because of the blend wall, the RFS will become problematic for both US ethanol producers and blenders and world ethanol producers. If the aim is to replace liquid fossil fuels with renewable ones it seems more appropriate to refocus policy on the development of infrastructure to deliver new fuel blends or the adoption of vehicles able to run on these blends. Another policy direction would be to promote the production of green hydrocarbons that are near-perfect substitutes for fossil fuels that can be used in the existing fuel system seamlessly.

According to Mueller, Anderson and Wallington (2011), the prices of many agricultural commodities more than doubled between march 2007 and March 2008 and this coincided with expanding biofuel production, which was blamed for the price increase. However, biofuel production kept increasing

also after March 2008, when grain prices declined by 50%. Available data suggest that record grain prices in 2008 were not caused by increased biofuel production but were the result of a speculative bubble related to high petroleum prices, a weak US dollar, and increased volatility due to commodity index found investments. According to the paper, factors that contributed in increasing commodity prices in 2007-2008 were increased demand, decreased supply, increased production costs (due to high energy and fertilizer costs). Disentangle and quantify these factors is a very difficult task. In 2008 many reports were published by international organizations on this topic. Available analyses quantify biofuels' contribution in rising commodity prices in 3 to 30%. The paper considers the methodology applied by Mitchell (2008), who estimated the biofuel impact on agricultural commodity prices to be around 75%, simplistic and not appropriate. Mitchell (2008) considered the difference in the IMF's index of internationally traded food commodity prices between two points in time (January 2000 and June 2008) corresponding to price extremes. Choosing the two extreme values in the index and defining biofuels as responsible for any effects which could not be attributed directly to either energy costs or US dollar strength, overestimates the impact of biofuel production on food prices.

### 4.1.3 Studies by international organizations.

The IFPRI (2010) estimated that rising biofuel demand accounted for 30% of the increase in weighted average grain prices between 2000 and 2007. However, the impact of higher commodity prices on national economies depends on country-specific circumstances: they have negative effects for net-food importers and for low income food deficit countries. Even in food net-exporter countries many smallholders and agricultural workers are net purchasers of food. Extremely poor people will experience decreased calorie consumption. Decreased food consumption in terms of calories, essential nutrients, fat and micronutrients can lead to weight loss, impaired developmental, mental and physical growth in children and micronutrient deficiency in all age groups. IFPRI projects that in 2020, if biofuel production proceeds at its current pace, calorie availability will decrease and child malnutrition will increase, especially in Sub-Saharan Africa.

The 2011 edition of the FAO report on food security in the world (2011) focuses on price volatility, as it has increased a big deal in recent years and has become a matter of concern for governments and people around the world. The report uses previously unavailable data sources and studies to find out what happened on domestic markets and to draw lessons from the world food crisis of 2006-08. The impact of world price changes on household food security and nutrition is highly contest-specific. It depends on the commodity, the national policies that affect price transmission from world to domestic markets, the demographic and production characteristics of different households and a range of other factors. The paper pays special attention to the fact that talking about price volatility is very different from talking about high price levels. In the short-term it is very important to design cost-effective safety nets that deliver the right

targeted assistance to the right people at the right time (these short-term intervention are very important for poor people). High agriculture prices do not harm only consumers but also small farmers since they might have to cope with higher input prices. In the long-term, investment in agriculture is very important to provide sustained access to food for all and reduce vulnerability to price volatility due to natural disasters. Investments mean improved seeds, farm management techniques, irrigation and fertilizers. All things that increase productivity and reduce production risk. Food and economic crises affect especially small import-dependent countries, mainly in Africa. Large countries can isolate themselves from crises through trade policies and functioning safety nets. However, trade insulation, in turn, worsens price volatility on international markets. High and volatile prices are likely to continue: demand from emerging countries will not stop and any further growth in biofuels will place additional demands on the food system. On the supply side, challenges are the increasing scarcity of some resources in some countries and declining rates of yield growth for some commodities. Food price volatility may increase due to stronger linkages between agricultural and energy markets and increased frequency of weather shocks. Price volatility make both smallholder farmers and poor consumers worse off since food represents a large share of their budget. Short episodes of high prices may suck poor people down poverty traps as well as short period of low prices can do the same to smallholder farmers. Short-term price changes might have strong repercussions on development in the long-term (reducing children's consumption and leading to a permanent reduction of their future earning capacity). High prices benefit primarily farmers with access to sufficient land and other resources, while small ones buy more food than they can produce. High food price and, especially, high volatility inhibit investment (especially long-term) in the agricultural sector due to increased risk levels, which, in turn, can increase food insecurity. For this reason, governments, should develop safety-net mechanism, to apply in case of high prices. A successful food-safety strategy should combine policies aimed at increasing agriculture productivity, trade openness (protectionism may increase price volatility due to domestic market turbulences), and must be consistent and predictable in order not to disincentive private investment.

A recent report by the Global Subsidy Initiative (GSI) (2012), an agency of the International Institute for Sustainable Development, examines whether biofuel consumption mandates in the EU and the US play a significant role in increasing global food commodity prices or not. The work acknowledges the fact that biofuels are just one of the many factors able to affect food prices and that it is difficult to isolate their role, however it provides some policy recommendations that could reduce the negative impact increasing biofuel consumption may have on riding commodity prices. Because of high fiscal cost in supporting the biofuels industry, both the EU and the US are phasing out tax preferences and direct subsidies in favor of consumption mandates to ensure market penetration. Biofuel consumption targets are now the main domestic policy to foster biofuel consumption. A number of studies have tried to assess the impact of biofuel policies on agricultural prices. Special focus was paid to the 2006-08 price bubble. Estimates of the

impact of biofuels on commodity prices vary a lot because studies issued by different institutions used different approaches and different underlying assumptions. According to the World Bank (2008, Mitchel), estimates the price increase due to biofuel policies to be around 70-75% of the total increase. Estimates from other bodies are much lower. According to the FAO the biofuels' impact on agricultural prices was estimated to be around 10-15%, according to the IFPRI around 25-30%, and according to the OECD around 5-16%. Nevertheless, even if estimates are very different, it has been acknowledged that expanding biofuel production does, in some way, affect food prices, however evidence is much less clear than in the case of weather-related supply disruptions, and short-term market speculation. Other research focused on estimating the impact EU and US biofuel policies will have on commodity prices in the future, when the respective consumption targets will be reached. Also in this case estimates vary a lot from a study to another. In general, however, the impact is forecasted to be higher for oilseed than cereals, probably because of the substitution effect. Since all these modeling exercises are subjected to many uncertainties, it is very difficult to say to what extent biofuel policies impact on food prices. The GSI study, even if does not quantify the impacts, tries to identify how biofuel consumption mandates impact food commodity markets. Food price volatility could have been exacerbated by the speed at which biofuel production have been increasing in recent years. From 2000 to 2009, production increased 6 times and it is forecasted to keep increasing also in the future. Consumption mandates also contribute eroding food inventories before they could be replenished therefore reducing the elasticity of global food markets to withstand external shocks. The conflict between energy and food markets is worsened by the fact that consumption mandates are rigid policies, while agricultural production is also relatively rigid. Agricultural production is unable to meet short-term increases in demand and, since blending mandates are fixed, demand for biofuels is inelastic in response to price signals related to feedstocks.

The study provides two main policy recommendations. The first one is to reduce the rigidity of biofuel consumption targets to ease competition between energy and agricultural markets. Reducing mandates in response to forecasted supply shortfalls can reduce price volatility. Mandates could be adjusted on the basis of indicators on the health of inventories or food prices during a fixed period. It might be very difficult to establish such a mechanism across countries, moreover the EU and the US biofuel industries might not agree since their manufacturing base would remain idle. It is also important that mandatory reporting mechanism on the use of food crops as feedstocks is put in place. They formally already exists in the EU (Article 17 of the RED, Sustainability Criteria for Biofuels and Bioliquids): cultivation methods for feedstock must meet certain minimum sustainability standards and the Commission must take corrective action if evidence shows that biofuel production has a significant impact on food prices. If this requirement is fully respected, it would formally link feedstock production with food production and prices. Formal reporting on biofuel production and food prices would provide policy-makers with information on at least one factor affecting commodity prices.

### 4.1.4 Literature reviews.

Among the works based on a review of the existing literature, Harrison (2009) focuses on the effects biofuel production has on commodity and retail prices. The general conclusion is that growth in biofuels production since 2004 has contributed to higher corn prices. High corn prices are a consequence of tight global supplies, increased usage for feed (long term), and corn ethanol expansion (short term). Another important factor is that high demand for ethanol is associated with high oil prices. The paper also reports evidence from other studies that indicate that increased corn prices contributed to food price inflation of items that have corn as primary feed: eggs, poultry, pork, beef, and milk. These findings imply that price inflation of some food items is related to increased production of corn ethanol, which in turn is triggered by high oil prices. High oil prices also contribute to food price inflation because they result in higher fuel and energy costs, which increase the marketing cost of all food categories.

Elliot (2008) reviews the literature on biofuel production and agricultural prices and analyzes data on production consumption, and prices. It concludes that it is difficult to know the precise contribution of biofuels in surging food prices but it is possible to affirm that policies promoting first generation biofuels are not increasing energy independence nor reducing GHG emissions. Corn ethanol will not reduce petroleum consumption without changes in automobile technology and without a major increase in the share of food production diverted to fuel. Moreover biofuels are not slowing climate change since new lands must be lowed to grow food. Biofuels made from palm oil, soybeans, rapeseed and corn add GHG emissions relative to petroleum-based fuels when land use changes are taken into account. Sugarcane is much more efficient as a source of ethanol and may have a role to play but attention must be paid to ensure that soybeans and cattle production displaced from sugar-growing areas do not end up with additional clearing of the Amazon forest. The food crisis adds urgency to the need to change biofuel policies but it does not change the basic fact that there is little justification for the current set of policies. If oil prices stay above $60-80/barrel, demand for ethanol will stay high, even without government intervention, so it is needed to introduce conservation measures to reduce energy use and significant investments in agriculture in developing countries.

Kuchler & Linnér (2012) perform a textual analysis by examining documents, reports, and other papers issued by international organizations on biofuels and their influence on food prices. The time span of the analysis ranges from 1990 to 2010. The authors selected documents issued by the FAO, the IEA, and the IPCC, using a keyword search. In the first stage, authors did not discriminate between different forms of bioenergy. The authors found a surprisingly high level of similarity in the way the selected international organizations form and modify the biofuel discourse in relation to agriculture. This is a direct consequence of the fact that such organizations use each other's expertise in elaborating their claims. Moreover the similarity of their arguments may reflect a policy consensus based on the mainstream notion of industrial

agricultural production. The authors argue that this conceptual trend in which policies promoting the expansion and intensification of rural production are seen as highly desirable to ensure the biomass needed to meet ambitious fuel targets. In the 90s all international organizations pointed out that the amalgamation of agricultural and energy markets were a fundamental requirement for their biofuel discourse. Organizations supported their thesis citing the potential macro-economic benefits and pointing out the feasibility of biofuel production. The 2007-08 food crisis completely changed the trajectory of the discursive formation by evidencing the discontinuities within it and directing it towards the argument of a distant future, leaving its unresolved current situation suspended in temporality.

According to Abbott (2009) world agricultural prices will probably remain high and volatile because of demand rising faster than supply, especially because of persistent new biofuel demand. Commodity prices, agricultural and non, are nowadays more linked than in the past. This is due to biofuel expansion, and on bilateral exchange rate adjustments and global macroeconomic outcomes. High food prices hit harder poor people, especially in developing countries. The WB estimates that an additional 105 million people are experiencing extreme poverty due to the food crisis. The IMF highlights the fact that high food prices do also have effects on inflation, deteriorate terms of trade and slow down economic growth. The paper argues that both national governments in developing countries and donor organizations have responded strongly to the food crisis even though in different ways. Donor organizations tried to protect vulnerable people through emergency aid and renewed investment in smallholder agricultural investment. National governments have instead pursued policy measures to protect consumers from high international prices (mainly through trade measures). However, protectionist measures not always were successful, since often there are no domestic alternatives to imported food or useless, in case of a low level of integration between urban/rural markets and international ones. But these actions – all against the advices on open markets that international organizations have been giving for the last 20 years - only contributed to increase instability at international level. International markets failed also because disciplines under the WTO do not restrict countries from taking the protectionist and isolating measures they took.

## 4.2 Biofuels and the environment.

### 4.2.1 Introduction.

Usually biofuels' impact on climate change mitigation are assessed through life cycle analysis (LCA). However, even for a particular feedstock, the results of standard LCAs of biofuels reported in the literature are characterized by a great extent of variability. This variability in the results is caused by varying underlying assumptions on system boundaries, co-product allocation, and energy sources used in the production of agricultural inputs and feedstock conversion to biofuels. Most studies show that biofuel yield emission reductions relative to their fossil fuel counterparts only when emissions from land use changes

(direct and indirect) are not taken into account. LCAs assessment, however, tend to converge in affirming that Brazilian sugarcane ethanol is the one that yields the greatest reductions in GHG emissions. It is true, however, that the use of biofuels in road transport can improve local air quality especially in urban areas. Apart from rapeseed-based biodiesel, biofuels usually generate less primary $PM_{10}$ and volatile organic chemicals (VOCs) than fossil fuels. Moreover biodiesel do not produce sulfur emissions, while ethanol's are substantially lower than those of gasoline. Both biodiesel and ethanol emit less carbon monoxide (CO), which, together with sulfur compounds is the major threat to local air quality (Timilsina & Shrestha, 2011).

Some of the existing literature on the effects of biofuel subsidies on the environment is based on static analysis and most authors have found that biofuel production expansion actually increases GHG emissions (a direct consequence of the Green Paradox[9]): biofuel production processes are not green since they employ many inputs with a high carbon content. Moreover, first-generation biofuels displace land for food and therefore increase food prices (Grafton, Kompas, & Van Long, 2012).

The impact on biodiversity is another controversial matter. Also in this case many are the studies that have tried to measure biofuels' effects on natural ecosystems but also in this case results show a high degree of variability. The effect of biofuel production on biodiversity depends on the type of land utilized. If degraded land is used for biofuel feedstock production the impact should be positive. On the other hand, if peat land is employed, like in the case of oil palm in Indonesia and Malaysia, the effect can be strongly negative. The problem is particularly serious in tropical areas, because they are characterized by a higher level of biodiversity than temperate zones. Also second-generation biofuels can compromise biodiversity since some of the promising feedstock are classified as invasive species, which require proper management to avoid unintended consequences. Many of the enzymes necessary for biofuel production, moreover, have been genetically modified and might require special treatment. Biodiversity, nevertheless, can also be enhanced by biofuel expansion, namely in the case perennial mixed species are introduced to degraded or marginal areas (Timilsina, Mevel, & Shrestha, 2011).

Also the impact of biofuels on water supply is matter of serious concern. Already 70% of world's freshwater is used in agriculture, and all major biofuel feedstocks: sugarcane, corn, and palm oil require plentiful of water at commercial yield levels. This implies an increase in demand for water for irrigation use. In Brazil some irrigated sugar-producing regions in the country's North-East are already approaching the hydrological limits of their river basins. The implementation of ambitious biofuel programs in India and China is likely to be strongly limited by short water supply. Biofuels not only can jeopardize water availability but also create big problems in terms of water pollution because of the increased use of fertilizers and agrochemicals. This is already a documented problem in Brazil since higher crop prices

[9] The Green Paradox means that an environmental policy (like those subsidizing biofuels) acts like an announced expropriation for the owners of fossil fuel resources, inducing them to anticipate resource extraction and hence to accelerate global warming (Sinn, 2012).

encourage farmers to intensify fertilizer use on existing cropland in order to enhance yields (Timilsina, Mevel, & Shrestha, 2011).

The next subsections review the existing literature on biofuels sustainability in terms of GHG emissions, land use changes and the impact of their introduction in developing countries.

### 4.2.2 Biofuel production and greenhouse gas emissions.

Bioenergy can reduce GHG emissions (leaving food consumption by humans unchanged) only if land and plants are managed to grow additional biomass and take up additional $CO_2$ beyond that they would absorb without conversion into bioenergy, or bioenergy uses feedstocks such as crop residues or wastes, that would otherwise decompose and release carbon into the atmosphere anyway. Only biomass grown in excess of that which would have grown anyway or biomass that would have otherwise decomposed can be considered “additional biomass” containing “additional carbon” and has the potential to reduce carbon emissions when used for energy.

The assumption that all biomass is carbon-neutral results from a misapplication of the original guidance provided by the United Nations Framework Convention on Climate Change (UNFCC), under which countries report their emissions from energy use and from land-use change separately: if an hectare of forest is cleared and wood is used to produce energy, the carbon lost from the forest is counted as land-use emission. To ignore double-counting, these rules allow countries to ignore emissions for the combustion of the biomass. This does not mean that biomass is carbon-neutral, but that emissions can be reported in the land-use sector. The system is correct since emissions are reported from both land and energy sectors worldwide.

The accounting rule, under the Kyoto protocol is different since it caps emissions from energy use but it does not apply worldwide and only incompletely to land use. The Protocol excludes biogenic emissions from the energy system meaning that they are almost never accounted for. Also many national policies (and among them the EU ones) and many LCA analyses ignore biogenic emissions from energy use without including changes in land-based carbon as a result of that bioenergy use.

In the last few years, many studies have tried to assess the capacity of biofuels in reducing GHG emissions but results depend on the type of production process and the initial feedstock, also for the same type of biofuel. First-generation biofuel production can be carbon-neutral only by increasing yields (but without increasing the amount of chemical fertilizers nor tillage) or by using waste or crop residues as feedstock or cropping marginal or degraded areas. However, this would not be sufficient without a new computing system of $CO_2$ emissions, new sustainability criteria, energy policies liked agricultural and land management ones at a world scale, and an increase in production efficiency and in recycling. Second-generation biofuels are very promising but all measurements are based on laboratory tests or on pure theory. Even in case current biofuels would be able to reduce GHG emissions, they are still the most

expensive option to reduce GHG emissions and comply with the Kyoto protocol. Buying "emission quotes" in the international market is much more easy for governments. Many countries, the US and the EU *in primis*, should revise their biofuel policies, which, at the moment, are useful only to increase the demand for agricultural commodities and, consequently, of land. New policies should encourage the use of bioenergy obtained from "additional biomass" that is biomass not suitable for neither human consumption nor animal feed. New GHG emission computation technologies should take into account emissions generated from biofuels in all cases in which they are not produced from waste or residues or when it is not possible to demonstrate that they have been produced using additional biomass.

In recent years many researchers have focused on the estimation of GHG emissions due to biofuel production. One of the reasons for which many governments started to subsidize the biofuel sector was that they were thought to be a "green" substitute for fossil fuels. Therefore, burning them into motor engines instead than fossil fuels would have implied a reduction in GHG emissions, responsible for the global warming. Moreover, the fact that, under the Kyoto protocol, biofuels were considered carbon-neutral further incentivized governments to subsidize the sector. Unfortunately only a few studies addressed this topic before governments started their support programs, while the majority of them were carried out only very recently that is well after policy implementation.

The impact of biofuels on global GHG emissions have historically been investigated through Life Cycle Analysis (Birur, Golub, Hertel, & Rose, 2009), which basically is a form of engineering analysis with limited economic content. Some studies based on this approach found that corn-based ethanol and soybean-biodiesel not only yield more energy than their fossil counterparts but also substantially reduce GHG emissions. But if one takes into account also the economic dimension and the effects biofuel production has on land use the picture might change substantially.

Birur at al. (2009) compute GHG emission using an economic model instead than the LCA approach. In particular they use a global computable general equilibrium model, which is an extension of the GTAP-E model. They incorporate three types of biofuels: corn-based ethanol, sugar-based ethanol and vegetable oil-based biodiesel. They also adopt a constant elasticity of transformation (CET) function which allocates land in two steps. In the first one land-owners make optimal allocation of a given parcel of land under crop, pasture or commercial forest, while in the second stage producers decide what to crop on it. They also take into account the fact that biofuel production byproducts – distillers dried grains and oilseed meals – can be used as animal feed in the livestock sector. The model incorporates also GHG emissions data linking them to the combustion of fossil fuels and takes into account the emissions associated with biofuel feedstock, crop conversion to fuel, and direct and indirect land cover conversion. The indirect effect on land use is defined as the repercussions of a region's biofuel activity in another region. These indirect changes (iLUC) have recently increased their importance since their magnitude determines whether a type of biofuel is a net GHG emitter or not.

Beckman et al. (2011) employ a global computable general equilibrium (CGE) model to simulate the regional impacts of biofuel mandates on economic patterns of production, consumption, trade, land use, and GHG emissions on a 30-year time horizon. They found that projected current mandates in the US, EU, Brazil, and several other Latin American and Asia countries will yield relatively small reductions in global emissions in the medium run. This study is broader in scope than LCA studies since it takes into account all categories of market feedback effects and finds that global $CO_2$ emissions are greater than the projected reduction in emissions for the more narrow life-cycle accounting. Also this study, like many others, found that feedstock crop production increases in mandate regions, which translates into pasture and forestland converted into crop production.

Kim at al. (2010) develop a dynamic, regional analysis of the effects of US and European biofuel mandates on land use, forestry stocks and carbon emissions through a general computable equilibrium model and a dynamic optimization model. The former is used to measure the intensity of shifts in land rental functions for different agro-ecosystem zones around the world, while the latter is used to account for the response of forest stocks and forest management to the biofuel policies. The two models use the same set of agro-ecosystem zones and regions so that the economic shifts in land rents impact the correct ecosystem. Results indicate that 23-26 million hectares of forestland would be lost globally in the next 30 years as a result of the US and European biofuel mandates. Such loss corresponds to 1.2-1.6 billion additional tons of present-value $CO_2$ emissions. The largest proportional losses occur in the US and the EU but the largest in physical terms in Central and Southern America, which are also characterized by the largest carbon losses associated with the land-use changes. Surprisingly, some regions, such as South-East Asia experience a growth in forestland.

Thompson et al. (2011) assess the impact of US biofuel policies on US and world petroleum markets, which in turn can have implications in terms of GHG emissions. Under this approach, biofuel policies would have an indirect impact on GHG emissions. This field of study is partially unexplored but potentially very interesting. The authors also point out that LCA to estimate GHG emissions from biofuel production and consumption is subjected to many uncertainties. The paper is centered on the fact that US biofuel rules (and many studies) assume that one additional liter of biofuel displaces one liter of petroleum-based fuel, in energy equivalent terms. It is theoretically possible that the reduction in petroleum-based fuel quantity demanded causes a decrease in prices of these fuels, which in turn triggers a rebound in fossil fuel consumption that offsets the initial one-liter reduction. The exact magnitude of such effect depends on elasticities of demand and supply in petroleum and petroleum fuel markets and on the policy mechanism that caused the initial change. Even though there is no reason to think that such effect is zero, it is assumed to be so by many researchers and policy makers. Thompson et al. represent markets for petroleum products, that is both gasoline and diesel and their byproducts in order to estimate cross-effects between products that are produced jointly from the same barrel of crude oil. The economic model used regards US

biofuels and agricultural markets and US and world petroleum product markets and the main objective of the research to show that the removal of the US tax credits (that took actually place in 2012) and ethanol tariff lead to lower ethanol use and might increase petroleum consumption in the US a reduce it in other parts of the world. Authors' findings show that the effects of US biofuel policies on petroleum products markets are a cause of concern. Discontinuing the tax credits and the ethanol tariff or eliminating the biofuel use mandates can cause a reduction in GHG emissions, but these very surprising results depends on many assumptions. One of these is whether biofuel mandates are binding or not: since if they are, their cost plays a large part in determining outcomes. Another uncertainty is represented by petroleum products supply and demand elasticities. About GHG emissions the authors point out the fact that many studies omitted petroleum products market effects or oversimplify them. However such complexities matter (i.e. the distinction between diesel and gasoline) and can reduce or even reverse the environmental benefits of US biofuel policies.

Haberl et al. (2012) analyze GHG accounting methods related to bioenergy and found fundamental errors and give recommendations for correcting such errors. According to the study, most biofuel policies promoted by governments around the world inaccurately assess the GHG emissions and can have very bad environmental consequences if not corrected. The cornerstone of many biofuel policies is that they consider biomass combustion as "carbon-neutral", regardless of the source of the biomass. In other words, even if they take into account the fact that GHG might be generated by biofuels' production processes, they ignore the fact that they omit the carbon dioxide ($CO_2$) released by the burning of the biomass itself. The replacement of fossil fuels with biomass does not cancel emissions, the combustion of biomass results in its own emissions. Biofuels are considered carbon-neutral because it is assumed that plants, in their growing phase, will absorb the same amount of carbon that is released when the biofuel produced from it is burned. However this generate a baseline error since such approach does not recognize the fact that plants, if not harvested, would continue absorb carbon, therefore reducing its concentration in the atmosphere. This carbon reduction would occur anyway and it is already accounted for in global GHG emission projections: if one considers biomass produced from this carbon as carbon-neutral, results in double counting. The decision to use land for biofuel production results in more carbon stored underground (since less fossil fuels are burned) but this benefit comes at the expenses of the carbon stored in pants and soils (since that land, instead than used for agriculture could be covered by a forest). Therefore bioenergy reduces emissions if and only if the first effect offsets the second.

Also the use of food crops for the production of transportation biofuels is problematic since the crops absorb carbon whether they are used for biofuel production or not. The use of crops can reduce emissions only through a series of indirect market responses. Food crops store carbon for short periods of time since they are consumed by people and livestock. So, if crops are used for bioenergy and are not replaced, there is reduction in carbon emissions because people and animals will consume less food, but

this is not a desirable outcome. If, instead, crops used for bioenergy are replaced by food production elsewhere, then the emission consequences depend on how this is done. It can be done intensifying the cultivation process or by converting more land to crops, but in this case one must take into account the lost carbon storage or sequestration due to changing land-use.

Russo et al. (2012) review the existing literature on the impact of oil-based biofuels on GHG emissions. Most of the studies reviewed are based on LCA. Biomass-based fuels are potentially carbon dioxide-neutral since recycle the same carbon atoms but their environmental impact might not necessarily be positive. The scientific literature is full of studies on the impact of biofuels on emissions, most of them using LCA. Results are very different since they depend on the different inputs taken into consideration and the different boundaries considered for the analysis. Even though biofuels are claimed to be a renewable form of energy and carbon-neutral, GHG savings are often not as substantial as one might expect. Many LCA studies evidence substantial environmental impacts due to biofuel production due to intense crop cultivation. GHG emissions come out along the entire biofuel production chain and there is consensus on the fact that the most critical phase is crop cultivation: it is in this stage shat most of $CO_2$ and $N_2O$ emissions are generated. The GHG emission impact is assessed through the Global Warming Potential (GWP) index. This index was created in the Kyoto protocol to measure the potential of gases or volatile liquids to heat up the atmosphere. In other words the GWP index is used to “translate” the emission levels of various gasses into a common measure, in order to compare them. The index is calculated over a specific time interval, usually 100 or 500 years and is expressed in $CO_2$ equivalents. The final value of the index is calculated from total GHG emissions released all along the chain, multiplied by their respective equivalence factors. Even though the calculation of such index is, in principle, quite straightforward, in practice results from various LCA are very heterogeneous: in some cases it is possible to come to the conclusion that biofuel production actually increases GHG emissions. Russo et al. (2012) acknowledge that, due extreme variation in data, inputs and boundary systems it is not possible to say which LCA study is more reliable.

EU policies that make accounting errors are many. The EU Emissions Trading System (which caps emissions from major factories and power plants) ignores $CO_2$ emissions from biomass combustion but does not apply to land use. The Renewable energy directive (which requires member states to increase their renewable energy consumption to 20% by 2020) explicitly sets $CO_2$ emissions from biomass to zero, regardless to the source of biomass. Also the Fuel Quality Directive (which requires reductions in the carbon intensity of transportation fuels) are characterized by accounting errors. All these directives use LCA analyses that count emissions involved in the growing of crops or in the production of biofuels and those from land use changes only if a bioenergy crop is planted in a previously forest area or other high carbon ecosystem, but they completely ignore actual emissions by vehicles that use biofuels, without any assurance that the biomass used is additional. If bioenergy is supplied by crops growing in existing cropland, the directive assumes that this land would otherwise grow no plants, that the crops it would

generate are not replaced or that the crops are replaced entirely by intensifying planting and harvesting of existing cropland. The analysis proposed by the EU does account the emissions due to converting grassland to cropland for energy crops, for example, but it does not consider the fact that the forage needed to feed livestock would have to be produced elsewhere.

An incisive analysis of the RED, like the one provided by Soimakallio and Koponen (2011), permits to highlight all the defects and imperfections of current biofuel policies and of current method to assess their environmental sustainability. This methodology is based on LCA approach but excludes many critical issues. In particular, the EU methodology does not take into account indirect impacts due to competition for land, biomass, and other inputs. Timing issues, allocation problems, and uncertainty of individual parameters are not considered adequately neither. According to the RED, GHG emissions reductions compared to fossil fuels should be at least 35% for biofuels and other bioliquids produced before 2016. From 2017 onwards the GHG emission reduction should be at least 50% and at least 60% for biofuel production installations where production begins after January 1st 2017. The RED also provides the methodology to calculate the GHG emission balance for biofuels, however it is characterized by several pitfalls.

The RED methodology provides default values for GHG emission reductions (%) compared to fossil reference fuels for a range of biofuels. These values can be used if GHG emissions from land-use changes can be proved to be equal or less than zero. The RED provides also default values for cultivation, fuel processing, and transport and distribution for a range of biofuels expressed as g $CO_2$-eq./MJfuel. These default values can be used only if the raw materials are cultivated outside the European Union, are cultivated in specific areas within the Union, or are a waste or residues from other than agriculture, aquaculture, and fisheries.

The RED defines the relative reduction in GHG emissions achievable by replacing fossil fuel comparator by certain biofuel as:

$$\text{Emission saving} = (E_F - E_B)/E_F$$

**Eq. 1**

Where EB is total emissions from the biofuel or other bioliquid and EF is total emissions from the fossil fuel comparator. The part C of the Annex V of the RED provides the details to compute EB, that is the actual values for the total emissions from the use of biofuels or other bioliquids. This formula takes into account the GHG emissions from the different phases of the biofuel production from cultivation to the collection of raw-material to the use of biofuel. Emissions are expressed in g $CO_2$-eq./MJfuel. The EU also provides member states with guidelines on how to implement such a system. According to the RED methodology, the spatial system boundary includes the biofuel product system from raw material cultivation (crops), harvesting (residues) and collection (waste) to the distribution of biofuel. However it does not include GHG emissions from production machinery, infrastructure, buildings and plants. The

climate impacts are assessed with the Global Warming Potential (GWP) values for 100 years given by the IPCC. The study compares the GHG emission default values provided by the RED with figures from the literature. These figures vary significantly around the default values. In some cases – like for palm oil and soya oil – some very high GHG emission estimates were found in the literature. But also values significantly lower than those provided by the RED. In synthesis, it was not possible to conclude whether the RED estimates are plausible or not.

Regarding the spatial system boundaries, there are significant omissions in the RED methodology. Many recent studies have concluded that increased biofuel production might trigger iLUC and, in turn, increase deforestation and GHG emissions. iLUC are very difficult to identify and quantify or attribute to various economic actions. The EU is currently examining how these iLUC should be considered: member countries are deeply divided on this issue and currently there is no decision on modifying the RED.

The RED encourages the use of "waste and residues" in biofuel production but does not provide any definition of such materials, ignoring the fact that they might have significant indirect effects. Using waste and residues in biofuel production is efficient only when they are generated by other economic activities, when they are not effectively utilized and when they can be gathered and used in a sustainable way. However, avoiding generating such wastes is likely to reduce GHG emissions more than re-utilizing them for biofuel generation.

Another critical aspect is GHG emissions from the use of auxiliary energy, that is the energy needed to produce biofuels (i.e. to power production facilities). A possible solution could be the use of energy sources with low GHG emissions such as hydroelectric power but using such forms of energy for biofuel production would limit their availability for other purposes. The re-utilization of biofuel production byproducts might also contribute significantly in reducing the impact on GHG emissions.

Another oversimplification made by the RED is that GHG emission impacts are considered by a static method, which means that all GHG emission and GHG sinks are assumed to take place at the same time and are equalized during the period under study. However, exuding the dynamics of GHG emissions is not problematic in the case of annual crops because the carbon released with the burning of the fuel is re-absorbed by the plants while growing. Problems arise when one has to evaluate emissions from deforestation, the destruction of peat swamps, or other carbon stock losses due to biofuel production. The RED methodology does consider the impact of direct land-use changes (dLUG) in a 20-year time horizon but does not take into account indirect ones. Other important aspects, neglected by the RED, are the allocation of the environmental impacts to the different products and parameters' uncertainty, which, especially the latter, can significantly undermine the results. An example of such uncertainty is nitrous oxide ($N_2O$) since the use of nitrogen fertilizers depends on site-specific aspects such as crop, soil, and climatic conditions. Uncertainty is involved in the calculation of every parameter involved in GHG emissions calculations.

Furthermore, in the RED methodology the amount of carbon "saved" by replacing the consumption of fossil fuels with biofuels is computed through the difference – in GHG emissions - between the fossil reference fuel and the corresponding biofuel. This methodology is not able to measure the effectiveness of biomass utilization as a measure to reduce GHG emissions. As a consequence, GHG emission savings might look particularly favorable for scarcely efficient biofuel producing processes that use low GHG emission-intensive feedstocks than, even if less efficient than others based on more efficient techniques but that employ a larger amount of fossil fuels in the production process. Therefore, a better way to promote the most efficient production process would be to measure the GHG emission savings in terms of biomass, land, or money spent, instead that the "relative emission reduction" as stated by the RED.

Summarizing the GHG emissions due to biofuel production calculated with the RED methodology depend on case-specific features and on the interpretation of the concepts and definitions given in the RED. There is the serious risk that the RED methodology underestimates GHG emissions related to biofuel production because of subjective setting of system boundary and other methodological choices. The LCA approach, on which the RED methodology is bases, is a an approach full of potential sources of uncertainty and variability input data, scenarios, and models with no "right answer." The approach could be improved taking into account the uncertainty, through statistical methods and/or discussion of social implications.

According to Soimakallio and Koponen (2011) there is the serious risk that the RED methodology promotes biofuel with low reduction or even increase in the overall GHG emissions, and prevents biofuels with higher benefits at the same time.

Taheripour at al. (2010) point out that, even though many papers have tried to assess the environmental consequences of first-generation biofuels (FGB) through general equilibrium models, almost all of them almost ignored the role of biofuel by-products. Examples of by-products are dried distillers grains and oilseed meals that can be employed in the livestock industry as feed. They can, in theory, mitigate the impact of biofuel production and, at the same time, reduce the demand for cropland and moderate the indirect land use consequences of FGB. The paper explicitly introduces such by-products into a global computational general equilibrium model and show how such a model yields substantially different results from those of a model that does not take by-products into account. The temporal horizon of the analysis is 2015. Both models show significant changes in agricultural production across the world but the model with by-products shows smaller changes in the production of cereals and larger ones in the production of oilseed both in the US and the EU, and the reverse for Brazil. The model that omits by-products overstates cropland conversion from US and EU mandates by 27%.

A deep review of current policies is of paramount importance. They should be revised to encourage bioenergy use only from additional biomass and reduces GHG emissions, without displacing food or fiber production. Accounting standards should take into account GHG emissions from biomass combustion and should count, as an offset, additional plant growth or reduced decomposition. Policies should also

encourage energy production from biomass by-products, wastes, and residues (except if these are needed to maintain soil fertility). Biomass for energy production should add to food production and not displace it. Finally, policy-makers should adjust global expectations of bioenergy on the planet's capacity to generate additional biomass, without jeopardizing ecosystems.

### 4.2.3 Biofuel production and land use changes.

Another relevant topic related to biofuel production is land use changes (LUC) that is land use changes generated by increased biofuel production. Land use changes occur when there is a change in the way agricultural land or forests are used or if land is used for other purposes such as roads or real estate. In either case LUC lead to a decrease in the carbon contained in the soil and/or in the vegetation. LUC can be either direct (dLUC) or indirect (iLUC). Direct LUC arise when, for example, forest land is converted into crop land like it happens in some tropical countries. Indirect LUC, conversely, arise when, for example, energy crops are planted on land previously used for food production and elsewhere land is converted to cropland to replace the previous production that has been displaced (Lahl, 2010). An example of iLUC is what has been happening in Brazil, where sugar cane plantations have been expanding at the expenses of the *cerrado*, the tropical savanna (used as grazing land by the extensive cattle farms), which in turn expands at the expenses of the tropical forest. The decrease in forest area is an indirect land use change.

Some argue that negative effects on food prices and LUC could be limited with the introduction of second generation biofuels produced from crop residues or from plants that can be grown on marginal land. Governments have understood this and have started subsidizing the sector. The US invested 1 billion dollar for research in the second generation biofuel sector, Canada 430 million, and Australia 12 million. The US Renewable Fuels Standard mandates the consumption of at least 60 billion liter of cellulosic ethanol by 2022 and observance of sustainability criteria. However, second generation biofuel still have to fully demonstrate their competitiveness with respect to conventional biofuels and fossil fuels. The sector is still not well developed and it is destined to remain small in the medium term. Furthermore, it is not to be taken for granted that second- or third-generation biofuels are more sustainable than conventional ones: in some cases they can still be in competition, in terms of land and water requirements with food crops.

Direct land use changes are already taken into account by existing certification systems adopted by, for example, the RE Directive of the European Union. However, iLUC are much more difficult to estimate. The methods generally used in the literature can be grouped in two broad categories: complex econometric models and simplified deterministic approaches (Lahl, 2010). Econometric models are useful to assess the impact of a change in the demand for agricultural raw materials (like that triggered by biofuel expansion) affects prices and agricultural land. Most of the studies (of which a review is provided later) conclude that, when iLUC are accounted for, biofuel production does not reduce GHG emissions but, instead, increase them.

Carriquiry et al. (2010) assessed the impact on world markets of a high biofuel use in the European Union. They focused on land-use impacts. They used the CARD partial equilibrium model to test two scenarios to be compared to the baseline. In the first a high wheat ethanol use is simulated, while in the second a high rapeseed oil biodiesel use. According to the simulations of the first scenario, an increase of 1 million tons oil equivalent of wheat ethanol in Europe would expand world land area used in agricultural commodity production by more than 360,000 hectares, 0.039% of total area. In the second scenario the same 1 million tons oil equivalent increase, this time in rapeseed oil biodiesel, would lead to an expansion of world cropped area by 352,000 hectares, more or less the same of the first scenario. The main difference between the two scenarios is the spatial distribution of the area increases. Because the wheat sector in Europe is large, when wheat use for ethanol production expand (1$^{st}$ scenario) most of the adjustment is met within the EU, in fact EU's net exports reduction is just 9%. In the second scenario, since the rapeseed sector is much smaller, the increase in biofuel production is supplied by imported rapeseed (or biodiesel), with most of the area adjustments taking place outside the EU.

Timilsina and Shrestha (2011) point out that, by 2030, in order to meet the additional demand for food (without taking biofuels into account) at least 500 million hectares of new land will need to be put under cultivation from current levels and assuming that yields will continue increasing at the same rate they have been doing so far. A large number of studies tried to assess the impact of biofuel expansion on land use. Nevertheless, results vary considerably due to difference in methodological approach, different assumptions about crops used and conversion coefficients from biomass to biofuels.

A paper assessing the impact of biofuel policies on forest carbon using a general equilibrium approach is the one by Kim et al. (2010). The authors develop a dynamic, regional analysis of the effects of US and EU biofuel mandates on land use, forestry stocks, and carbon emissions. The results show that biofuel policies may cause an additional 23-26 million hectares of forestland losses globally and additional carbon emissions of 1.2 – 1.6 billion t CO2. However estimates are sensitive to the elasticity parameters of the land supply function of the model: the higher the elasticity, the higher the losses. It is important to highlight the fact that, while world global emission increase, some regions end up gaining forestlands, therefore increasing their carbon stocks.

Taheripour et al. (2008) modified the GTAP model to assess the impact of increased biofuel production (and consumption) on land use taking biofuel production by-products into account. They argue that many studies have undervalued the impact of liquid biofuels on agricultural markets because have ignored the role of by-products resulting from biofuel production. Both distilled dried grains (from corn-based ethanol production) and soy and rapeseed meals (from biodiesel production) can be used for animal feed. Their presence therefore mitigate the effect of biofuel production on the livestock sector. In the paper, the authors includes both types of by-products into a CGE model and analyze the economic and environmental impacts of regional and international biofuel policies. The model includes 22 commodities,

20 industries, and 18 regions. The policies under scrutiny were the US Energy Independence and Security Act (2007) and the EU mandates for promoting biofuel production. They run the model both taking by-products into account and not. The simulation horizon is 2015. In both models biofuel policies cause significant changes in agricultural production worldwide, however the model with by-products shows smaller changes in the production of cereal grains and larger changes for oilseed products in the US and EU, the reverse for Brazil. Moreover, taking by-products into account, results in a smaller price changes due to mandate policies. It is therefore crucial to include by-products into the analysis, otherwise land use changes can be misleading. The fact that biofuel production results in land use changes cannot be disputed even though allocation to the various agricultural sectors is not easy.

Havlík et al. (2011) employ an economic partial equilibrium model (GLOBIOM) to assess the effects of expanding biofuel area in terms of iLUC, deforestation, irrigation water use, and crop price increase. The model represent global forest, agriculture and biomass sectors. Results indicate that first-generation biofuels generate GHG emissions due to iLUC that only after 25 years will be paid back by GHG savings from the substitution of biofuels for conventional fuels. Conversely second-generation biofuels (fed by wood from sustainably managed existing forests) would lead to a negative iLUC factor, meaning that overall GHG emissions are 27% lower compared to the no-biofuel scenario by 2030. Second-generation biofuels perform better also with respect to other investigation criteria provided they do not compete directly for land with the food sector. Nevertheless, second-generation biofuel perform worse than first-generation in all aspects except GHG emissions (deforested area, irrigation water use, commodity prices) if they are produced from dedicated short rotation plantations on current agriculture land. Therefore second generation biofuels should be produced from wood from sustainably managed forests or from feedstock cultivated on marginal or abandoned land, provided other sustainability criteria are satisfied (biodiversity conservation, soil erosion, *etc.*). Biofuel expansion creates a complex system of positive as well as negative externalities: the objective of reducing GHG emissions will not be reached through a general biofuel mandate since general biofuel mandate because it is accompanied by bioenergy costs twice as high as the second outcome (carbon debt), and thus would be avoided by the industry. To achieve the environmentally positive outcome, forest ecosystem services would have to be explicitly targeted. Similarly, a biofuel-induced food price increase will not provide any benefit to the poorest populations without appropriate public action. Therefore the authors recommend policy-makers not to focus on biofuel production only but also on the positive and negative environmental and social effects generated by biofuel production. However, results have certain limitations, due to uncertainties of input datasets, limited availability of economic data at the global scale and the low level of detail of the representation of the livestock sector.

Villoria and Hertel (2011) warn about the possible misleading results that global or partial equilibrium models can lead to if the international trade specification assumed in the model is not correct. They investigate the relationships between international trade and the global distribution of coarse grain

production responses to market developments in the United States. Their null hypothesis is that world markets are fully integrated, rendering the geographic persistence of bilateral trade flows irrelevant in the global production response to a change in US prices. The alternative is that price transmission vary along with the intensity of competition among countries in specific markets. They reject the null (using data from 1975 to 2002) and the results have direct implications for the analysis of the global land use impacts of biofuel mandates. The analysis of iLUC due to biofuel expansion has been tested by many works in the literature almost always through large-scale economic models that have resulted in very different predictions of iLUC. One of the reasons at the basis of such discrepancy in results amongst different studies is due to differences in the treatment of the interaction between bilateral trade and supply behavior. The article investigates, using a reduced form land demand equation (focusing in changes in the areas of coarse grains triggered by changes in the US price of these products), which of the two competing views of global agriculture trade – IWM and product differentiation by place of origin (Armington model) – has a better grounding in the historical data. They reject the IWM in favor of the Armington assumption. This has important consequences for the global distribution of land area response following a shock to the US coarse grain price. Allowing competition in third markets leads to strong differences in the predictions of area changes, especially for the largest producers in the world. The total estimates of the two models are quite different in terms of production, land conversion and GHG emissions due to differences in productivity and emission factors across countries. International trade specification used for global carbon life-cycle analyses of policies with global production effects has a critical effects in the size of GHG emission estimates. Results therefore support the notion that the geography of trade is an important factor in explaining the global distribution of agricultural production and global GHG emissions responses to national biofuel programs.

Another study that employs macroeconomic computable equilibrium models is that by Hellmann and Verburg (2010). They combine the GTAP model with an integrated assessment model (IMAGE) to assess the potential impact of the EU biofuel directive on European land use and biodiversity. They analyze four scenarios of land use change for the period 2000-2030 and for each scenario two policy variants are considered: with or without the implementation of the biofuel directive. The results show that there area of semi-natural vegetation, forest and high nature value farmland replaced directly by biofuel crops is small in all scenarios and varies little with or without policy implementation since biofuel crops would be cultivated in areas already interested by agricultural activity. Therefore biodiversity, in the EU, is only marginally affected by dLUC due to biofuel expansion. However, indirect effects are much larger. The area semi-natural vegetation is forecasted to decrease by 3 to 8% (depending on the scenario) with the directive compared to scenarios without the directive. Little difference is found between scenarios in the case of forest area. The semi natural areas will be replaced by grassland or arable land to compensate for the displacement of such areas caused by biofuel crop expansion in the most productive agricultural areas.

Since semi-natural areas are likely to be characterized by the presence of high-value ecosystems, a considerable loss in biodiversity might result as a consequence. The study does not consider, however, the impact of biofuel expansion on agricultural prices (which can further increase agriculture intensity) and iLUC in countries outside the EU. Therefore indirect effects on biodiversity are much larger than direct ones and must be take explicitly into account when assessing the environmental effects of biofuel crop cultivation and in biofuel policy planning.

A general equilibrium model has been used also by Elobeid, Carriquiry and Fabiosa (2011) to assess the impact of biofuel expansion and policies on both Brazilian and world agriculture. The Brazilian model is part of the FAPRI agricultural modeling system, a multimarket, multi-commodity international agricultural model. The authors evaluate two scenarios. In the first one they simulate the introduction of an exogenous increase in the global demand for ethanol, while in the second they simulate a 50% increase. The authors analyze the impact of such increases in terms of land-use changes and commodity price changes, with special focus on Brazil. Assuming that abundant additional land can be incorporated into production the authors find that the expansion of sugarcane plantations (sugar cane being the main feedstock for Brazilian ethanol) occurs mainly in Brazil's Southeast region and that total sugar cane area increase, in Brazil, is higher than the increase in overall area used for agriculture. This means that sugar cane expansion takes place at the expenses of other crops or pastures that are, then, displaced elsewhere even if not completely, meaning also an intensification in land use. If a lower level of land expansion elasticity is assumed, then expansion of agricultural activities is smaller and a higher proportion of the expansion in sugarcane area takes place at the expenses of pasture land, implying an intensification of beef production. In these two cases prices change only little. Doubling the demand for ethanol does not change the results, which indicates that the limit for intensification is beyond the 50% expansion assumed in the second scenario.

Andrade de Sa et al. (2010) investigate the direct and indirect impacts of ethanol production on land use, deforestation, and food production with a partial equilibrium model of a national economy with two sectors and two regions, one of which includes a residual forest. The paper shows how an exogenous increase in the ethanol price affects input allocation (land and labor) between sectors (energy crop and food) and identifies three potential effects. The first one is the well-documented effect of direct land competition between rival uses that increases deforestation and decreases food production. The second one is the indirect displacement of food production across regions, caused by a shift in the price of food, which in turn increases deforestation and reduces the total output of the food sector. The third effect is the labor mobility between sectors and regions, which tends to decrease both food production and deforestation. The authors conclude saying that the impact of ethanol production on forest conversion is ambiguous, providing a number of interesting pointers to further research. The main ambiguities refer to the price elasticity of the food sector, which might vary from country to country, the size of the displacement effect, and the total land available for food and energy crops. Growth of the biofuel sector

can also lead to water shortages and contamination. Sugarcane and corn are particularly water-intensive. Water scarcity in developing countries may negatively affect agricultural productivity, health and sanitation. Appropriate policies can make bioenergy development more pro-poor and environmentally sustainable: poor farmers could be incentivized in cultivating energy crops on marginal or degraded land. Further investment is needed in developing technologies to convert cellulose into energy, therefore creating a market for crop residues. Poor people could be better off also through the organization of groups of smallholders through contract farming schemes to grow biomass, with special arrangements for women. Furthermore, similarly to what already happened in the fair trade framework, codes of conduct should be developed to constraint excessive exuberance on cultivating biofuels or to ensure that cultivation occurs in a sustainable manner. The Roundtable on Sustainable Biofuels has already developed a third-party certification system for biofuels sustainability standards, encompassing environmental, social, and economic principles and criteria for which biofuel producers can apply.

Kauffman and Hayes (2011) tackle the problem from another angle by building a model to solve the optimization problem of a social planner who has to minimize the environmental cost of biofuel production while maximizing the value associated with the production, given a land constraint. The model was structured in a way to encompass the opportunity costs associated with selection among competing alternative biofuel pathways. The structure of the model requires GHG emissions to be measured on a per acre basis, rather than on a per gallon base like in most life cycle analyses. Data and parameters are from the Environmental Protection Agency (EPA) life cycle analysis for corn ethanol and cellulosic ethanol (from corn stover and switchgrass). Per acre measurement of GHG was calculated for corn, using both grain and stover, and for switchgrass. Results show that at reasonable Midwest US corn and switchgrass yields, there is no price at which switchgrass is optimal since corn yields more energy per acre and has a better carbon profile per acre. The interesting fact is that conventional life cycle analyses would predict switchgrass to have a better carbon profile than ethanol since they do not take into account differing energy yields per acre once a land constraint is imposed. Therefore one should be cautions in saying that switchgrass is an environmentally superior choice relative to corn since there is a trade-off between GHG emissions and energy production and the presence of a land constraint makes this trade-off less obvious than what is often implied by conventional life cycle analyses.

Many scientists have pointed out that using non-crop marginal land to cultivate cellulosic feedstock for liquid biofuels could potentially reduce many of the side-effects of expanded biofuel from cropland. Furthermore, perennial cellulosic biomass crop need less fertilizer and pesticides than conventional crops and would therefore help in reducing water pollution and GHG emissions. Swinton et al. (2011) try to assess (through a theoretical model) whether the US have enough non-crop marginal land to meet the growing need for liquid biofuel (136 billion liters by 2022, including 57 billion liters from cellulosic ethanol). Other studies have already analyzed this issue but very often the analysis was limited to biophysical

characteristics of marginal land: a necessary but not sufficient condition since farmers also have to choose to convert their land to produce bioenergy crops. The article looks back at how much cropland became available after a recent leap in crop prices to try to estimate the willingness of US farmers to grow dedicated cellulosic bioenergy crops on marginal land. If the 57 billion liter target of cellulosic ethanol consumption set by the Energy Independence and Security Act (EISA) is to be met, at least 21 million hectares of marginal land would be needed for feedstock cultivation (estimate based on mature switchgrass yields from marginal land). Farmers' choice of whether to put land into cultivation of a specific crop depends on the land's productive potential and location, the price of the inputs and of the products, and the landowners' earnings from other land uses and his/her appreciation of the land in non-crop uses. The main finding is that owners of non-crop land show reluctance to convert their land to crop production, therefore the potential for current non-crop lands to produced increased biomass for energy is limited. After the strong increase in agricultural prices of 2007-08, farmers' expected profitability grew by a large extent, which corresponded to an increase in crop planting in subsequent years. The standard economic measure of such changes is represented by the elasticity of planted area with respect to expected returns. Despite the 64% increase in profitability that took place in 2007-08, US crop planted area increased only 2%. Therefore a doubling in profitability increases crop area by only 3.2%. Despite the apparent presence of land classified as "idle", farmers appear to be reluctant in putting it under cultivation in the near term. This will happen, given such a low elasticity, only if biomass prices increase substantially. A doubling in biomass profitability, with an elasticity of 0.032, would elicit only 3-4 million hectares of cropland, less than one-fourth of total land required for producing the 57 billion liters of cellulosic ethanol mandated by law. It is true that biomass supply response to increased profitability might and are likely to be different than those of major crops but large increases in biomass production would have to come from new plantings of dedicated biomass crops, which lack familiar markets and proven production technologies. This means that strong initial investments are required and farmers might be very reluctant in investing large amounts of money in something characterized by a high level of profitability uncertainty. Moreover increased biomass production will compete with food production for land and will therefore influence food prices, triggering, in turn, an increase in demand for land for food production. The fact that owners of non-crop land show reluctance to convert their land to crop production means limited potential for current non-crop land to produce increased biomass for energy. In other world biophysical measures of marginal land available for dedicated biomass production can overestimate the supply of cropland truly available since landowners can have other plans.

Lahl (2010) shows that models that consider iLUC changes as a global effect and define global factors to combat iLUC are not sufficiently sound and produce highly varying results. The study argue that a regional approach should be used instead, in which the goal is to quantify the GHG emissions of biofuels brought about by iLUC in a specific region. A regional approach is more flexible than a global one and allows

the inclusion of particular factors, specific to the region itself. The study argue that iLUC are mainly caused regionally and that most of the trade in biofuels and feedstocks takes place regionally. Nevertheless it will be always possible to completely capture global emissions caused by iLUC by adding together the regional totals. The study concludes that the biofuel sector currently causes only a relatively small part of the entire iLUC effect and therefore iLUC are not suitable for legal solutions. iLUC are caused not only by biofuel expansion but also by increasing demand for food, especially meat. At regional level, more specifically EU level, iLUC effects can be minimized by expanding the biofuel regulations from the RE directive to other agricultural sectors or through the binding introduction of land use planning and protection strategies in the key agricultural countries. Bilateral agreements between the EU and important agricultural countries like Brazil, Indonesia, Malaysia and Argentina would be desirable to limit the iLUC in third countries.

Recently, results obtained from partial and general equilibrium models have been questioned since different models produced different results when applied to the same questions. In the US, the Environment Protection Agency (EPA) tried to choose a model for regulatory purposes but experts' answers were that there is not a "right" model since they often start from different assumptions. Big econometric models are often very complex and little transparent but still they are not complex enough to incorporate all dependent factors sufficiently. Moreover the degree of subjectivity in choosing elasticities and in model calibration is still very high and can change substantially the results.

Börjesson and Tufvesson (2011) analyze biofuel production from agricultural crops in Northern Europe and its impacts on agriculture area, energy efficiency, GHG emissions and eutrophication following a life cycle approach. They find that dLUC have a significant impact on GHG balances and eutrophication for all biofuels and that the choice of taking by-products into account significantly affects the results. The study clearly shows the importance of including dLUC in the life cycle analyses of biofuels. Depending on whether traditional crop land or unfertilized grassland is used for biofuel production, the GHG balance might vary by a factor of two and the contribution in terms of increase in eutrophication may be even larger. This is due to changes in the biogenic emission of $CO_2$ and $N_2O$ from the soils and leakage of nitrate to water. If peat soils are used (like it happens in South-East Asia), biogenic emissions can increase 10-20 times. The GHG balance can be significantly improved by treating production by-products appropriately. Second generation biofuels (such as those from lignocellulosic crops) have many advantages in the form of energy efficiency, lower GHG emissions and low contribution to eutrophication potential. Also the design of individual production systems can affect substantially energy and environmental performance of biofuels. One of the most important factors is whether renewable of fossil fuels are used in the conversion process of agricultural crops into biogas or ethanol, the magnitude of methane emissions form biogas plants and the efficiency of the extraction process. The authors conclude stating that the analysis of biofuel production should be done taking into account the specific local and/or regional conditions since every production system is unique in some way. They also point out, like many other studies in the literature, that there is no

”right” or “wrong” calculation method for the life cycle analysis of biofuels since different methods can be relevant under specific conditions. Nevertheless it is important to identify crucial parameters which have the greatest impact on the energy and environmental performances of biofuels. Furthermore iLUC must be recognized in conjunction with biofuel expansion even though it is very difficult and sometimes impossible to include them in life cycle assessments (scientific, methodological, practical). For this reason certification systems are not enough and they must be complemented by national land use plans and international agreements.

It has been estimated that the European Union, in order to meet its consumption targets will need 18.5 to 21.1 million hectares (Misra & Murthy, 2011). Since competition for land, in the future, is destined to grow, due to increased demand, it is of key importance to analyze all possible consequences of a major shift in land use. An approach usually followed to assess the impact of biofuel production on land use is that of water and land footprints. The water required for harvesting a unit of feedstock crop (CWR) is calculated as the rate between the seasonal water evapotranspiration (cubic meters/ha) and the crop yield (Kg/ha). Then, this values is multiplied with the biofuel density and the amount of feedstock necessary to yield a Kg of biofuel. In this way one obtains the water footprint of a certain biofuel. The land footprint is calculated as the rate between biofuel density times feedstock conversion ratio and the crop yield (Crookes, 2006). The highest water and land footprints is due, in the case of biodiesel, to soybean feedstock, followed by rapeseed. One ,must also bear in mind that biofuels need major water footprints than fossil fuels because fertilizers and other agrochemical products can pollute water bodies.

Harvey and Pilgrim (2011) addresses the new competition for land arising from growing and changing demand for food in a framework characterized by an increased demand for energy, especially in the transport sector, under condition of declining fossil energy reserves and the urgent need to reduce GHG emissions. The paper reviews all the main drivers of demand for food and of liquid transport fuels and weights the controversies surrounding biofuels arising from food price spikes, the demand for land, and the consequent dLUC and iLUC. The paper then reviews evidence of land availability and finds that competition for land significantly increased in the US, Brazil, and the EU, that is the major biofuel producing countries. According to the results of the reviews carried out by the authors, competition for land, in recent years, was driven by two major objectives: the need of increasing food production and the need of developing a post-fossil carbon economy. The authors find that agricultural production cannot continue on current lines and practices without incurring in the risk of major crisis, given the strong impact that agricultural activity has on GHG emissions. A key element in the future will be to develop low-carbon emitting agricultural techniques able to sustain agricultural intensification. Furthermore, biofuel policies will have to be developed in a more pro-active, long-term, strategic way, focused on innovation since current technologies are not adequate to meet the biofuel consumption targets. This implies a paradigm change from the petro-chemical technological model of the world that has characterized the previous epoch. A shift to a

bioeconomy and sustainable agriculture will be needed. Land, water and climate as a global resource provides different regions with widely contrasted agricultural potentials. The shift to sustainable agriculture for food and energy is likely to re-shape the geopolitical environment of the world. Flows of food and energy/materials will be re-drawn, and different regions will pursue different innovation pathways as a consequence of their diverse political objectives and natural endowments. Competition for land can be reduced only if all contributing factors, energy and food demand, petro-chemical depletion and the various sources of anthropogenic climate change involved in land use, are treated all together. Moreover policies will have to be re-shaped, promoting long-term investments in science and innovation since without them it will not be possible to deliver the goals of sustainability.

## 4.3 Biofuel production and its consequences in developing countries.

In industrialized countries the main reason behind the implementation of biofuel policies was the need to reduce GHG emissions, while in middle-income and developing countries the main rationale was to improve energy security, promote exports and foster rural development. Nevertheless, many stakeholders (environment NGOs, indigenous peoples' groups and development organizations) have pointed out the negative environmental and social impacts of biofuel production, especially in developing countries. Feedstock production, like any other agricultural intensive activity, has big environmental problems: high use of water, pollution due to agrochemicals use, soil erosion and biodiversity loss. In Asia and Latin America the strong increase in oil palm and soybean area due to biofuel expansion is considered one of the major deforestation drivers in recent years. Moreover, as analyzed in previous sections, there are many studies that question the climate change mitigation benefits biofuels are supposed to yield (Dufey & Grieg-Gran, 2010).

The social impact of biofuel is even more controversial. It has been argued that biofuel expansion has been one of the drivers of the strong increase in food prices that took place in the last decade even though the magnitude of the impact is a matter of dispute. Several studies tried to estimate the impact of biofuel production on food prices and estimates vary from 3 to 75%. It is difficult to say what are the "good" and the "bad" estimates since results often depend on initial assumptions, however, a median range of 30-40% in the case of corn (main ethanol feedstock in the US) can be taken for granted (Dufey & Grieg-Gran, 2010). The economic sustainability of biofuels has also been questioned since biofuel policies are costly and hard to defend in a period of economic crisis in many developed countries. Even though biofuel policies are regarded as "risky" for middle and low income countries it might also represent an opportunity provided that biofuel production helps in reducing poverty without having negative effects on biodiversity. Most depends on the type of feedstock used, the context and the policy framework that producing and consuming countries put in place.

Tirado et al. (2010) analyze the three major challenges that threaten current and future efforts to overcome food insecurity and malnutrition. They are: climate change, the growing use of food crops for biofuel production and the economic crisis. The recommendations of this paper follow the human rights-based approach applied to address ethical issues on agriculture and sustainability. It is a conceptual framework normatively based on human rights standards. Biofuel production can have negative impacts on nutrition through increased GHG emissions that may result from burning forests to clear land for crop cultivation. Biofuel production can also have direct effects on health and sanitation, food availability and associated price effects. The main problem is the diversion of food and feed crops from food production since returns to biofuel production are usually greater. Such practices reduce food availability and may consign food and feed production to less productive land.

The book edited by Dufey and Grieg-Gran (2010) collects case studies in several developing countries in which potential and pitfalls in biofuel expansion have been assessed. Case studies refer to Pakistan, Costa Rica, South Africa and Ecuador, all countries characterized by a big biofuel potential but by a very low current biofuel production. In all cases biofuel development can represent a win-win situation since it would allow to meet many policy goals: economic, environmental and even social. In order to meet these goals, however, production must take place in suitable land and without competing with food production. The situation is however different from country to country. In Costa Rica and Pakistan, for example, the main driver of biofuel expansion was exports to the US and the EU, since these two countries could benefit from preferential market access. However, currently it is import fossil fuel substitution the main driver of biofuel expansion. Three of the countries studies have in place pilot project to try out mixing biofuels with oil-based petro land diesel and all four have set objectives for biofuel concentration in gasoline and diesel, such as it happens in Brazil and the US. Even though all countries examined are oil producers they are all net importers of fossil fuels. It is important for these countries to reduce their dependence on fossil fuel imports since they would increase their energy security and reduce the risk of depending highly on a very distorted and volatile market such as that for crude oil. In the case of South Africa it has been estimated that meeting a target of a blend 8% of bioethanol in gasoline and a 2% blend in biodiesel would reduce the current account deficit by US$0.5 billion per year.

Nevertheless, volatility in oil markets can have repercussions on the development of the biofuel market in developing countries. Crude oil prices affect biofuel prices (see section 6.1) and the cost of biofuel production through their impact on fertilizer and agrochemical prices. Ecuador is characterized by an ideal environment for oil palm cultivation but the private sector has shown very little interest in investing there because of the unpredictability of returns. Most developing countries have in place policies in favor of oil-derived energy, which represent a further competition challenge for domestic biofuel use. National policies should be developed in a way to allow biofuels to compete. The four countries under

study did little in this direction. Some countries, such as Pakistan where industrial alcohol is taxed and no subsidies are given to ethanol, are in fact hampering biofuel development.

Developing countries also have little experience with export of biofuels, since in the past they relied too much on trade preference agreements. Pakistan was a large exporter of industrial alcohol to the EU until it was removed from the General System of Preferences. Costa Rica's exports have been driven by US preferences under the Caribbean Basin Initiative but this did not stimulate domestic production but, rather, the import of alcohol from the EU for further processing.

In the four countries studied smallholders play an important role in the production of biofuel feedstocks. This means that the right biofuel policies could bring benefits to small farmers. Biofuel expansion can also increase employment even though estimated new jobs from biofuel expansion are exaggerate. Other positive impacts are environmental. Urban air quality can improve thanks to the diffusion of biofuels in the fuel mix even. Also GHG emission reduction are possible provided emissions in the feedstock cultivation and processing are controlled.

Nevertheless, biofuel expansion, if not managed in a correct way, can also have negative impacts, especially regarding the environment and food security. Costa Rica will need, for example, to expand its production area by 26.5% to meet a 10% blending target. The key problem, like in the rest of the world, is where such expansion will take place. It is difficult to define which kind of land is "suitable" for biofuel feedstock cultivation, moreover, even if most developing countries have laws that protect biodiversity-rich areas such as the rain forest, enforcement is weak. Finally, impacts on food security might be also negative but the problem is that such effects are difficult to predict and often are country-specific.

Even though enthusiasm towards biofuel has been declining in the last few years, demand in rich countries is likely to increase and this can represent a good opportunity or a formidable threat for developing countries where the feedstock or part of the biofuel needed to meet consumption targets in the US or the EU can be produced. However, the unfavorable treatment of biofuels within the WTO and the prevalence of policies favoring domestic production in rich countries are likely to impede middle and low income countries to capitalize their comparative advantage in producing biofuels.

Investing in biofuels in developing countries is a very risky business. First benefits are likely to be captured by big foreign companies that might be interested in investing in such countries to produce biofuels both for the domestic and the foreign markets. Moreover, the effects in terms of direct and indirect LUC are likely to be strong and irreversible. Already in developed countries, were legislation is much more advanced and the public opinion much more aware of the risks of biofuel production, it is highly questionable to affirm that biofuels have been effective in reducing dependence on fossil fuels and to reduce GHG emissions. There is no evidence in favor that in developing countries the situation would be different. Developing countries, like it is already happening in the case of many other agricultural

commodities, risk to become a place of production for goods (in this case biofuels) destined to other countries characterized by low labor cost and weak law enforcement.

Hall at al. (2009) use a case study methodology drawing on original qualitative and technical data to assess the effect, in developing countries, of the adoption of large-scale mechanized farming practices to increase economic efficiency. This could exclude small-scale farmers from participating in the emerging biofuel market, therefore exacerbating poverty and social exclusion. The paper discusses the development of the Brazilian agricultural policy, which has emerged as one of the most efficient producers in the global marketplace. Brazil has comparative advantages such as extensive arable land and long growing seasons, coupled with technological innovation, government policy, industry participation and high international demand. However, success in agriculture resulted also in the dislocation of subsistence farmers and a widening gap between the rich and the poor, increasing violent crime and social exclusion since most of the development took place thanks to the adoption of large-scale farming practices. The Brazilian soybean and sugar cane sectors have been expanding greatly in recent years also thanks to biofuel expansion. Policies in favor of ethanol consisted in subsidies to industry and large-scale agriculture with no guarantees on the pay level of working conditions. A big consequence was the loss of biodiversity at large scale because of chemical-intensive mono-crop production. The key stakeholders involved were government, military groups, the alcohol industry, sugarcane agricultural “aristocracy”, Ministry bureaucrats and researchers. In this framework the losers were subsistence farmers, which capture none of the benefits yielded by Brazil becoming a major ethanol producer and agriculture super-power. The Brazilian government is trying, at least to a certain extent, to avoid making the same mistakes in the case of biodiesel, which is produced from soybeans (produced in big and heavily mechanized farms in the South of the country) in the Latin America country. Current biodiesel policies are targeted towards the industry but also to small-scale farmers and are designed in a way to favor both large scale and small scale producers. In particular the government implemented tax benefits and special credit to industries that encouraged producer participation from the poor northern regions. In order to receive the Social fuel stamp biodiesel industries must purchase part of their feedstock from small farmers, sign agreements with them and provide them with technical assistance. In this way biodiesel producers can obtain tax exemptions that vary on the basis of the feedstock and the region. To receive the highest tax exemption the industry must purchase castor or palm oil produced by small farmers in the North or Northeast semiarid regions. Sometimes the implementation of the social stamp scheme was not easy and many operators, also belonging to big refining companies, say that the project will not work and that also biodiesel will end up like ethanol moreover foreign countries, such as the EU, are not interested in the social sustainability of biofuel production processes but only in the environmental one. This create problems in international markets, especially in perspective since it is possible that Brazil will become a major biodiesel producer in the future and the EU might start importing large quantities of biodiesel from it to meet its consumption targets. If the

EU does not require imported biofuels to be produced respecting not only environmental criteria but also social ones, there will be little incentive for big companies to respect small farmers and therefore will cancel government efforts to protect small-holder producers.

The Brazilian sugarcane/ethanol sector has not only be criticized because of the strong subsidies provided to big farms and refining companies but also because of the poor working conditions in sugarcane plantations. McGrath (2012) analyzes slave labor among sugarcane workers in Brazil in a framework characterized by a globalizing production network (GPN). The paper rely on qualitative data, principally semi-structured interviews and archival material. The paper refers to slave labor to cases in which "labor inspectors in Brazil judged conditions to be degrading and employment relations to involve a significant element of unfreedom." Brazil is often regarded as a model for other countries trying to tackle the problem of slave labor. The study found that slave labor is found in the labor-intensive stages of production, in a production network that is partially buyer-driven. Buyers can capture the value created by workers devaluing their labor. Those principally interested by unfair working conditions in Brazil are migrant sugarcane workers from the poorest regions of the country. They are usually employed as seasonal workers in manual cane cutting. They might be employed either by *usinas* (mills or distilleries) or by growers ho supply the *usinas* with cut cane. Informal recruiting is very common as well as labor subcontracting. The sugarcane/ethanol sector in Brazil, even if it has been progressively deregulated and privatized, the role of the government is still very important. The state provides the external regulatory environment where firms operate and stimulates and it is directly involved in production (Petrobras, the state-owned oil company accounts for a big share of ethanol production). The employment practices of distillers and independent growers must be analyzed within the context of their relations with fuel distributors and the state. If firms are unable to keep up with the progressive mechanization and expansion of the sector, they are more likely to resort to slave labor. In other words, they try to increase productivity by increasing the intensity of labor. Intensification takes place through the "piece rate system", that is workers are paid on the basis of how many canes they are able to cut in a given day. However, often calculation systems are not transparent and it has been proved that death rates among sugar cane workers depend on the piece-rate. Nowadays only 10% of sugar cane workers are women. Migrant workers from poor regions in the North are those most interested by slave labor since they are easier to recruit. Migrant workers are very often racially discriminated. Even if it is true that the state has subsidized for a long a sector known for degrading work, it has also been undertaking, especially recently, efforts to combat slave labor. The number of slave liberated has been raising in recent years mainly thanks to changes in labor legislation, provision of social protection and state-level inspection teams. The Brazilian government also implemented a "Dirty List" of firms and individuals using slave labor published since 2003. Names of firms or individuals on the registry are removed if there are no serious violations identified during a 2-year compliance period. Those on the list

become ineligible for official finance such as subsidized credit. Also some private banks have decided not to extend credit to those found using forced labor.

Brazil is not the only Latin America country interested by biofuel production. Also Colombia, Venezuela, Costa Rica and Guatemala have recently started ambitious biofuel programs, mainly focused on ethanol production from sugarcane. In Argentina, conversely, biofuel production is based on soybean biodiesel. Like in the major biofuel producing countries, the strong increase in biofuel production in these countries raises concerns about the sustainability of biofuel production and its environmental and social implications.

Janssen and Rutz (2011) overview the main aspects of biofuel production in Latin America and analyzes the presently available tools to measure and guarantee the sustainability of production processes. Even though biofuel expansion is not the main driver of the deforestation process of the Amazon forest, it is certainly an active part of the process. Sugarcane in Brazil is cultivated along the coast so it does not directly affect deforestation. However, sugarcane area expansion can trigger indirect land use changes since it expands at the expenses of the *cerrado* the tropical savannah, which is used for cattle breeding and soybean cultivation. If more *cerrado* is used for sugarcane production then soybean cultivation and cattle farms will expand inland at the expenses of the rain forest. The fact that biodiesel, which the Brazilian government has just started subsidizing, is produced from soybean oil in Latin America might further speed up the process. The *cerrado* is not only a place where agricultural activities can take place, it is also a vast tropical biome characterized by a high level of plant and animal biodiversity. According to the WWF it is the biologically richer savannah in the world. The *cerrado* was considered not suitable for agriculture but since it was discovered that it can be made fertile by adding the adequate amount of phosphorus and lime to increase the pH value of the soil it has been interested by a strong increase in agricultural activity, especially by soybean cultivation. Colombia is the second-largest ethanol producer in Latin America (mainly from sugar cane) and has started to explore its potential in in biodiesel production from palm oil. Colombia rapidly become the biggest palm oil producer in South America raising concerns, amongst environmentalists on the progressive deforestation to increase oil palm area. The biofuel sector has also been blamed for the forced re-allocation of land for palm oil cultivation, which was formerly owned by Afro-Colombians. The reallocations was mainly done by paramilitary corps by the means of violence and in violation of human rights. The Colombian government is promoting oil palm cultivation as an alternative to illegal narcotics. Even though it has been reported that the Colombian government ordered several palm oil companies to return thousand hectares of land to the original farmers, the ensuring of land tenure rights in Colombia and other Latin American countries is crucial for future sustainability schemes aimed at reducing the negative social impacts of biofuel production. In Argentina the main problem related to the biofuel sector is represented by the employment of GMO in soybean cultivation. The use of GMO is more accepted in Latin America than in the EU, especially in the non-food sector. Brazil is also experimenting GMO

varieties of sugar cane to employ in the ethanol sector. The main reason of concern, in developing countries, regarding biofuel expansion is the effect it has on food prices, which increase might in turn have negative consequences for poor people who spend a high portion of their income on food. Latin America countries make no exception. In 2008 the strong increase in food prices, for example, caused riots in Mexico. Several initiatives are springing in Latin America and in other parts of the world, encompassing, in some cases, also local governments, aimed at addressing the problems related to feedstock production for food, feed and biofuels. The Better Sugar Cane Initiative (BSI), for example, is an open voluntary non-profit multi-stakeholder organization aimed at improving the social, environmental, and economic sustainability of sugarcane production internationally. Key objectives of the BSI, which includes sugar retailers, investors, traders, producers and NGOs, is promoting responsible business practices, free of corruption, respecting labor employment practices, providing a safe and healthy working environment, improving production efficiency, respecting the environment by recognizing the importance of biodiversity and reducing emissions to air and water. BSI members developed a set of principles criteria, indicators and standards for a responsible sugar cane production and verification mechanisms of compliance. The Brazilian government is very active in these aspect and promotes several initiatives, both at national and state level. In the biofuel sector the INMETRO (Brazilian National Institute of Metrology, Standardization and Industrial Quality) is developing an ethanol sustainability certification program to facilitate the export of Brazilian ethanol. The State of São Paulo, the most important for sugarcane cultivation, has recently established the Green Ethanol Program, which is a voluntary scheme that includes several ambitious measures and an official certificate of conformity to certain sustainability criteria. As stated earlier the Brazilian biodiesel program is particularly aimed at preserving biodiversity and at favoring small producers giving them special credit lines and providing them priority market access. At international level the Inter-American Development Bank created a Biofuels Sustainability Scorecard to encourage higher levels of sustainability in biofuels projects by providing a tool to assess the range of complex issues associated with biofuels. It was specifically designed for the private sector at the project level to provide guidance on how ensuring compliance with environmental and social sustainability criteria. In the case of soybeans, the Round Table on Responsible Soy has been established. It is an international platform in which soy producers, merchants, the processing industry, banks and organizations collaborate to establish and implement sustainability criteria for the worldwide cultivation of soy. It has been widely acknowledged that a strong biofuel sector can represent a big opportunity for development in Latin America, however it can also represent a threat because of its potential negative impacts on the environment and the social welfare. The dated was initiated by stakeholders in developed countries, such as the EU, and led to the development of many sustainability initiatives encompassing industry stakeholders and governments. These schemes are still on a voluntary basis but have a strong potential especially because it will facilitate biofuel exports to the European markets, which are or will be subject to a series of sustainability requirements. However,

sustainability requirements can become a burden for biofuel producers and inhibit development. Harmonization among the wide range of initiatives currently in place is essential as well as the development of an international sustainability program since negative effects of biofuel production can be avoided only if international coordination is assured.

Biofuel expansion, as stated by many studies, might have a substantial impact on food prices, which can in turn have negative consequences for the poor, who spend a large share of their income in food, especially in developing countries. In 2008, for example, riots unlashed in Mexico because of the strong increase in the price of *tortillas* due to the surge in international corn price. In 2011, the increase in wheat prices was the main reasons that triggered the revolts in Northern Africa and led to the collapse of the regimes in place in Egypt and Libya. However the effects on rural poor might have been overestimated. Dyer and Taylor (2011) use and agent-based, general equilibrium model to explore the impacts of world corn price increases on land use and income in rural Mexico. Simulation results show that the impact of the price surge of 2007-08 on both rural incomes and land-use changes might have been overestimated. According to the authors subsistence farmers might have had few reasons to expand their crops into marginal or forest land as a consequence of the international price increases in southeast Mexico (are characterized by a high level of deforestation). The reason lie in imperfect price transmission, subsistence demand, increased labor cost that limit the impact of the price surge on land rents, keeping deforestation rates unchanged. The opportunity cost of land might have risen in the northwest of the country, better integrated to world markets but it is water scarcity the limiting factor in that area. Changes in world corn prices observed in 2007-08 had widely varied effects in different parts of Mexico but it seems unlikely that they had a significant effects on rural incomes at the forest margin.

Huang et al. (2012) worked on the same topic at international level and employed a modified version of the GTAP modeling platform (CGE modeling) to assess the future impacts of biofuel production on regional agricultural and related sectors on vulnerable regions of developing countries. The impacts depend on assumptions about the future price of energy and the extent to which biofuels can be considered substitutes for fossil fuels. When energy prices are low the demand for biofuels decreases and great government support is needed to meet biofuel consumption targets. Conversely, when energy prices are high the volume of produced biofuels will easily exceed mandates. The authors show that, even though biofuels are currently produced mainly in developed countries, the effects of their production extend also in other countries. Due to biofuel expansion, more corn, sugarcane and rapeseed are produced but less is going to world markets because it is employed domestically by the big biofuel producing countries to meet their consumption mandates. Agricultural commodity price rise, according to the model, will induce increases in production, exports and self-sufficiency in developing countries and a raise in agricultural value added. However impacts depend on two factors. The first is oil price and the other the degree to which gasoline and regular diesel can be substituted by biofuels. In oil price rises above US$120/barrel and

biofuels and fossil fuels become increasingly substitutable then biofuel production will take place independently from government policies. This will imply that developing countries will be forced to cope with higher commodity prices and less availability of commodities in international markets. Growth in biofuels has positive implications for producers that own their land and are net-sellers of crops on the market. Biofuel expansion and consequent high food prices, according to the study in question, will have negative repercussions on consumers and farmers that are also food purchaser, like in many developing countries. In the long term, higher prices are likely to spur investment from both private and public bodies in agriculture, which can result in higher productivity and a source of additional income for farmers.

This vision, however, appears too much optimistic. Most of the times agricultural production, in developing countries, is in the hands of big landowners or multinational companies which often exploit the work of local farmers. Small holder farmers and workers in big plantation are not likely to receive any benefit from the higher international commodity prices. The first are unlikely to be able to reach international markets, while the latter are often underpaid and without any welfare guarantee. Furthermore both categories are worse off by higher food prices as consumers since they have to pay higher prices for their food. The work by Ivanic at al. (2012) supports this hypothesis. The study assesses the impact of price changes that took place in 2010-11 for 38 agricultural commodities on poverty using data on production and consumption in 28 countries. The authors analyze the short-run impacts of the price surge using a set of observed and estimated changes in domestic agricultural and food prices in some developing countries and calculate their implications for individual households' cost of living and agricultural net incomes. They conclude that the price surge of the second half of the 2010 is likely to have led to an increase in the number of the poor globally even with significant differences across countries. The difference are the result of the different degree of price transmission from world to domestic markets worldwide. Countries characterized by a high level of price transmission (e.g. Tajikistan and Pakistan) there were significant increases in poverty. In net food-selling countries, the benefits of higher agricultural commodity prices are captured mainly by medium and large farmers. A notable exception is Vietnam where a significant share of rural poor are net producers of rice. At world level the negative effects to net consumers outweighs the positive effects on net producers. The study does not take into account the supply response to higher prices by producers or the impact on wage rates. It is true that in the long term wages and incomes will adjust but the short term consequences might have long term implication especially in the case of infants and pregnant women. Countries can limit the negative effects of price volatility by favoring the diffusion of cushion measures such as forward contracting and other market-based hedging mechanisms. Moreover governments should implement safety-net programs to which household can access to and promote investments, safeguarding the environment, in agriculture to increase domestic production. Also a better management of food stocks can help in mitigating the negative effects of price volatility. Finally it must be stressed that such price shocks underline once more the

necessity of promoting a broad-based economic growth that would increase incomes, therefore reducing the vulnerability of households to sudden price changes.

Also the African continent has been interested by the debate concerning the role biofuels can play to reduce energy dependence of African countries from fossil fuel imports and in increasing rural incomes and foster economic development. Also in this case, like elsewhere in the world, biofuel production raises several social, environmental and economic concerns. Amigun et al. (2011) provide a review of the development of biofuels in Africa highlighting country-specific economic, environmental and social issues and provides solutions for a sustainable development of the biofuel sector in the Continent. At the moment there are very few operational commercial biofuel systems in Africa and the situation is most countries is characterized by research efforts, pilot projects, technical trials and the design-study of policies. The main aspect that must be analyzed and considered, when assessing the opportunity of subsidizing biofuel production in Africa is the fact that biofuel production has an effect on food prices. In Africa the priority is to strengthen the local production in order to guarantee the satisfaction of national needs. If left unregulated, biofuel expansion in the Continent will lead to very negative consequences for the poor who will have to face higher food prices and will be involved in an agricultural production system that fails to ensure the equal distribution of benefits and the improvement of living conditions. In Africa more than in any other place biofuels development needs to take place in a framework of sustainable development that considers the economic, social and ecological issues. The best way to do this is promoting biofuel production from wastes or the implementation of flexible production systems that would allow to switch between food and biofuel production according to the contingencies. The biggest threat related to biofuel expansion is the development of large-scale plantations, which can be avoided only by involving small landowners in an integration process for the construction of a large value production and supply chain. Therefore policies should be developed in a way to take into account the interests of small farmers and of women, like it happened, to a certain extent, in the case of Brazilian biodiesel. Biofuel program should not be in contrast with the Millennium Development Goals but should, rather, be a mean to reach them.

Kgathi et al. (2012) assess the potential of the impacts of biofuel development on food security in Botswana drawing on informal and semi-structured interviews. The paper concludes that there is the potential, in Botswana, for the development of the biofuel sector without having adverse effects on food security due to the fact that the country is rich in idle land that could be cropped (72% of agriculture land in the Eastern part of the country). Farmers could producer more food as well as biofuel crops on such land. The development of biofuel policies in third countries had an impact on commodity prices in 2007-08, which in turn affected food price in the country but the promotion of a domestic biofuel production will not lead to an increase in food prices because land availability is not an issue. The government of Botswana is currently working on a policy biofuel development. Until 2016 meat tallow will be used as feedstock and later jatropha, which plantations, however, have still not been started. Jatropha will be cropped on idle and

marginal land that will adapt easily to the local climatic conditions since its high drought tolerance. The risk however, is that farmers will switch from food to jatropha production triggering an increase in food prices as well as the competition between biofuel and food crops for ferltizers and labor. This risk can be reduced through the implementation of government guidelines and their enforcement. It is key that food security will be included in the new Botswana's energy policy, which will have to be centered on second and third-generation biofuels. Even though the major findings of this paper are embraceable, it is not clear how this will be put in practice since second generation biofuels are currently not produced on a large commercial scale not even in developed countries and it will be very difficult to make sure farmers will not give up cropping scarcely profitable food crops in favor of the more rewarding energy ones.

China, the second-largest economy in the world is also starting to explore the possibility of starting subsidizing biofuel production in a similar way as the US, Brazil, and the EU. Already now China is the third-largest ethanol producer in the world. Given the economic and size of the Asian country it is important to assess the impact that the decision of the Chinese government of subsidizing the biofuel sector would make on international markets. Qiu et al. (2010) provide an overview of China's current bioethanol program and its future trend, as well as the likely impacts on its agricultural economy in the future. Also in China the main reason that induced the Chinese government to invest in the biofuel sector is the necessity of increase the country's energy security. China shifted from being an net energy exporter to a net energy importer at the beginning of the 90s, and nowadays is one of the major energy importers in the world. It has been estimated that, by 2020, 60-75% of China's oil demand will have to come from imports. In this framework China has developed a long-run biofuel development plan (see section 3.6). Since China lacks sufficient land to crop all the food it needs for ensuring food security to its inhabitants, it has been decided, at government level, to promote biofuels from non-food crops. Moreover it has been decided to use marginal land for feedstock production. Potential crops for biofuel production include: sweet sorghum, cassava, and sweet potato. At current prices and technologies cassava is the most promising crop for feedstock. However the decision of China of bringing large amounts of marginal land into cultivation might be problematic because of scarce water availability and the fact that expanding feedstock production in new marginal land needs further investigation. In the future the price of agricultural commodities used as feedstock for ethanol production will rise substantially but the impact on the prices of other agricultural commodities will be moderate. Despite the forecasted strong increase in feedstock production, if China is set to meet its 2020 consumption targets it will still have to import large quantities of feedstock from abroad. Even though the impact of China's increased biofuel production on domestic food prices is forecasted to be "minimal" consequences on international markers might be substantial. Furthermore the fact that China is amongst the most active counties in the world in purchasing land in African developing countries (land grabbing) increases the risk of negative consequences on agricultural markets worldwide.

China, like any other country in the world, can be affected by biofuel expansion in the US and the EU, which can alter income distribution and agricultural production in China. Huang et al. try to quantify these impacts of biofuel production in the world's major biofuel producers to the Chinese economy using a computable general equilibrium model. They estimate that increased biofuel production in the EU, Brazil, and the US will increase the price of biofuel feedstock and their demand in those country therefore reducing the amount of commodity exported, which in turn will trigger price increases. The consequences for China are positive. In China the poor have access to the land and since they earn most of their income from agriculture, they will benefit from higher prices. Of course this assumes that price transmission between world and Chinese markets is perfect and that Chinese farmers are net-seller of food. The fact that Chinese supply of commodities such as corn and soybeans will increase due to higher prices, will also help China to achieve its goals of food self-sufficiency. The model predicts that China's self-sufficiency in grains will be almost 87% in 2020, imports will fall by 20% and production will rise by 2.1% with respect to 2006 levels. Rural poor in China will benefit, especially those of the Northern part of the country even though consumers will lose in terms of higher food prices.

## 4.4 Final considerations.

Even though high oil prices might have favored biofuel expansion, the main driver was policies implemented by many countries around the world. The first food crisis of 2007-08, followed by another one in 2010 and the ambiguity regarding the environmental footprint of biofuels, however, induced many developed and developing countries to reconsider their initial optimism regarding biofuels and to take a more cautious approach. In some cases they announced (it is the case of the EU) that they would re-design their support programs in order to limit the risk of a food vs. fuel conflict. The recent spike in agricultural commodity prices, convinced the UN that the situation was not sustainable anymore. In September 2012, the UN officially asked the US and the EU to immediately suspend government mandated ethanol and biofuel production because of their repercussions on world food prices. While the US tergiversated (because of the upcoming presidential elections), the EU recognized that biofuel policies may be, indeed, a problem and started thinking about lowering its 2020 consumption targets (Financial Times, 2012).

Despite the great number of studies and methodologies adopted, it has not been possible to give an estimation of the role biofuel policies played in the recent spikes in world agricultural commodity prices. Even though almost all studies examined, more or less clearly, admit that biofuel expansion did have an effect on agriculture prices, the debate on the magnitude of the influence is still very open. A lot of big interests are at stake. Ethanol and biofuel producers, both in the EU and the US, have made strong investments to build production facilities based on first-generation biofuels and exert pressure on governments to maintain current policies (mainly consumption mandates). Biofuel lobby groups are very powerful, especially in the US. Consumers and taxpayers can do little since they are many and not organized in pressure groups.

It seems clear, though, that first-generation biofuel capacity in reducing GHG emission has been overestimated, and carbon accounting mechanisms are far to be perfect. In absence of a major technology change, first-generation biofuel expansion will necessarily have to slow down after 2020 since already now big quantities of agricultural commodities that could be used for human consumption (directly or indirectly) are diverted into biofuel production.

Even though there is a general consensus on the fact that biofuel expansion contributed to the recent increase in food prices, the magnitude of the impact is matter of contention. It is not easy to estimate the impact of biofuel production since many other factors might have played a role (oil price, weather patterns, and currency variability). The main way to reduce the negative of biofuel production on food prices and food availability is the development of second- and third-generation biofuels, which however are in most cases still in the experimental phase. It is true that second-generation biofuels may stop the use of food crops for fuel production but they might still compete for land with food crops. There is no consensus in establishing the impact of biofuel production on GHG emissions neither. GHG balances are not favorable for all biofuel feedstocks, especially when cultivation of feedstocks causes the conversion of native ecosystems to crop lands, directly or indirectly. It is true, however, that the cultivation of perennial biofuel feedstocks on marginal land can yield GHG savings. The increasing use of biofuels in the transport sector might improve local air quality in terms of some pollutants but might worsen it in terms of other pollutants.

Biofuel expansion also has and will have a big impact on land use worldwide. Already now the production of some popular biofuel feedstocks such as corn, sugarcane and oilseeds has started to grow at the expenses of other crops. In the next decades additional land will have to be put under cultivation, not only for biofuel feedstock cultivation but also to satisfy the increasing demand for feed and food especially in developing and emerging countries. Most of additional land is expected to come from pasture land since it is easier to convert and implies less negative consequences in terms of GHG emissions.

Biofuels will play a significant role in the future energy supply mix only if it will be possible to avoid the food vs. fuel conflict and dramatic improvements in global agricultural productivity will take place, especially in developing countries. (Timilsina & Shrestha, 2011).

The fact that even industrialized countries have been struggling in regulating their biofuel markets and in controlling their negative spillovers on the environment and on food markets raises many doubt on the possibility that developing countries, characterized by a high level of corruption and by a strong influence of foreign investors and multinational companies in domestic affairs, could success in what developed countries failed. Moreover it seems quite unrealistic that developing countries would increase their energy security by undertaking large and ambitious biofuel production. It is true that the employment of second- or third-generation biofuel would reduce the negative effects implied by the use of food commodities as feedstock (rising food prices, increase in input use, increase in total GHG emissions, iLUC,

*etc.*) but the fact that such technologies are still in the experimental phase in the developed world make their use in developing countries, if not utopic, at least very difficult to achieve.

In a report, the Global Subsidy Initiative (*State of Play on Biofuel Subsidies: Are policies ready to shift?,* (2012)), an agency of the International Institute for Sustainable Development, provides guidelines to governments on how reform public support to biofuels. First of all governments should gather information, through scientific studies, on the effective cost and benefits of biofuels in economic, environmental and social terms. Governments should also inform, at least annually, citizens on the amount of resources provided to the biofuel sector. Governments should also completely avoid subsidizing conventional fossil fuels, which they currently (although indirectly) do with blending mandates. Blending mandates should be replaced by more flexible measures, especially in presence of new food price bubbles. In the medium term polices stimulating the production of biofuels from food crops should be completely removed. Furthermore governments should invest on infrastructure that allow a more flexible use of biofuels: on the demand side it should be possible to switch between biofuels and other forms of energy, while on the supply side it should be possible produce either food or fuels from in same production facility, like in Brazil happens for sugarcane. However it is difficult to imagine that different countries, each with its own political interests, will find the necessary coordination to reform and harmonize policies anytime soon.

The main conclusion that can be drawn from this analysis of the state of the art on biofuel sustainability is that factors affecting it are many and that most of them have been guiltily neglected by policy-makers when, almost 20 years ago started subsidizing the biofuel sector. Now that policies are already in place is much more difficult to change them since interests at stake are many. Even though many studies have provided plenty of solutions to the biofuel sustainability problem (second-generation biofuels, the use of marginal land, the use of waste feedstocks, better policy coordination amongst countries) almost none said anything on how this could be put into practice anytime soon. The biofuel problem should be tacked at the highest possible level, similarly to what happens in the WTO for trade disputes, but it might require years to put a similar system in place (establishing the rules of the game) and then to find an agreement.

# 5 Assessing feedstock needs for biofuel production in the next decade.

This chapter provides an estimate of the quantities of agricultural commodities that has been needed to produce biofuels (ethanol and biodiesel) in the US, Brazil, and the EU in the last two decades and projections of quantities that will be needed in the future to achieve the biofuel consumption mandates of the US, Brazil, and the EU.

The estimates rely on some assumptions. It has been assumed that in Brazil the only ethanol feedstock is sugarcane, while in the US it is corn. Both Brazil and the US are assumed to use (now and in the future) only domestically produced sugarcane and corn to make ethanol, since they are the most important producers in the world for the two commodities in question. In the case of the biodiesel, the main feedstock used both in Brazil and the US is assumed to be soybean oil since both countries are big soybean producers. Making assumptions regarding the EU was more difficult. Historically rapeseed oil (produced domestically) has been the major feedstock used for biodiesel production in the EU, however, in recent years, growing quantities of palm oil has been imported to produce biodiesel since EU rapeseed oil production is not sufficient to meet demand. When domestically produced rapeseed oil was not sufficient to produce all the biodiesel manufactured in a given year, it has been supposed that the remaining quantity was produced from imported palm oil. Brazilian ethanol production figures are from the Brazilian Ministry of Agriculture, while data on Brazilian biodiesel are from the National Agency on petroleum, natural gas and biofuels (ANP). Data on both ethanol and biodiesel production in the US are from the USDA, while EU biodiesel production figures are from the Eurostat database. Biofuel and feedstock production forecasts from 2012 to 2021 are from the FAO-OECD Agricultural Outlook.

Conversion coefficients to estimate, starting from biofuel production, the amount of feedstock needed for their production and the amount of land needed to crop them, are from Dias De Oliveira et al. (2005). Further details about assumptions made are provided in the country-specific sections. Section 5.1 is about biofuel production feedstock needs in Brazil, section 5.2 is about the United States, section 5.3 is about the European Union and section 5.4 concludes estimating the impact of biofuel production on agricultural area.

## 5.1 Brazil.

### 5.1.1 Brazilian ethanol.

In Brazil the most important biofuel is ethanol, which is produced from sugar cane. In the last five years also biodiesel has started to be produced in the country as a consequence of the introduction, by the Brazilian government, of measures to promote its consumption. Brazilian biodiesel is produced mainly from

soybean oil. Since Brazil is the most important sugarcane producer in the world and one of the largest soybean (and soybean oil) producers, it has been assumed that the domestic production of both commodities is, and will be, sufficient to satisfy the demand from the biofuel sector. Even in case current supply will not be enough to cover food, feed and biofuel demand, the fact that Brazil is endowed by a great amount of land that can be converted into agriculture, allows to assume that it is not very likely that the South American country will need to resort to imports. Of course land use changes might have strong implications in terms of GHG emissions and biodiversity losses, especially in a country like Brazil, characterized by a high degree of sensitive habitats.

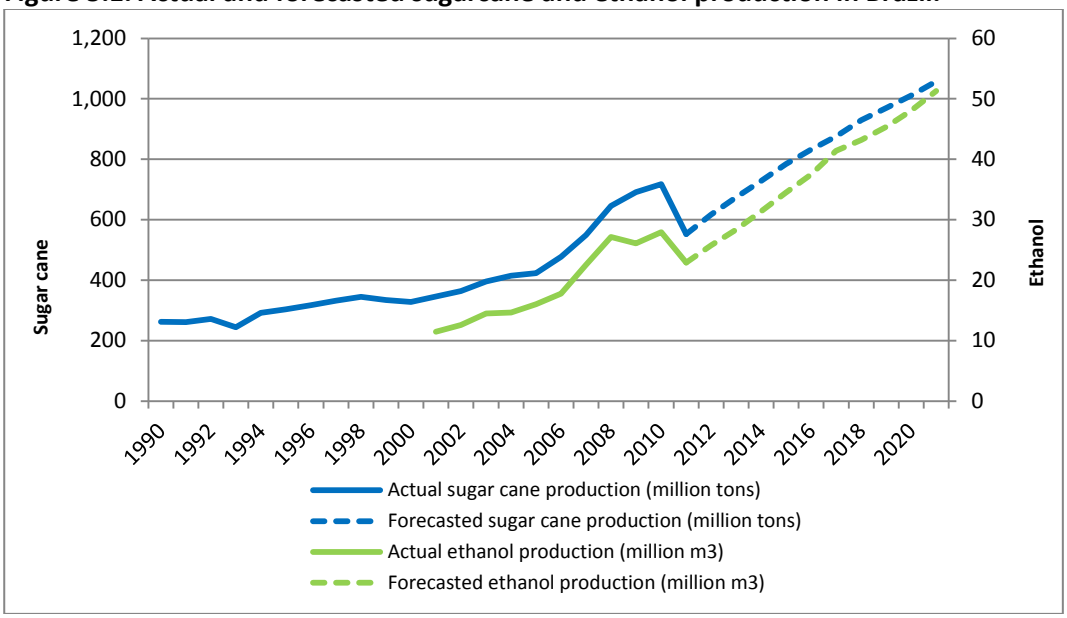
In 2011, last year for which data are available, Brazilian ethanol production was 22.9 million $m^3$, more than 18% down from 2010 levels. In 2011 Brazil was hit by a severe drought that seriously damaged the sugar cane crop. In 2011, therefore, Brazil imported big quantities of ethanol from the US, in order to meet its consumption mandates. The fact that, in a year characterized by a bad sugar cane crop, Brazil imported ethanol rather than the feedstock to possibly produce it domestically, support the *a priori* assumption that Brazil produces its ethanol mainly from domestically produced feedstock. In the same year Brazilian sugar cane production was 552.2 million tons, 23% lower than in 2010. With respect to the beginning of the decade, sugar cane production grew 1.6 times, while ethanol production almost doubled.

According to the OECD-FAO Agricultural Outlook, in 2021, Brazilian ethanol production will be 51.3 million $m^3$, more than twice as much than in 2011, while sugarcane production is forecasted to grow only 1.9 times (Figure 5.1. Actual and forecasted sugarcane and ethanol production in Brazil.).

In calculating the sugarcane needed to produce all the ethanol produced in the last years it has been assumed, following Dias De Oliveira et al. (2005), that 1 ton of sugarcane gives 0.08 $m^3$ of ethanol and that 1 hectare cropped with sugarcane allows the production of 6.4 $m^3$ of ethanol assuming an average yield of 80 t/ha.

In 2011, the last year for which actual data were available, 51.8% of the Brazilian sugarcane production was used for ethanol production for an absolute value of 286.2 million tons. 2011 was the first time that more than half of the sugarcane production was used for ethanol purposes, however, in absolute term it was 2010 when the highest amount of sugar cane was employed: 349.5 million tons. The quantity of sugar cane used for ethanol production almost doubled since 2001 as well as the area needed to grow the crop, which in 2011 was 4.2 million ha, half of the total area used for sugarcane cultivation and 1.6% of total Brazilian agriculture land.

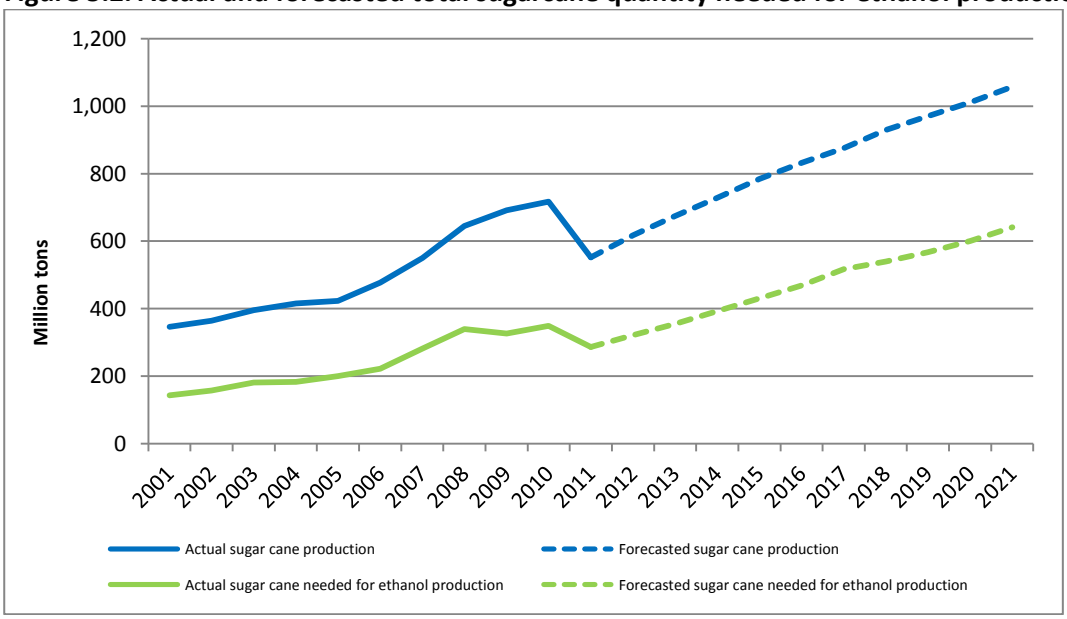
**Figure 5.1. Actual and forecasted sugarcane and ethanol production in Brazil.**




Source: own calculation on FAO and OECD data.

According to the estimates the amount of sugarcane needed to ethanol will be 321.9 million tons in 2012, 12.5 up from 2011 levels but still lower than in 2010. Quantities used for ethanol production, however, will grow rapidly in subsequent years to reach 641.3 million tons by 2021. Since sugarcane production is forecasted to grow at a lower rate than ethanol production, the share of total sugarcane production used in the ethanol sector will grow and reach 60.7% by 2021. Similarly to what happens for quantities produced, also the amount of land needed to grow all the sugarcane that will be used in the ethanol production process will expand and reach 8.0 million ha by 2021 (Table 5.1 and Figure 5.2).

**Figure 5.2. Actual and forecasted total sugarcane quantity needed for ethanol production in Brazil.**




Source: own calculations on FAO, ANP, OECD, and Brazilian Ministry of Agriculture data.

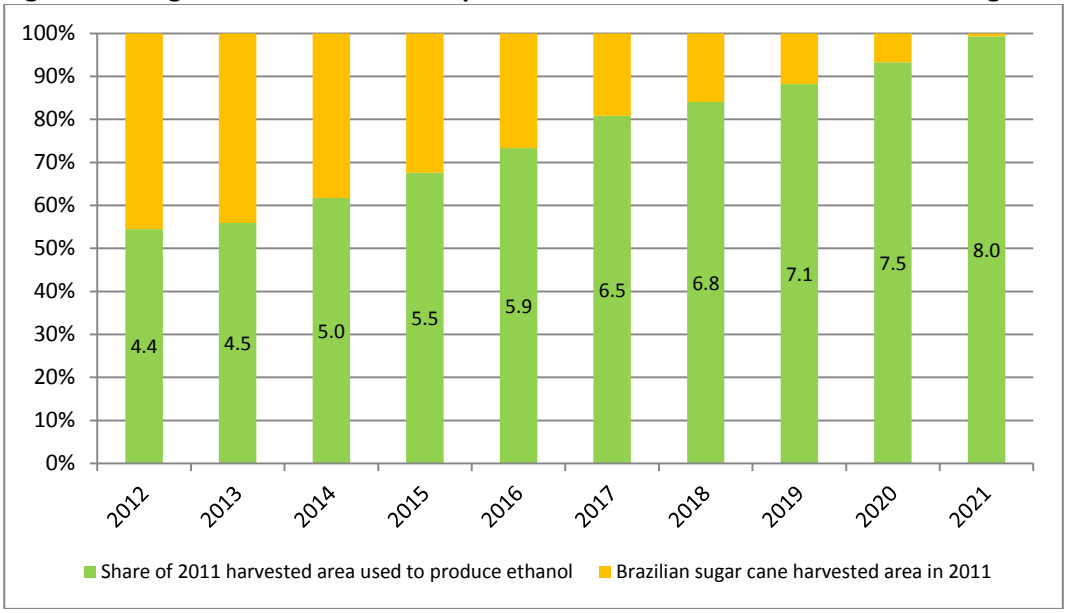
**Table 5.1. Brazilian sugar cane and ethanol production 2001-2021.**

| Year | Ethanol production (million m3) | Sugarcane production (million tons) | | | Sugarcane area harvested (million ha) | | |
|---|---|---|---|---|---|---|---|
| | | Total | For ethanol production | % for ethanol prod. | Total | For ethanol production | % for ethanol production |
| 2001 | 11.5 | 345.9 | 143.3 | 41.4 | 5.0 | 2.1 | 41.4 |
| 2002 | 12.6 | 364.4 | 157.4 | 43.2 | 5.1 | 2.2 | 43.2 |
| 2003 | 14.5 | 396.0 | 180.9 | 45.7 | 5.4 | 2.5 | 45.7 |
| 2004 | 14.6 | 415.2 | 183.1 | 44.1 | 5.6 | 2.5 | 44.1 |
| 2005 | 16.0 | 423.0 | 200.5 | 47.4 | 5.8 | 2.8 | 47.4 |
| 2006 | 17.8 | 477.4 | 222.1 | 46.5 | 6.4 | 3.0 | 46.5 |
| 2007 | 22.6 | 549.7 | 282.0 | 51.3 | 7.1 | 3.6 | 51.3 |
| 2008 | 27.1 | 645.3 | 339.3 | 52.6 | 8.1 | 4.3 | 52.6 |
| 2009 | 26.1 | 691.6 | 326.3 | 47.2 | 8.6 | 4.1 | 47.2 |
| 2010 | 28.0 | 717.5 | 349.5 | 48.7 | 9.1 | 4.4 | 48.7 |
| 2011 | 22.9 | 552.2 | 286.2 | 51.8 | 8.1 | 4.2 | 51.8 |
| **Forecasts** | | | | | | | |
| 2012 | 25.8 | 617.1 | 321.9 | 52.2 | 8.4 | 4.4 | 52.2 |
| 2013 | 28.4 | 673.9 | 354.6 | 52.6 | 8.6 | 4.5 | 52.6 |
| 2014 | 31.4 | 728.5 | 392.4 | 53.9 | 9.3 | 5.0 | 53.9 |
| 2015 | 34.5 | 784.4 | 431.1 | 55.0 | 9.9 | 5.5 | 55.0 |
| 2016 | 37.5 | 831.9 | 468.2 | 56.3 | 10.5 | 5.9 | 56.3 |
| 2017 | 41.4 | 875.4 | 517.2 | 59.1 | 11.0 | 6.5 | 59.1 |
| 2018 | 43.2 | 929.1 | 539.7 | 58.1 | 11.7 | 6.8 | 58.1 |
| 2019 | 45.4 | 970.0 | 567.1 | 58.5 | 12.2 | 7.1 | 58.5 |
| 2020 | 48.0 | 1,010.9 | 600.6 | 59.4 | 12.7 | 7.5 | 59.4 |
| 2021 | 51.3 | 1,057.3 | 641.3 | 60.7 | 13.2 | 8.0 | 60.7 |

Source: own calculations on FAO, ANP, OECD, and Brazilian Ministry of Agriculture data.

Since the conversion parameters used to calculate the amount of sugar cane and the amount of land needed to meet ethanol consumption mandates are assumed to be fixed for the whole period, the share of total production used in ethanol production and the share of land needed are the same. For this reason it is interesting to compare the amount of land that will be needed to produce ethanol in the next decade to current harvested area. The results are surprising and are shown in Figure 5.3.

**Figure 5.3. Sugarcane area needed to produce ethanol as a share of 2011 total sugarcane area in Brazil.**




Source: own calculations on FAO, ANP, OECD, and Brazilian Ministry of Agriculture data.

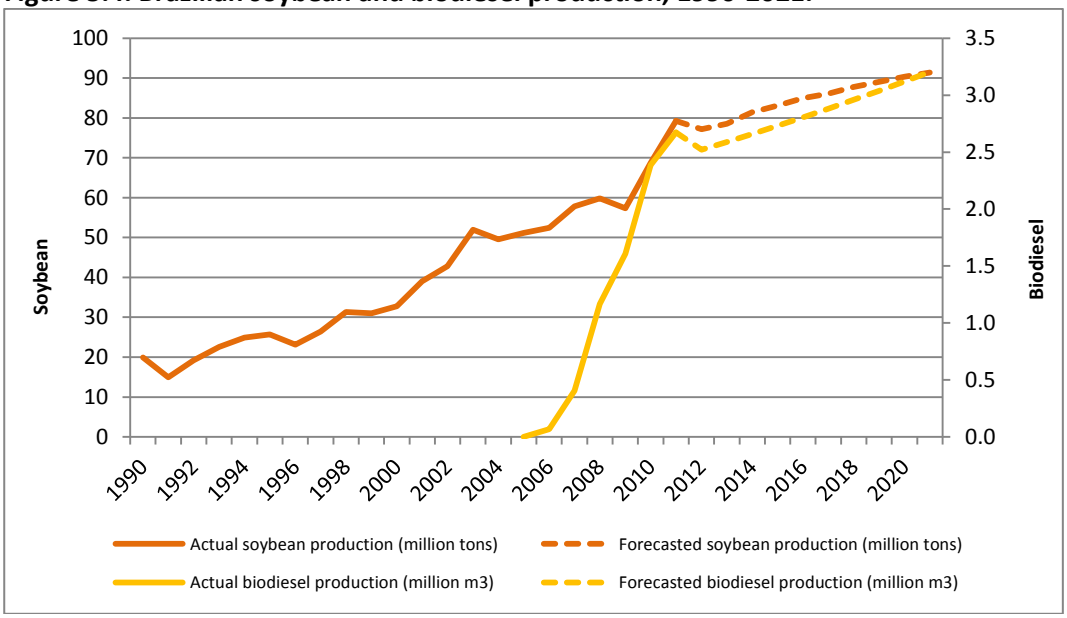
By 2021 the area needed to produce all the ethanol that the FAO-OECD forecast Brazil will be producing will be almost equal to the entire current sugarcane area in Brazil, or 3% of current total agricultural land. Since sugarcane, in Brazil, is cropped also to produce sugar, this means that a substantial amount of land will have to be put under cultivation in order to meet demand. It is true that the leading role that Brazil has in the sugar market could be, at least in theory, replaced by some other country but this would only displace the problem. If land use changes will not happen in Brazil (which probably will not be the case) they will happen somewhere else in the world, with the same consequences in terms of GHG emissions (which are likely to increase due to such land use changes) and biodiversity losses, since sugarcane can be cropped only in tropical climates, those usually characterized by high levels of biodiversity.

### 5.1.2 Brazilian biodiesel.

Starting from the mid-2000s, Brazil started subsidizing also the biodiesel sector, which is mainly produced from soybean oil. Biodiesel production was almost zero in 2005, but it reached 2.7 million $m^3$ already in 2011, thanks to blending mandates: all diesel sold in Brazil must contain 5% biodiesel. The production is forecasted to grow, but not as much as the ethanol one. The OECD-FAO Agricultural Outlook forecasts Brazilian biodiesel production to reach 3.2 million $m^3$ by 2021, an estimate that might seem too much conservative. Brazilian soybean production has been expanding greatly in the last 20 years. In 1990 Brazil produced slightly less than 20 million tons of soybean on 11.5 million ha of land. By 2011 production had grown to 79.2 million tons and area harvested to 25.8 million ha. The increase, however, has little to do with biodiesel expansion. Brazilian soybean production grew because of the progressive modernization of

the country's agriculture and because of the rapid economic growth experienced by the South American country that spurred demand. By 2021 soybean production is forecasted to reach 91.4 million tons, and area harvested to expand 29.9 million ha (Figure 5.4).

**Figure 5.4. Brazilian soybean and biodiesel production, 1990-2021.**




Source: own calculations on FAO and OECD data.

In order to estimate the amount of soybean needed to produce Brazilian biodiesel it has been assumed, following Dias De Oliveira et al. (2005) that 1 ton of vegetable oil yields 1.175 $m^3$ of biodiesel, that soybeans oil content is 20% and that the efficiency of the oil extraction process is 85%.

In 2011, last year for which actual data are available, 13.4 million tons of soybean were used for biodiesel production in Brazil, corresponding to 16.9% of total production. The increase, with respect to the previous years was quite dramatic given that only in 2005 biodiesel production was almost zero. In order to crop the soybean needed for biodiesel production, were needed, in 2011, 4.4 million ha, almost 17%of total Brazilian soybean area harvested and 1.7% of total agricultural area.

According to our estimates, in 2021 the quantity of soybean needed to produce biodiesel will grow to 16.0 million tons, a relatively modest increase if compared to that of sugarcane for ethanol. Since soybean production is forecasted to grow, more or less, at the same rate, the share destined to biodiesel production will grow only very slightly, to reach 17.6% by the beginning of the next decade. The area needed to crop soybeans for biodiesel production will grow by 0.8 million ha by 2021, to reach 5.2 million, 3.3% of total current agricultural area. If compared to sugar cane and ethanol, the effects of biodiesel production on Brazilian agriculture seem to be quite modest, provided that the OECD-FAO production forecasts do not underestimate biodiesel expansion. It is true that, at the moment, most of the Brazilian vehicle fleet is gasoline-fueled but nobody knows what could happen in the future. In case the government will increase the degree to which it subsidizes the sector (since ethanol prices are likely to go up due to

competition with sugar production for sugar cane), quantities consumed might raise as quickly as they have already done in the past few years (Table 5.2).

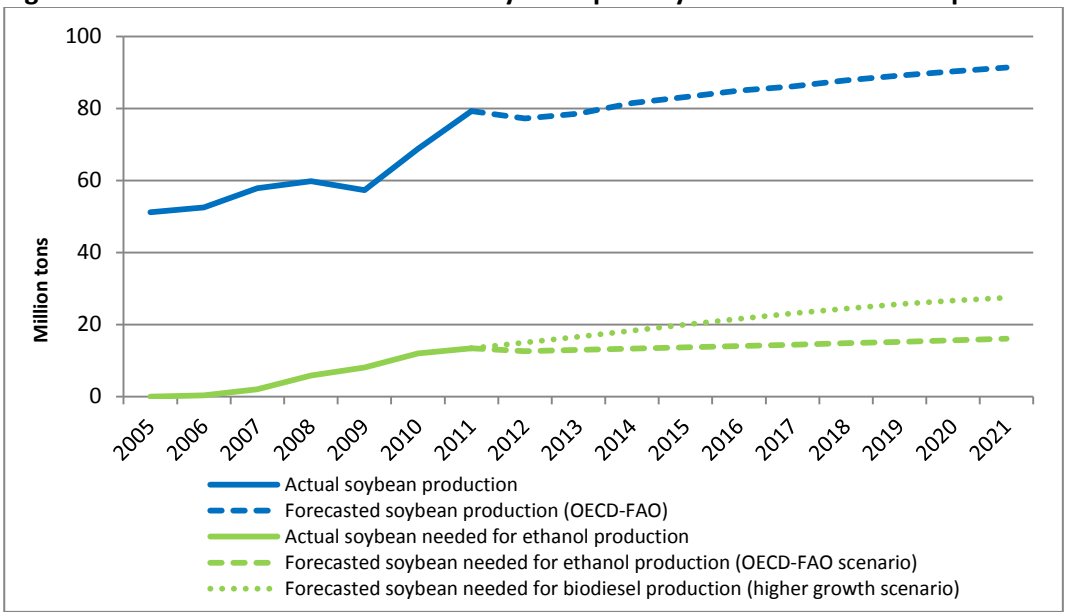
**Table 5.2. Brazilian soybean and biodiesel production 2001-2021.**

| Year | Biodiesel production (million m3) | Soybean production (million tons) | | | Soybean area harvested (million ha) | | |
|---|---|---|---|---|---|---|---|
| | | Total | For biodiesel production | % for biodiesel prod. | Total | For biodiesel production | % for biodiesel production |
| 2005 | 736.2 | 51.2 | 0.0 | 0.0 | 22.9 | 0.0 | 0.0 |
| 2006 | 69,002.0 | 52.5 | 0.3 | 0.7 | 22.0 | 0.1 | 0.7 |
| 2007 | 404,329.1 | 57.9 | 2.0 | 3.5 | 20.6 | 0.7 | 3.5 |
| 2008 | 1,167,128.4 | 59.8 | 5.8 | 9.8 | 21.2 | 2.1 | 9.8 |
| 2009 | 1,608,448.4 | 57.3 | 8.1 | 14.0 | 21.8 | 3.1 | 14.0 |
| 2010 | 2,386,398.5 | 68.8 | 11.9 | 17.4 | 23.3 | 4.1 | 17.4 |
| 2011 | 2,672,759.9 | 79.2 | 13.4 | 16.9 | 25.8 | 4.4 | 16.9 |
| **Forecasts** | | | | | | | |
| 2012 | 2,521,356.2 | 77.2 | 12.6 | 16.4 | 26.0 | 4.3 | 16.4 |
| 2013 | 2,589,432.8 | 78.6 | 13.0 | 16.5 | 26.3 | 4.3 | 16.5 |
| 2014 | 2,659,347.5 | 81.5 | 13.3 | 16.3 | 27.2 | 4.5 | 16.3 |
| 2015 | 2,731,149.9 | 83.1 | 13.7 | 16.4 | 27.7 | 4.6 | 16.4 |
| 2016 | 2,804,891.0 | 84.9 | 14.0 | 16.5 | 28.3 | 4.7 | 16.5 |
| 2017 | 2,880,623.0 | 86.1 | 14.4 | 16.7 | 28.5 | 4.8 | 16.7 |
| 2018 | 2,958,399.8 | 87.8 | 14.8 | 16.9 | 29.0 | 4.9 | 16.9 |
| 2019 | 3,038,276.6 | 89.1 | 15.2 | 17.1 | 29.3 | 5.0 | 17.1 |
| 2020 | 3,120,310.1 | 90.3 | 15.6 | 17.3 | 29.6 | 5.1 | 17.3 |
| 2021 | 3,204,558.5 | 91.4 | 16.0 | 17.6 | 29.9 | 5.2 | 17.6 |

Source: own calculations on FAO, ANP, OECD, and Brazilian Ministry of Agriculture data.

In case biodiesel production will increase at the same rate of the last few years (+12.0% from 2010 to 2011), the picture would be quite different. In the case in which biodiesel production will keep growing at a 12% growth rate in 2012 and then at a progressively declining rate in subsequent years (+0.11% in 2013, +0.10% in 2014 and so on) the quantities of soybean needed to produce biodiesel would increase to 27.5 million tons by 2021 (one-third of the forecasted 2021 soybean production) (Figure 5.5).

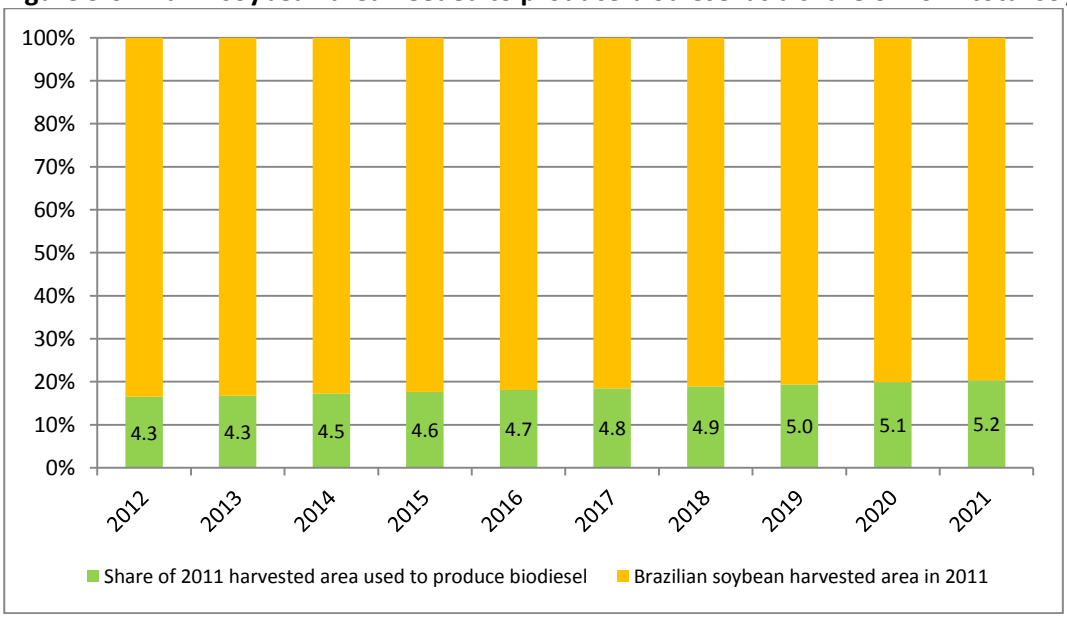
**Figure 5.5. Actual and forecasted total soybean quantity needed for biodiesel production in Brazil.**




Source: own calculations on FAO, ANP, OECD, and Brazilian Ministry of Agriculture data.

In 2021 the land needed to cultivate the soybean needed for biodiesel production, according to the OECD-FAO projections, will be equal to 20.3% of 2011 soybean area in Brazil or , which is a remarkably high share if one thinks that estimates of biodiesel expansion are quite conservative (Figure 5.6).

**Figure 5.6. Brazil: soybean area needed to produce biodiesel as a share of 2011 total soybean area.**




Source: own calculations on FAO, ANP, OECD, and Brazilian Ministry of Agriculture data.

## 5.2 United States.

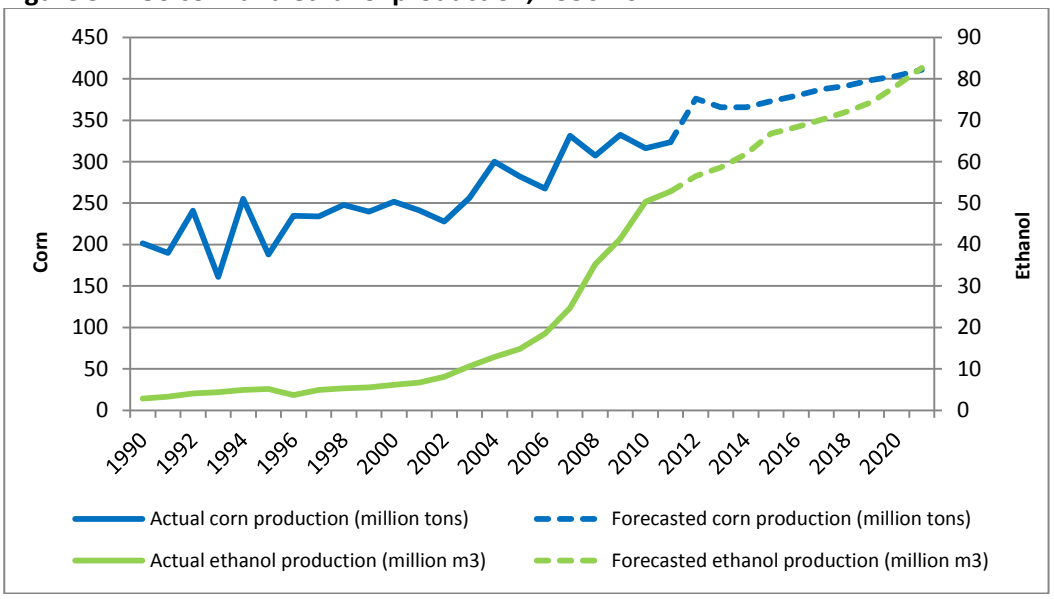
### 5.2.1 United States ethanol.

In the United States the main feedstock for ethanol production is corn, which production has been increasing significantly in the last two decades. In 2011, last year for which actual data are available, US corn production was 323.5 million tons, 2.3% up from 2010 but 2.7 down from 2009 levels. With respect to 1990, that is before the beginning of ethanol expansion, US corn production increased 1.6 times, more than the area harvested, which expansion was relatively smaller (+136%). In 2011, US corn harvested area was 36.8 million ha, 11.7% more than in 2010, and the highest value since the second world war. The great expansion in cropped area is due to high corn prices that spurred farmers to crop more corn than they would have done otherwise.

Ethanol production figures are available, from the USDA database, since 1990, when the US produced 2.8 million $m^3$ of ethanol. Production grew steadily until the late 90s (in 2000 it was 6.1 million $m^3$), when it started to grow exponentially. Output peaked 52.8 million $m^3$ in 2011 and, according to the OECD-FAO forecasts, it will keep growing more or less at the same rate for the next decade. In 2021 ethanol production will reach 82.6 million $m^3$, even though the US legislation says that a considerable share of its ethanol consumption will have to come from second-generation ethanol, it is still not clear if and how this will happen, since at the moment none of the "second-generation" techniques to produce ethanol is commercially available.

According to the OECD-FAO Agricultural Outlook, US corn production is forecasted to grow up to 410.8 million tons in 2021, 26.9% more than in 2011. Conversely the increase in ethanol production, with respect to current levels will be by 56.5% (Figure 5.7).

**Figure 5.7. US corn and ethanol production, 1990-2021.**




Source: own calculation on FAO, OECD, and USDA data.

Similarly to Brazil, also in the case of US it has been calculated the amount of corn that has been needed to produce ethanol in the past two decades and the amount that will be needed in the next ten years to meet consumption targets. Also in this case conversion coefficients are from Dias De Oliveira et al. (2005). It has been assumed that 1 ton of corn gives 0.387 m3 of ethanol.

In 2011 136.4 million tons of corn were transformed into ethanol in the US, almost 42.2% of total production. The share of US corn output used in the ethanol industry was relatively low until the beginning of the 2000s. In 1990 just 7.3 million tons (3.6% of total production) were used to make ethanol, while in 2000 this amount had grown to 15.9 million tons (6.3% of total output), it was in very recent times that the amount of corn employed in the ethanol sector grew substantially because of the implementation of the Renewable Fuels Standards in 2003 and of the Renewable Fuels Standard 2, in 2007. In total, in 2011, corn needed to produce ethanol needed 15.5 million hectares to be grown (42% of total corn area and 15.5% of total agricultural area), 14.6% more than in 2010. The difference with respect to 2000 and 1990 is striking: since then the area needed to crop corn for ethanol production grew 7.4 and 14.8 times respectively (Table 5.3).

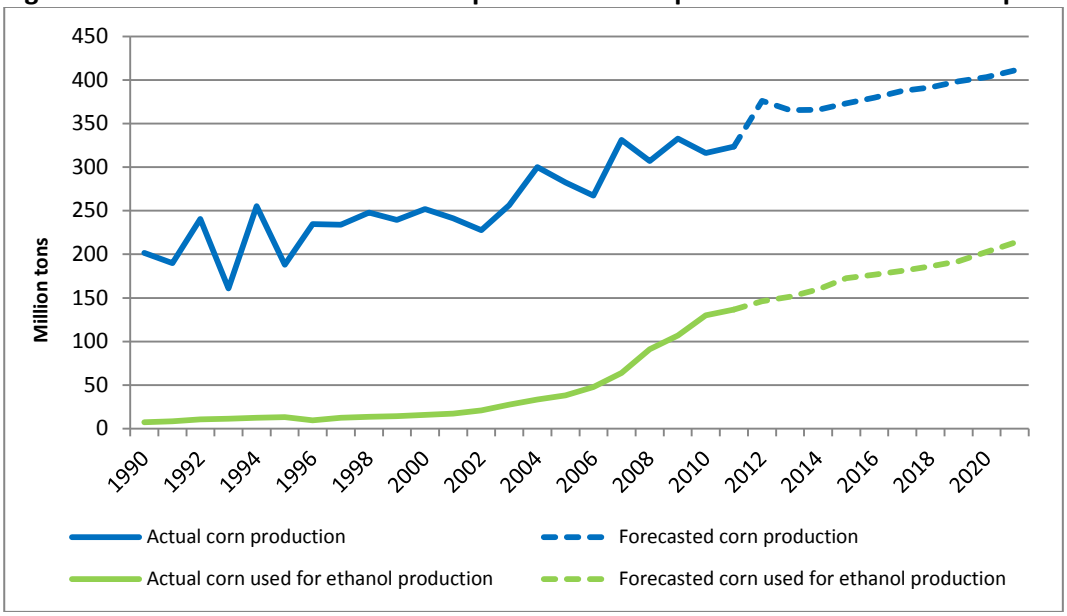
In the next decade the amount of corn diverted from food/feed uses to ethanol production is destined to increase. By 2021, if current consumption mandates, are to be met, 213.5 million tons of corn will be transformed into ethanol, 56.5% more than in 2011, if yields remain constant. This means that, by that year, more than half of the US corn production will be used for making biofuels. This might have strong repercussions on cereal prices and, indirectly, on animal products prices, across the world since the US is the largest corn producer and exporter in the planet. In terms of area harvested the impact will be also substantial. In 2021, just one year before the end of the current policy scheme in favor of ethanol, 19.6 million ha will be needed to crop all the corn needed, more than 20% of current total agricultural area. Conversely to what happens in Brazil or other tropical countries, where there is still room for cropped area expansion (even if at the expenses of wild land, such as the rain forest), in the US this is possible only to a very limited extent. Total corn harvested area is forecasted to grow only little, just by 2.5% from now to 2021 (Figure 5.8).

**Table 5.3. United States: corn and ethanol production 1990-2021.**

| Year | Ethanol production (million m3) | Corn production (million tons) | | | Corn area harvested (million ha) | | |
|---|---|---|---|---|---|---|---|
| | | Total | For ethanol production | % for ethanol prod. | Total | For ethanol production | % for ethanol prod. |
| 1990 | 2.8 | 201.5 | 7.3 | *3.6* | 27.1 | 1.0 | *3.6* |
| 1991 | 3.3 | 189.9 | 8.5 | *4.5* | 27.9 | 1.2 | *4.5* |
| 1992 | 4.1 | 240.7 | 10.6 | *4.4* | 29.2 | 1.3 | *4.4* |
| 1993 | 4.4 | 161.0 | 11.3 | *7.0* | 25.5 | 1.8 | *7.0* |
| 1994 | 4.9 | 255.3 | 12.6 | *4.9* | 29.3 | 1.4 | *4.9* |
| 1995 | 5.1 | 188.0 | 13.3 | *7.1* | 26.4 | 1.9 | *7.1* |
| 1996 | 3.7 | 234.5 | 9.5 | *4.1* | 29.4 | 1.2 | *4.1* |
| 1997 | 4.9 | 233.9 | 12.6 | *5.4* | 29.4 | 1.6 | *5.4* |
| 1998 | 5.3 | 247.9 | 13.7 | *5.5* | 29.4 | 1.6 | *5.5* |
| 1999 | 5.5 | 239.5 | 14.3 | *6.0* | 28.5 | 1.7 | *6.0* |
| 2000 | 6.1 | 251.9 | 15.9 | *6.3* | 29.3 | 1.8 | *6.3* |
| 2001 | 6.7 | 241.4 | 17.3 | *7.2* | 27.8 | 2.0 | *7.2* |
| 2002 | 8.1 | 227.8 | 20.9 | *9.2* | 28.1 | 2.6 | *9.2* |
| 2003 | 10.6 | 256.2 | 27.4 | *10.7* | 28.7 | 3.1 | *10.7* |
| 2004 | 12.9 | 299.9 | 33.3 | *11.1* | 29.8 | 3.3 | *11.1* |
| 2005 | 14.8 | 282.3 | 38.2 | *13.5* | 30.4 | 4.1 | *13.5* |
| 2006 | 18.5 | 267.5 | 47.8 | *17.9* | 28.6 | 5.1 | *17.9* |
| 2007 | 24.7 | 331.2 | 63.8 | *19.3* | 35.0 | 6.7 | *19.3* |
| 2008 | 35.2 | 307.1 | 91.1 | *29.6* | 31.8 | 9.4 | *29.6* |
| 2009 | 41.4 | 332.5 | 107.0 | *32.2* | 32.2 | 10.3 | *32.2* |
| 2010 | 50.3 | 316.2 | 130.0 | *41.1* | 33.0 | 13.6 | *41.1* |
| 2011 | 52.8 | 323.5 | 136.4 | *42.2* | 36.8 | 15.5 | *42.2* |
| **Forecasts** | | | | | | | |
| 2012 | 56.6 | 376.0 | 146.1 | *38.9* | 38.6 | 15.0 | *38.9* |
| 2013 | 58.6 | 365.5 | 151.3 | *41.4* | 37.1 | 15.3 | *41.4* |
| 2014 | 61.9 | 365.8 | 159.8 | *43.7* | 36.7 | 16.0 | *43.7* |
| 2015 | 66.8 | 373.0 | 172.5 | *46.2* | 36.9 | 17.1 | *46.2* |
| 2016 | 68.3 | 379.7 | 176.6 | *46.5* | 37.1 | 17.2 | *46.5* |
| 2017 | 70.1 | 387.3 | 181.2 | *46.8* | 37.3 | 17.5 | *46.8* |
| 2018 | 72.0 | 391.4 | 186.2 | *47.6* | 37.3 | 17.7 | *47.6* |
| 2019 | 74.3 | 398.5 | 192.1 | *48.2* | 37.5 | 18.1 | *48.2* |
| 2020 | 78.4 | 403.3 | 202.6 | *50.2* | 37.5 | 18.8 | *50.2* |
| 2021 | 82.6 | 410.8 | 213.5 | *52.0* | 37.7 | 19.6 | *52.0* |

Source: own calculation on FAO, OECD, and USDA data.

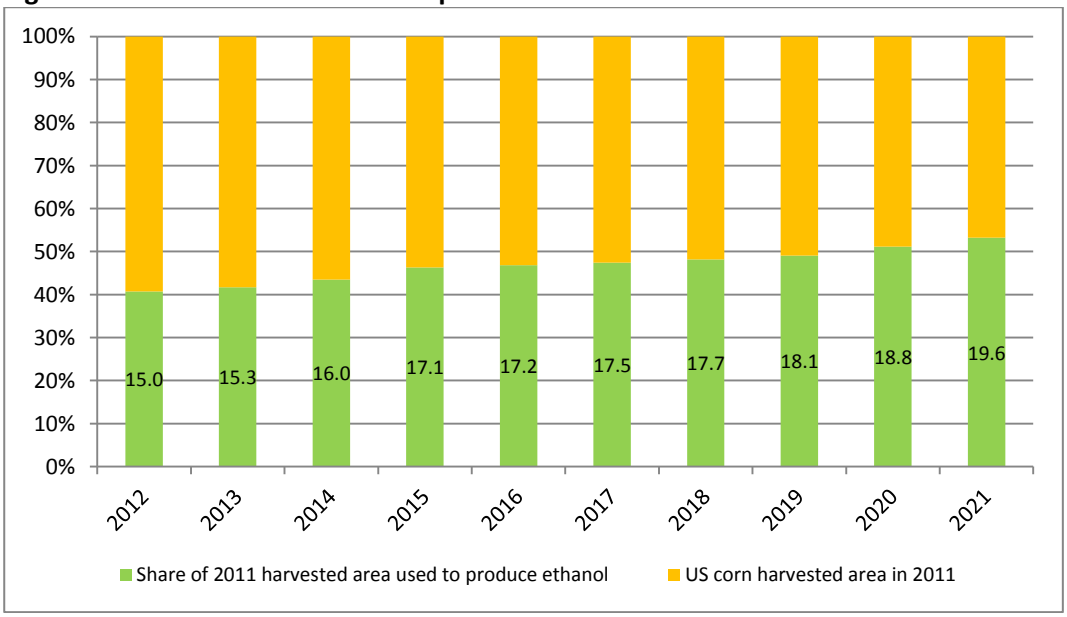
**Figure 5.8. Actual and forecasted corn production and quantities used for ethanol production.**




Source: own calculation on FAO, OECD, and USDA data.

In 2021, in order to produce the forecasted 82.6 million $m^3$ of ethanol, it will be needed more than 53% of the current area used for corn cultivation and 6.3% of current total agricultural area. It seems clear that, unless new and more productive production systems are introduced and employed in the ethanol sector, this is not sustainable on the long term. World demand for corn is increasing at great pace due to increased demand for feed (mainly produced from corn and soybean) in emerging economies where people are demanding more animal products thanks to their higher income that allows them to move from staple food to processed ones, like in developed countries (Figure 5.9).

**Figure 5.9. US: corn area needed to produce biodiesel as a share of 2011 total corn area.**




Source: own calculation on FAO, OECD, and USDA data.

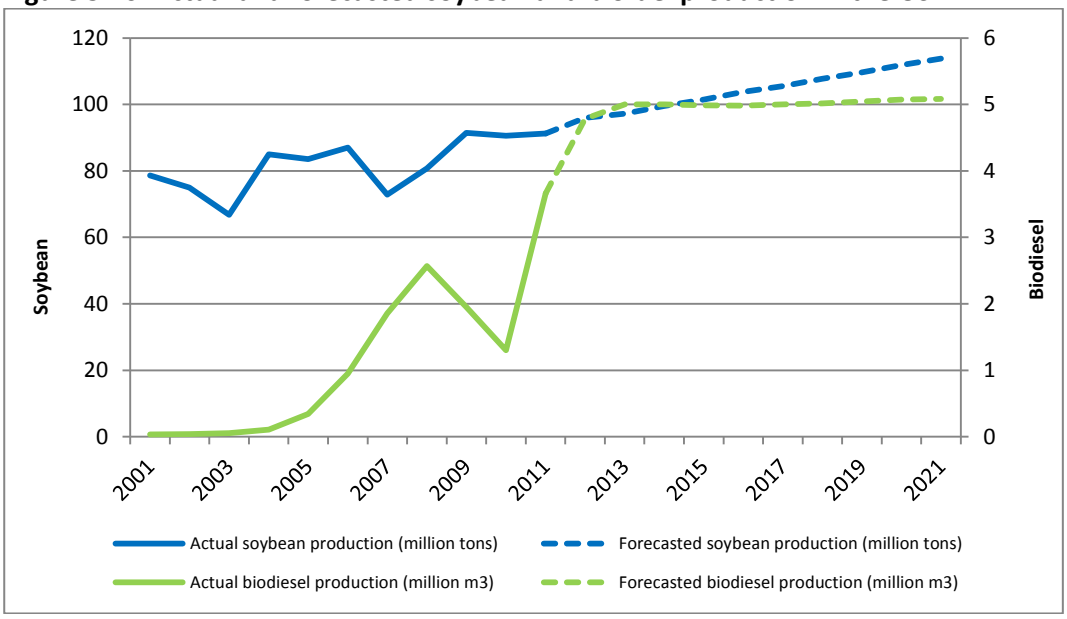
### 5.2.2 United States biodiesel.

Similarly to Brazil, also the US has started to subsidize the biodiesel sector and, analogously to the South American country, also in the US, the main feedstock for biodiesel production is assumed to be soybean oil, the cheapest and most widely available source of vegetable oil in the country.

In 2011 the US produced 91.2 million tons of soybean, 0.7% up from 2010. Production has been increasing steadily since the beginning of the 90s, without the big spikes that characterized corn expansion. Nevertheless, soybean production did increase: 2011 production was 21.5% higher than in 2000 and 74.1% higher than in 1990. Also harvested areas expanded, even though by a slightly lesser extent, meaning an increase in productivity. In 2011 harvested soybean area in the US was 35.2 million ha, 13.5% more than in the previous year. The difference with respect to 2000 and 1990 was of 20.1% and 53.9% respectively.

Biodiesel started to be produced at a commercial scale only in the early 2000s but production has increased significantly in the last few years. according to USDA data, 2011 biodiesel production, in the US, was 3.7 million $m^3$, almost 1.8 times higher than in the previous year. Production, however, has not been increasing continuously since the beginning of the decade. In 2001 US biodiesel production was just 0.03 million $m^3$ but already in in 2008 it reached 2.6 million $m^3$, to decrease in 2010 to 1.3 million (Figure 5.10).

**Figure 5.10. Actual and forecasted soybean and biofuel production in the US.**




Source: own calculation on FAO, OECD, and USDA data.

In 2011 25.3 million tons of soybean were used in the US to produce biodiesel. The estimate has been done using the same conversion coefficient used for Brazil in the previous section. This quantity represented 27.7% of the total US soybean production, and was sensibly higher than that of 2010 when just 9.0 million tons of soybean (or 9.9% of total production) were employed in the biodiesel industry. The substantial and increase in biodiesel production in the very last years might be among the causes of the surge in soybean prices that characterized 2012. In 2001 just 0.3%of the US soybean production was used

to produce biodiesel, while in in 2012 it is forecasted to be more than one-third. While biodiesel production increased 113 times since 2001, soybean output grew only 1.15 times and this certainly had an impact on soybean availability and, consequently, on price levels. In terms of harvested area, in 2011, 9.8 million ha were needed to produce the feedstock necessary for biodiesel in the US (2.4% of total agricultural area), 116 times more than in 2001 (Table 5.4).

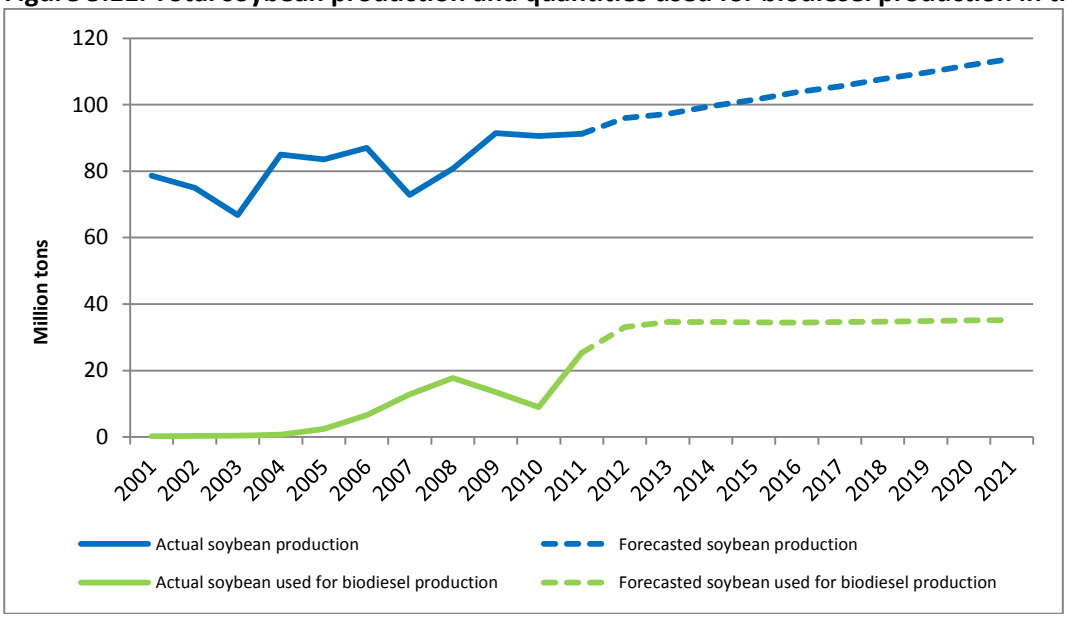
According to our estimates, in 2012, 33.1 million tons of soybean will be needed to produce the 4.8 million $m^3$ that the OECD-FAO outlook forecasts the US will be producing. For the following years, quantities needed should stabilize, provided current policies remain unchanged. In 2021, 35.1 million tons of soybeans will be employed in the biodiesel sector in the US, or 30.9% of total production. The area needed to grow soybeans used for biofuel production will be slightly less than 12 million hectares, 2.9% of current total agricultural area. This might cause big problems in terms of soybean availability, especially for the animal feed sector. It must be highlighted the fact that, however, making forecasts for the biofuel sector, in the US, is more difficult than in the case of ethanol since in last years production has been erratic and it is not easy to make assumptions about the future (Figure 5.11).

**Table 5.4. United States: soybean and biodiesel production, 2001-2021.**

| Year | Biodiesel production (million m3) | Soybean production (million tons) | | | Soybean area harvested (million ha) | | |
|---|---|---|---|---|---|---|---|
| | | Total | For biodiesel production | % for biodiesel prod. | Total | For biodiesel production | % for biodiesel prod. |
| 2001 | 0.0 | 78.7 | 0.2 | *0.3* | 29.5 | 0.1 | *0.3* |
| 2002 | 0.0 | 75.0 | 0.3 | *0.4* | 29.3 | 0.1 | *0.4* |
| 2003 | 0.1 | 66.8 | 0.4 | *0.6* | 29.3 | 0.2 | *0.6* |
| 2004 | 0.1 | 85.0 | 0.7 | *0.9* | 29.9 | 0.3 | *0.9* |
| 2005 | 0.3 | 83.5 | 2.4 | *2.8* | 28.8 | 0.8 | *2.8* |
| 2006 | 0.9 | 87.0 | 6.6 | *7.5* | 30.2 | 2.3 | *7.5* |
| 2007 | 1.9 | 72.9 | 12.8 | *17.6* | 26.0 | 4.6 | *17.6* |
| 2008 | 2.6 | 80.7 | 17.7 | *22.0* | 30.2 | 6.6 | *22.0* |
| 2009 | 2.0 | 91.4 | 13.5 | *14.8* | 30.9 | 4.6 | *14.8* |
| 2010 | 1.3 | 90.6 | 9.0 | *9.9* | 31.0 | 3.1 | *9.9* |
| 2011 | 3.7 | 91.2 | 25.3 | *27.7* | 35.2 | 9.8 | *27.7* |
| **Forecasts** | | | | | | | |
| 2012 | 4.8 | 96.0 | 33.1 | *34.4* | 35.9 | 12.4 | *34.4* |
| 2013 | 5.0 | 97.3 | 34.6 | *35.5* | 36.0 | 12.8 | *35.5* |
| 2014 | 5.0 | 99.5 | 34.6 | *34.7* | 36.4 | 12.6 | *34.7* |
| 2015 | 5.0 | 101.4 | 34.5 | *34.0* | 36.7 | 12.5 | *34.0* |
| 2016 | 5.0 | 103.8 | 34.4 | *33.2* | 37.1 | 12.3 | *33.2* |
| 2017 | 5.0 | 105.5 | 34.6 | *32.7* | 37.3 | 12.2 | *32.7* |
| 2018 | 5.0 | 107.7 | 34.7 | *32.2* | 37.6 | 12.1 | *32.2* |
| 2019 | 5.0 | 109.7 | 34.9 | *31.8* | 37.9 | 12.0 | *31.8* |
| 2020 | 5.1 | 111.9 | 35.1 | *31.4* | 38.2 | 12.0 | *31.4* |
| 2021 | 5.1 | 113.8 | 35.1 | *30.9* | 38.5 | 11.9 | *30.9* |

Source: own calculation on FAO, OECD, and USDA data.

**Figure 5.11. Total soybean production and quantities used for biodiesel production in the US.**




Source: own calculation on FAO, OECD, and USDA data.

The FAO-OECD outlook forecasts US soybean production to increase in the future but it is not clear how this will happen since harvests in recent years have been often damaged by extreme weather events and it is difficult to imagine a substantial increase in yields.

## 5.3 European Union.

Biodiesel is the most important biofuel produced in Europe and the EU is the major biodiesel producer in the world. Historically, biodiesel has been produced from rapeseed oil in the EU, however, in recent years, due to the great expansion of production, the EU started to import significant quantities of palm oil from Indonesia and Malaysia. Estimating the amount of rapeseed and palm oil used for biodiesel consumption, in the EU has been more problematic that estimating the amount of sugar cane or corn used to make ethanol in Brazil or the US. In the EU one cannot assume that the Union is self-sufficient in terms of biofuel feedstock: since the mid-2000s domestic rapeseed production was lower than the quantity needed to make the biodiesel actually produced.

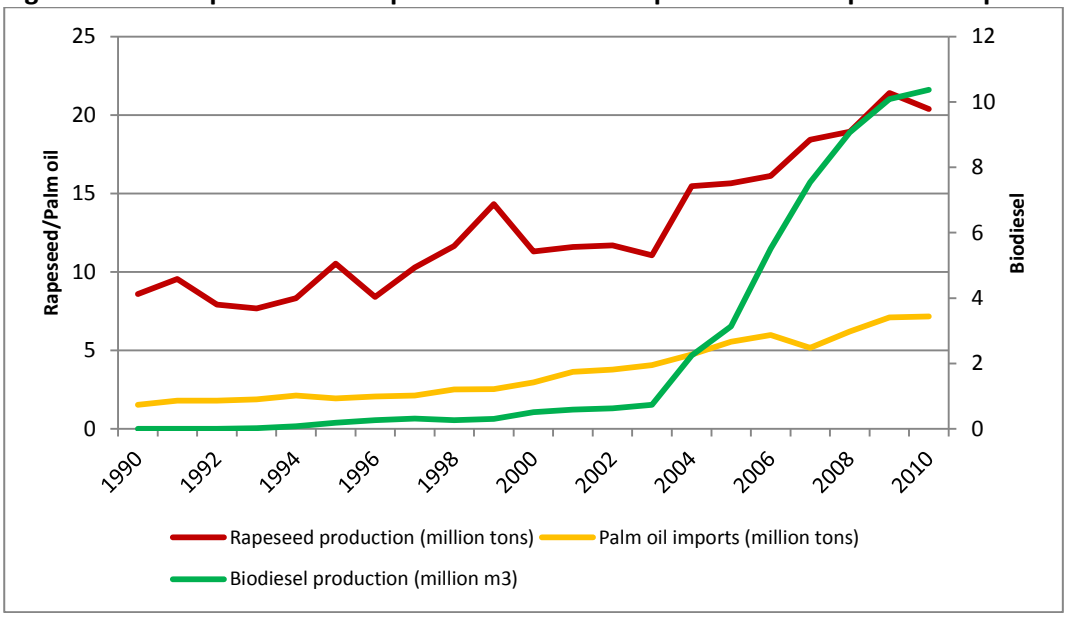
Since rapeseed oil is used also for food consumption, the quantity of rapeseed oil available for biodiesel consumption has been extrapolated subtracting (on the basis of FAO estimates) the amount of rapeseed oil used for food purposes from total production. It has been assumed that until domestic rapeseed oil production was sufficient to produce all the biodiesel actually produced in a given year the EU was not importing palm oil. When the estimated quantity of rapeseed oil needed to produce all the biodiesel manufactured in the EU in a given year was higher than the rapeseed oil available for non-food nor feed use, it has been assumed that the EU would import necessary vegetable oil from abroad, specifically it was assumed it would import palm oil from South-East Asia. This assumption is supported by actual trade flows data, which show a significant increase in palm oil imports in the second half of the 2000s.

Further assumption had to be made in order to make forecasts from 2012 to 2021. Since the OECD-FAO Agricultural Outlook provides production estimates for oilseed crops as a whole, it has been assumed that the share of rapeseed on total oilcrops production/area harvested would remain, in the years from 2012 to 2021, as it was in 2011, last year for which actual data were available.

According to the FAO, in 2010 (last year for which data were available), the EU rapeseed production was 20.4 million tons, 4.7% down from 2009 but 80.5% higher than in 2000 (that is before the implementation of the policies in favor of biodiesel) and 1.4 times higher than in 1990. EU production of rapeseed followed the same path: it increased slowly until the beginning of the 2000s and then increased to grow at a higher rate. In 2010 the EU production of rapeseed oil was 9.0 million tons, more than twice than in 2000, when it was just 4.4 million tons. Eurostat started recording EU biodiesel production since the

early 90s. Production of biodiesel remained very low until 2002, when the EU output was 0.73 million $m^3$. Production started to grow exponentially in 2003, thanks to the introduction of the Directive 30/2003/EC aimed at promoting biofuel consumption in the Union. Already in 2003 production jumped to 2.2 million $m^3$ and kept increasing at a high rate until 2011, when it reached 10.9 million $m^3$. In the same time span also total palm oil imports increased, since palm oil can be also used as feedstock for biodiesel production. Imports (mainly from Indonesia and Malaysia) grew steadily from 1.5 million tons in 1990 to 3.8 million tons in 2003. Until that year one can be reasonably sure that most of the palm oil imported was used in the food industry, however, since 2004 onwards, increasing quantities of it started to be employed in biodiesel production. Imports grew consequently and reached 7.2 million tons in 2010 (Figure 5.12).

**Figure 5.12. European Union: rapeseed and biodiesel production and palm oil imports.**




Source: own calculations on FAO and Eurostat data.

Assuming an oil content of 38% in the case of rapeseed and of 20% in the case of palm oil, it was possible to estimate the quantities of rapeseed and palm oil used in biodiesel production in the EU in the past years.

Until 2004 one can assume that EU biodiesel had been produced almost exclusively from domestically produced rapeseed oil. In 2004 1.9 million tons of rapeseed oil were used to produced biodiesel in the EU, equal to 40.3% of total production. In the following years EU rapeseed oil production was not sufficient anymore to make all biodiesel the EU needed to meet its consumption mandates and it had been necessary to import vegetable oil from abroad. It is reasonable to assume that most of the imported vegetable oil for biodiesel production is palm oil from Indonesia and Malaysia, cheaper than Canadian rapeseed oil. Assuming that all rapeseed oil not used for food/feed was transformed into biodiesel from 2005 to 2011, the EU must have imported from abroad the difference. It must be affirmed that the EU, in 2011 imported at least 3.9 million tons of palm oil to make biodiesel since the maximum quantity of rapeseed oil that

could be used for this purpose was 5.4 million tons, which needed 5.2 million ha of land to grow the necessary raw material (equal to 5.2% of total agricultural area). The area needed to make the imported palm oil, in exporting countries, was 1.3 million ha in 2011, 18.5% up from 2010 (Table 5.5).

**Table 5.5. European Union: rapeseed and biodiesel production and palm oil imports, 1990-2021.**

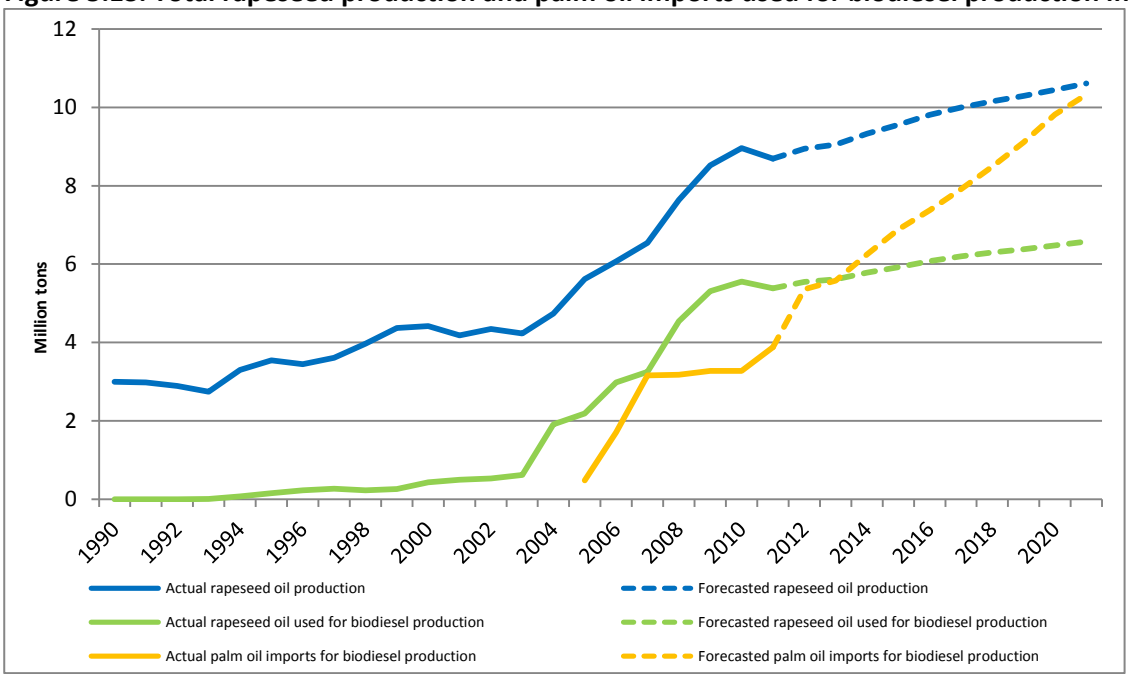
| Year | Biodiesel production (million m3) | Rapeseed oil prod. (m tons) | | Rapeseed area harvested (m ha) | | Palm oil | Oil palm fruit area in the world (m ha) | |
|---|---|---|---|---|---|---|---|---|
| | | For biodiesel production | % for biodiesel prod. on total prod. | For biodiesel production | % for biodiesel prod. | Imports to the EU (m tons) | For biodiesel production | % for biodiesel prod. |
| 1990 | 0 | 0.0 | *0.0* | 0.0 | *0.0* | | | |
| 1991 | 0 | 0.0 | *0.0* | 0.0 | *0.0* | | | |
| 1992 | 4,545 | 0.0 | *0.1* | 0.0 | *0.1* | | | |
| 1993 | 14,773 | 0.0 | *0.5* | 0.0 | *0.4* | | | |
| 1994 | 82,955 | 0.1 | *2.1* | 0.1 | *2.0* | | | |
| 1995 | 187,500 | 0.2 | *4.5* | 0.2 | *4.0* | | | |
| 1996 | 268,182 | 0.2 | *6.6* | 0.2 | *6.6* | | | |
| 1997 | 317,045 | 0.3 | *7.5* | 0.3 | *7.3* | | | |
| 1998 | 268,182 | 0.2 | *5.7* | 0.2 | *5.5* | | | |
| 1999 | 307,955 | 0.3 | *6.0* | 0.3 | *5.1* | | | |
| 2000 | 507,955 | 0.4 | *9.8* | 0.4 | *10.1* | | | |
| 2001 | 587,500 | 0.5 | *12.0* | 0.5 | *11.6* | | | |
| 2002 | 627,273 | 0.5 | *12.3* | 0.5 | *12.1* | | | |
| 2003 | 729,545 | 0.6 | *14.7* | 0.6 | *14.4* | | | |
| 2004 | 2,245,455 | 1.9 | *40.3* | 1.8 | *40.5* | | | |
| 2005 | 3,134,091 | 2.2 | *38.9* | 2.1 | *43.4* | 0.5 | 0.2 | 0.3 |
| 2006 | 5,514,773 | 3.0 | *49.2* | 2.9 | *53.3* | 1.7 | 0.6 | 1.1 |
| 2007 | 7,539,773 | 3.3 | *49.7* | 3.1 | *48.0* | 3.2 | 1.0 | 1.7 |
| 2008 | 9,065,909 | 4.5 | *59.4* | 4.4 | *71.5* | 3.2 | 1.0 | 1.8 |
| 2009 | 10,084,091 | 5.3 | *62.3* | 5.1 | *79.1* | 3.3 | 1.1 | 1.8 |
| 2010 | 10,375,000 | 5.6 | *62.0* | 5.4 | *77.8* | 3.3 | 1.1 | 1.7 |
| 2011 | 10,885,473 | 5.4 | *62.0* | 5.2 | *72.6* | 3.9 | 1.3 | n.a. |
| **Forecasts** | | | | | | | | |
| 2012 | 12,809,985 | 5.5 | *62.0* | 5.4 | 74.7 | 5.4 | 1.8 | n.a. |
| 2013 | 13,141,680 | 5.6 | *62.0* | 5.4 | 75.6 | 5.6 | 1.8 | n.a. |
| 2014 | 14,133,060 | 5.8 | *62.0* | 5.6 | 77.7 | 6.2 | 2.0 | n.a. |
| 2015 | 15,048,256 | 5.9 | *62.0* | 5.7 | 79.6 | 6.9 | 2.3 | n.a. |
| 2016 | 15,805,136 | 6.1 | *62.0* | 5.9 | 81.5 | 7.4 | 2.4 | n.a. |
| 2017 | 16,577,312 | 6.2 | *62.0* | 6.0 | 83.1 | 7.9 | 2.6 | n.a. |
| 2018 | 17,362,130 | 6.3 | *62.0* | 6.1 | 84.4 | 8.5 | 2.8 | n.a. |
| 2019 | 18,196,699 | 6.4 | *62.0* | 6.2 | 85.5 | 9.1 | 3.0 | n.a. |
| 2020 | 19,145,493 | 6.5 | *62.0* | 6.3 | 86.8 | 9.8 | 3.2 | n.a. |
| 2021 | 19,864,043 | 6.6 | *62.0* | 6.3 | 88.2 | 10.3 | 3.4 | n.a. |

Source: own calculations on FAO, OECD, and Eurostat data.

The quantity of rapeseed oil used in biodiesel production has been estimated assuming that the percentage of rapeseed oil on total vegetable oil production in the EU will remain the same of 2011 and that the share of it employed in the food sector will remain unchanged. In this way it is possible to state that, by 2021, at least 6.6 million tons of rapeseed oil (or 17.8 million tons of rapeseed) will be transformed into biodiesel. Nevertheless, in order to produce the 19.9 million $m^3$ of biodiesel the EU will have to import

at least 10.3 million tons of palm oil, mainly imported from South-East Asia, where at least 3.4 million ha will be needed to produce this quantity (Figure 5.13), an area equal to 3.4% of current Indonesian agricultural area.

**Figure 5.13. Total rapeseed production and palm oil imports used for biodiesel production in the EU.**




Source: own calculations on FAO, OECD, and Eurostat data.

In other words, the European Union will depend, for its biodiesel production, more and more from palm oil imports from tropical countries since the domestic vegetable oil production capacity is limited. This has important political and environmental implications. First of all one of the most important justifications politicians gave to their policies in favor of the biofuel sector was to increase energy security and raise agricultural income by "creating" a new market for agricultural products. However, if one uses imported vegetable oils to produce biofuels these two targets will never be reached. Moreover, since the methodology suggested by the RED to calculate the GHG emissions of the biofuel production process does not take into account feedstock produced outside the EU, the fact that large areas of rain forest are being logged down to create room for palm oil plantations in South-East Asia is totally neglected, leading to a strong underestimate of the GHG due to indirect land use changes in third countries.

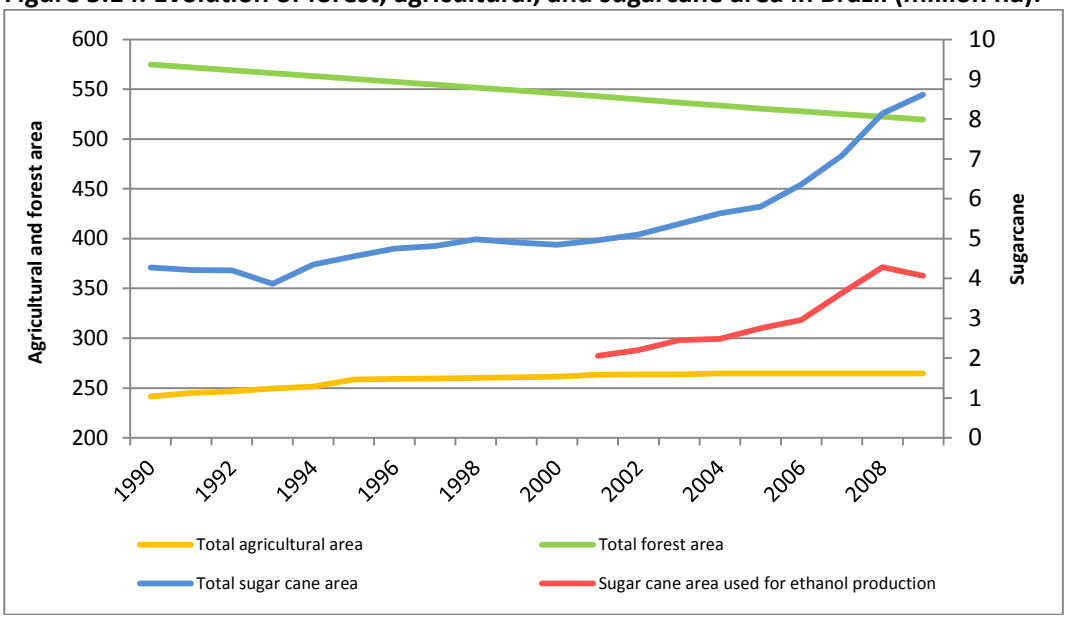
## 5.4 Biofuel production impacts on total agricultural area.

It is not easy to quantify the impacts of biofuel production on the agricultural sector as a whole, especially in terms of cultivated and forest area since updated data are not easy to obtain. The best source

in this sense is the Millennium Development Indicators published by the World Bank. These data are available up to 2009.

In the case of Brazil, since 1990 forest area has been decreasing steadily, from 575 million hectares in 1990 to 520 in 2009 (-9.6%). In the same time-span agricultural area expanded, even though with a less linear trend. In 1990 total Brazilian agricultural area was 242 million ha, while in 2009 it was 265 million ha, 9.5% more than twenty years before. The growth in total agricultural area, excluding sugarcane area (that almost doubled in the same period) would have been lower (+7.8%), meaning that ethanol expansion had a major impact on agricultural area increase. Even if it is difficult to establish whether the decrease in forest area is all due to ethanol expansion, since it is very likely that agricultural production in Brazil would have expanded anyways because of the increase in domestic demand, it is likely that it contributed significantly in the progressive erosion of the tropical forest (Figure 5.14).

**Figure 5.14. Evolution of forest, agricultural, and sugarcane area in Brazil (million ha).**

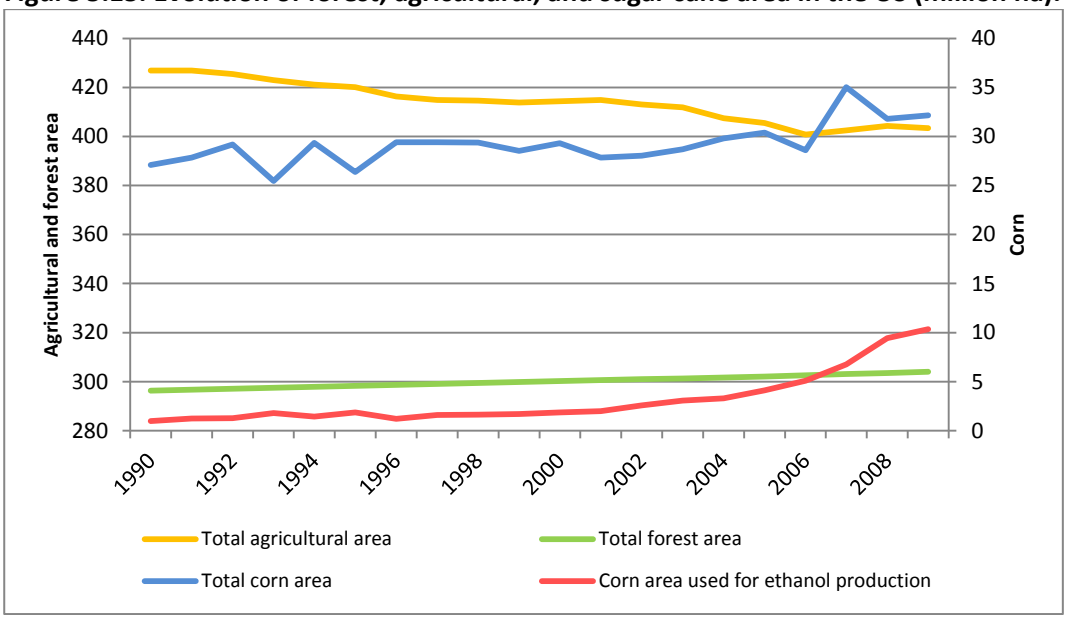



Source: own calculations on FAO, OECD, WB, and Brazilian Ministry of Agriculture data.

The picture, in the case of the United States in quite different. Between 1990 and 2009 total forest area, even if slightly, increased, as it happened in most of developed countries were awareness in terms of environment protection has been raising in the last two decades. Forest area grew from 296 to 304 million hectares (+2.6%) since 1990, while agricultural area decreased from 427 to 403 million hectares (-5.5%). This is another typical phenomenon of developed countries were marginal land is progressively abandoned and agriculture concentrates in the most productive areas where the cultivation intensity increases. In the US, for example, agricultural production has been increasing in the same time frame, meaning that more is produced in less land. Corn area increased in the last two years, especially in the second half of the 2000s, in coincidence with ethanol expansion. However the increase was not linear like that of corn area which

production has been used for ethanol production that increased exponentially during the 2000s (Figure 5.15).

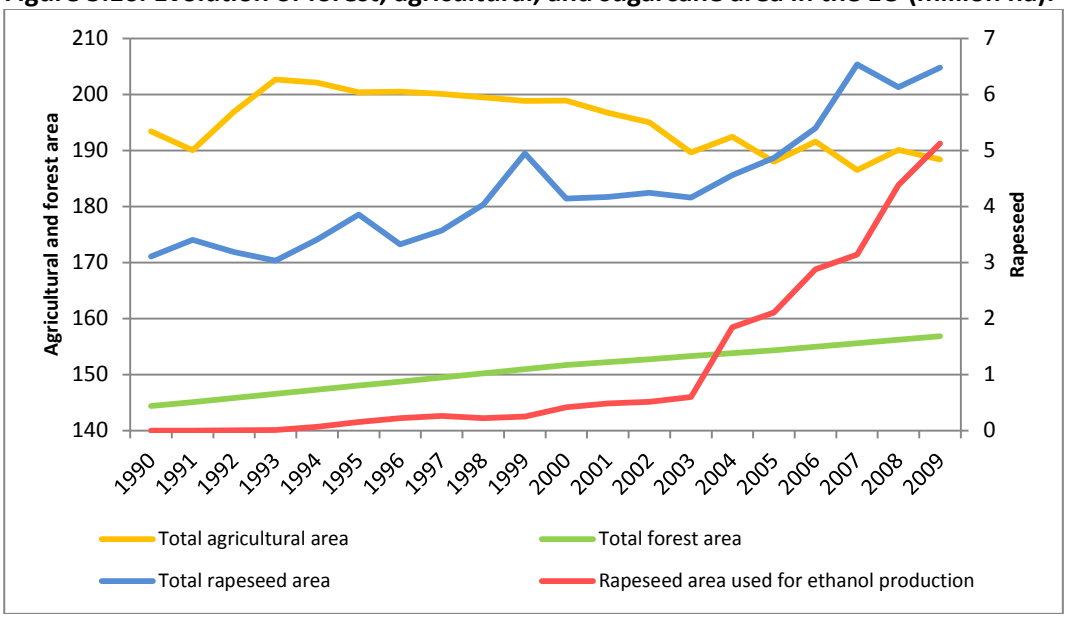
**Figure 5.15. Evolution of forest, agricultural, and sugar cane area in the US (million ha).**




Source: own calculations on FAO, OECD, WB, and USDA data.

In the European Union the situation is similar to the that of the US. Total agriculture area has been decreasing in the last two decades, falling from 193 million hectares in 1990 to 188 million ha in 2009 (-2.6%), while forest area has been increasing during the same time span, from 144 to 157 million hectares (+8.7%). Also in the EU case one can hypothesize that agriculture has been concentrating in the most productive area, where more is produced in less land. Similarly to what happened to US corn, also rapeseed area has been increasing in the last two decades, especially after 2003 (implementation of the Directive 2003/30/EC) (Figure 5.16).

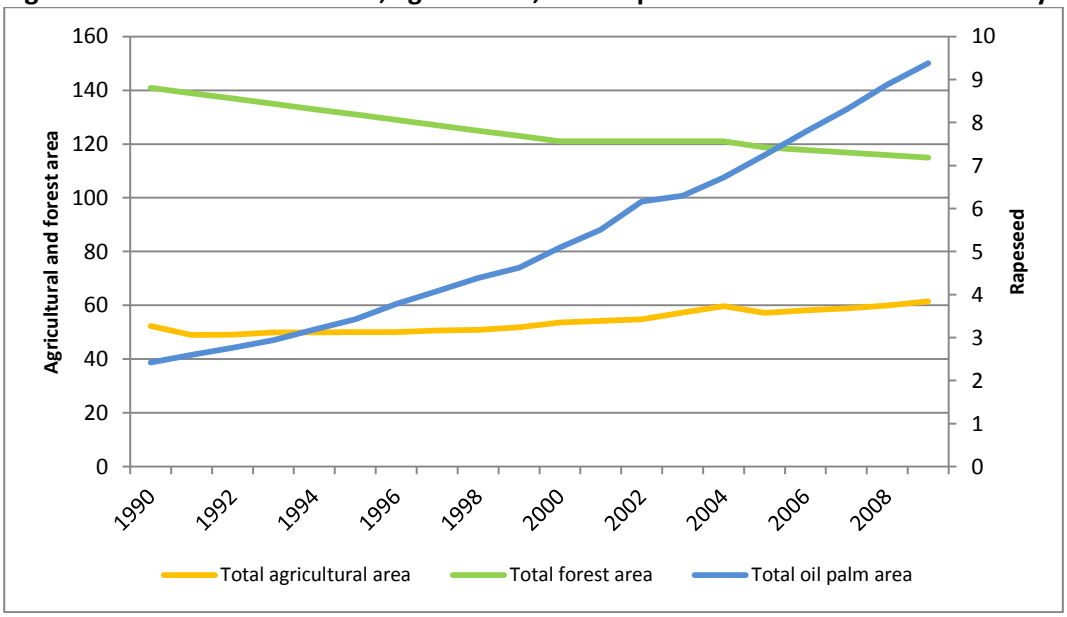
**Figure 5.16. Evolution of forest, agricultural, and sugarcane area in the EU (million ha).**




Source: own calculations on FAO, OECD, WB and Eurostat data.

In Indonesia and Malaysia the situation is much more like in Brazil and other emerging economies. Agricultural land increases at the expenses of forest area. In this part of the world the problem is particularly serious since deforestation is carried out by the means of fire on peat soils, implying a strong release of carbon into the atmosphere. Since 1990 forest area, in Indonesia and Malaysia, decreased by 18.5%, while agricultural land expanded by 17.5%. A substantial share of the agricultural land increase is due to oil palm plantation expansion. Oil palm plantation increased almost three times in the period under consideration (Figure 5.17).

**Figure 5.17. Evolution of forest, agricultural, and oil palm area in Indonesia and Malaysia (million ha).**




Source: own calculations on FAO, OECD, and WB data.

From these data one can conclude that biofuel expansion is developed and developing countries is leading to opposite phenomena. The first is the progressive intensification of agriculture in the US and the EU, which can in turn translate in an increasing level of pollution (due to increased use of herbicides and insecticides) and, ultimately, GHG emissions from the agricultural sector, that the reduction in fossil fuel consumption could only partially offset. In emerging countries, such as Brazil, and South-Eastern countries, agricultural area is expanding at the expenses of forest land since economic growth is allowing more and more people to consume more food, especially transformed or agricultural products. The increase in biofuel feedstock production is exacerbating the situation, especially in Asian countries.

# 6 Empirical assessment of the relationships between energy and agricultural prices in the US, Brazil and the EU.

This chapter is about price relationships between energy and agricultural markets in the US, Brazil and the EU, and on price transmission mechanisms between international and European agricultural commodity markets.

In recent years many studies claimed that, due to biofuel expansion, agricultural and energy markets are now more integrated than they used to be in the past (see chapter 4), because the rapid expansion of biofuel production created a new transmission channel between the energy and the agricultural sector. Until a couple of decades ago, or even less, changes in energy prices were transmitted to agricultural producer prices indirectly, that is through the increase or decrease in the cost of production factors (fertilizers, herbicides, gasoline for agricultural machinery). This typically meant that changes in energy prices would transmit to agricultural prices gradually and less directly than in the case of, for instance, manufactured goods. The transmission could even take place with some periods of delay.

Since the beginning of the 2000s, the strong increase in biofuel production might have created a direct channel of transmission given that the main feedstocks used for ethanol and biodiesel production are agricultural commodities such as corn and sugar cane. The fact that the biofuel and the food/feed sector share the same "production factor" increased the degree of integration between the two markets. This phenomenon is particularly strong in the US and in Brazil than in the EU since in the two American countries the biofuel sector is much more developed. Moreover, in the US and Brazil, the leading biofuel is ethanol, which is produced from corn and sugar cane, two major agricultural commodities used largely in the food and feed industry. In Europe the most important biofuel is biodiesel, which is obtained from vegetable oils, such as rapeseed oil and palm oil, which compete less with the food sector. Nevertheless, the increasing use of vegetable oils for biodiesel production can trigger indirect land use changes, especially in developing countries, that could in turn increase rather than reduce GHG emissions.

In the first part of this chapter (section 5.1) econometric techniques are employed to assess the extent to which changes in biofuel prices affect agricultural prices in the US, Brazil, and the EU and, *vice versa*, the extent to which changes in agricultural prices and oil price affect biofuel prices. Results show that the effect of ethanol prices on corn and soybean prices in the US is limited and taking place only in the short run, while in Brazil it is significant in the case of sugar cane. Nevertheless, estimation results show how in Brazil and in the US, ethanol prices are indeed influenced by agricultural and oil prices in the long run. In Europe, the relationship between biodiesel production and agricultural prices is negligible. However, in the last two decades the progressive dismantling of the old market measures of the Common Agriculture Policy (CAP) increased the level to which European agricultural markets are integrated with international ones. This means that the impact of changes in international prices on European prices has been increasing

in the last years. European farmers are less protected from fluctuations in International markets than they used to be in the past and therefore forced to work in a more risky environment. In the second part of this chapter (section 5.2), it has been investigated whether price transmission elasticity (the extent to which international prices are transmitted to European ones) has increased after the implementation of the Fischler reform. Results are in favor of the hypothesis of increased transmission. This means that European agricultural markets might be influenced by biofuel expansion in the US (since most of the international reference prices are fob US prices) in an indirect way, through the primary influence of increased biofuel production on US agricultural prices, which in turn influence EU prices, especially after the implementation of the last CAP reform that was specifically designed to re-align European prices to world ones.

It is not easy to isolate the effect of biofuel expansion and the Fischler reform from all other factors that might have an effect on agricultural prices, especially in the time span considered. In the same time-frame the world has experienced a strong increase in demand from emerging countries like China, India and Brazil and the progressive financialization of agricultural markets: since the early 2000s the number of financial transactions on agricultural future markets increased greatly even though the physical trade increased by a lesser extent. Furthermore, results, like it has already been acknowledged in the literature, depend on the methodology used, the time span considered, and data frequency.

## 6.1 Biofuel and agricultural prices.

This section analyzes the extent to which biofuel prices affect agricultural prices and *vice-versa* in the three main biofuel producing countries: the US, Brazil, and the EU. The analysis is carried out employing time-series econometric techniques. Since it would have been arbitrary to establish the causality relationship between agricultural and biofuel prices *a priori*, it has been tested both whether biofuel prices affect agricultural prices and *vice versa*. Results show that the effect of biofuel prices on agricultural prices is negligible, with the notable exception of Brazil, where, however, ethanol production started much earlier than in other countries. On the contrary, agricultural and oil prices affect biofuel prices, especially in countries characterized by efficient agricultural markets, such as the US, Brazil, and, in Europe, France. The next sub-section are about the methodology used (6.1.1), the data-set (6.1.2), the results (6.1.3), and the main policy implications (6.1.4).

### 6.1.1 Methodology.

The methodology used to assess whether and the extent to which energy and agricultural prices affect each other is cointegration techniques. Usually price series (especially when particularly long) are not

stationary[10], which means that they cannot be regressed on each other without occurring in the spurious regression phenomenon[11]. However, even if two (or more) variables are not stationary, it might exist a linear combination of them that is in fact stationary (Engle & Granger, 1987). When this happens the variables are said to be cointegrated. When two variables are cointegrated, they can be safely estimated through OLS without incurring in the spurious regression problem[12]. The cointegrating equation describes the long-run equilibrium between the variables. In case the null of no-cointegration is not rejected there is not a long run equilibrium between the variables. When neither the single series nor any linear combination of them is stationary it can still exist a short-run relationship between the variables, which can be estimated through OLS on the first-differences of the variables. In the bivariate case the long-run cointegrating equation is of the form:

$$y_t = \alpha + \beta x_t + \varepsilon_t$$

**Eq. 2**

Where $y_t$ and $x_t$ are the variables of interest (in this case prices) at time $t$, $\alpha$ and $\beta$ are parameters to be estimated and $\varepsilon_t$ is the error term. The null of no-cointegration can be reject if $\varepsilon_t$ is a stationary variable. The conventional Augmented Dickey-Fuller (ADF) unit root test can be applied to test whether $\varepsilon_t$ is stationary, provided that special critical values are used (provided in Davidson & MacKinnon, 1993).

The presence of a cointegrating relationship between two or more variables implies the existence of an error-correction specification that describes the short-run dynamics consistently with the long run relationship (Verbeek, 2006). Therefore if Eq. 2 is the long-run/cointegrating equation, the error-correction model (ECM) is of the form:

$$\Delta y_t = \delta + \theta \Delta x_t + \gamma \varepsilon_{t-1} + u_t$$

**Eq. 3**

Where $\theta$ is the short-run effect that is how much of a given change in $x$ is transmitted to $y$ in the current period, while $\gamma$ is the error-correction term representing how much of the difference between $x$ and $y$ occurred in the past period is eliminated in each period thereafter (Baffes & Gardner, 2003). $\varepsilon_{t-1}$ is the residuals of the long-run equation at time $t-1$.

[10] (Weak) stationarity means that the series is characterized by constant mean, variance, and co-variances. That is, after a shock, it tends to return to its long-run equilibrium and do not drift apart.

[11] The spurious regression problem arises when the OLS estimator finds a significant correlation between two variables even if they are completely unrelated. This might be due to the fact that the two variables (i.e. rabbit population in Italy between 1970 and 2000, and nominal GDP in the USA in the same time span) are both characterized by a similar stochastic trend (Verbeek, 2006).

[12] Spurious regression occurs when two or more variables, even if they do not have any direct causal connection, seems to be linked by a mathematical relationship due to simple coincidence or because of the presence of some other factor such as a time trend.

If one of the processes can be treated as exogenous, both the long-run equation and the error correction model can be estimated using the two-step procedure illustrated in Engle and Granger (1987). The two-step technique consists in estimating the long-run relationship through OLS (after having verified the price series are integrated of the same order) and then testing for stationarity of the residuals. When the null of no-cointegration is rejected the error-correction model can be also estimated through OLS using the residuals from the long-run equation.

The same methodology can be applied also in the multivariate case, which is what has been done in this work. In some cases, no cointegrating relationship can be identified between two or more variables, but this can be the consequence of a misspecification of the model or, in other worlds, the consequence of the omission of a relevant variable.

In the following sub-sections it will be tested the presence of a long-run, or cointegrating, relationship between energy and agricultural commodity prices in the US, Brazil, and the EU, making, in each case, different assumptions and different causal relationships.

### 6.1.2 Data.

Data used in this work are weekly prices for the main biofuels produced in the US, Brazil, and the EU: ethanol in the first two countries and biodiesel in the latter. The time span under consideration varies according to data availability as shown in Table 6.1. All prices have been converted in euros using the official exchange rate provided by the European Central Bank.

**Table 6.1 Description of the variables.**

| Variable | Beginning | End | Obs. | Source |
|---|---|---|---|---|
| US ethanol | 13/4/07 | 25/5/12 | 268 | United States Department of Agriculture |
| Brazilian ethanol | 22/11/02 | 25/5/12 | 497 | Brazilian Ministry of Agriculture |
| German biodiesel | 26/7/02 | 6/6/08 | 307 | (Busse, Brummer, & Ihle, 2012) |
| US corn | 8/1/99 | 25/5/12 | 699 | FAO |
| US soybean | 8/1/99 | 25/5/12 | 699 | FAO |
| US wheat | 8/1/99 | 25/5/12 | 699 | FAO |
| US oil (Texas) | 8/1/99 | 25/5/12 | 699 | US Energy Information Agency |
| Brazilian corn | 8/9/00 | 25/5/12 | 612 | Brazilian Ministry of Agriculture |
| Brazilian soybean | 8/1/99 | 25/5/12 | 699 | Brazilian Ministry of Agriculture |
| Brazilian sugar | 23/5/03 | 25/5/12 | 471 | Brazilian Ministry of Agriculture |
| French wheat | 8/1/99 | 25/5/12 | 699 | Canadian Ministry of Agriculture |
| French corn | 11/2/05 | 25/5/12 | 381 | MATIF |
| Italian wheat | 4/1/02 | 25/5/12 | 543 | Milan Board of Trade |
| Italian corn | 4/4/02 | 25/5/12 | 543 | Milan Board of Trade |
| EU oil (Brent) | 8/9/00 | 25/5/12 | 699 | US Energy Information Agency |

All prices have been transformed in natural logarithms in order to reduce heteroskedasticity problems and to allow the interpretation of coefficients as price elasticities.

In the case of the US and Brazil it was relatively easy to gather the price series needed, however, in the case of Europe, it was more problematic, especially in the case of biodiesel. The European reference biodiesel price can be considered Germany's since it is the leading EU biodiesel producer and one of the very few countries endowed with an efficient market for this commodity. French prices have been considered to be representative of EU prices in the case of corn and wheat since France is the major EU producer of both commodities. Even if these choices are rather arbitrary, it was possible to find similar justifications in the literature, especially in works concerning price transmission mechanisms (see Listorti (2009)). However, in the case of the EU, all estimates have been done also using Italian corn and wheat prices (Italian markers being less efficient and transparent that French ones), in order to verify whether results were similar.

### 6.1.3 Results.

In this subsection the results are presented by country, in order to better explain price dynamics in different contexts. Before running any regression, it has been tested for stationarity of the variables in levels using the conventional ADF unit-root and KPSS tests. Results show that all variables contain an unit-root but are integrated of order one (their first differences are stationary) meaning that it might exist a linear combination of them that is stationary. Results of the unit-root tests are provided in Table 6.2 and in Table 6.3.

**Table 6.2 Augmented Dickey-Fuller unit-root test.**

| Variable | Constant | Trend | Lags | Obs. | ADF | Verdict |
|---|---|---|---|---|---|---|
| US ethanol | No | No | 14 | 253 | -1.42 | Do not reject |
| BR ethanol a | Yes*** | Yes*** | 6 | 490 | -3.14* | Reject |
| BR Corn | Yes*** | Yes*** | 11 | 600 | -4.00*** | Reject |
| BR soybeans | Yes*** | Yes** | 13 | 685 | -2.63 | Do not reject |
| BR Sugar | Yes** | Yes* | 15 | 455 | -2.21 | Do not reject |
| US Corn | Yes** | Yes** | 14 | 684 | -2.23 | Do not reject |
| US soybeans | Yes*** | Yes** | 13 | 685 | -2.91 | Do not reject |
| US wheat | Yes*** | Yes** | 2 | 696 | -2.97 | Do not reject |
| IT Corn | Yes*** | No | 4 | 538 | -2.08 | Do not reject |
| IT wheat 2 | Yes*** | Yes** | 15 | 631 | -2.87 | Do not reject |
| FR wheat | Yes*** | Yes** | 14 | 684 | -2.8 | Do not reject |
| FR Corn | Yes** | No | 7 | 373 | -1.99 | Do not reject |
| GER Biodiesel | No | No | 1 | 305 | 1.91 | Do not reject |
| US oil | Yes*** | Yes*** | 14 | 684 | -3.88** | Reject |
| Oil Brent | Yes*** | Yes*** | 14 | 684 | -3.78** | Reject |

Source: own elaborations.
*, **, *** denote 10, 5, 1% significance level respectively.
Null hypothesis: unit root.

**Table 6.3 KPSS stationarity test.**

| Variable | Constant | Trend | Lags | Obs | Test stat. | Verdict |
|---|---|---|---|---|---|---|
| US ethanol | Yes*** | Yes*** | 6 | 268 | 0.59*** | Reject |
| BR ethanol a | Yes*** | Yes*** | 6 | 497 | 0.30*** | Reject |
| BR Corn | Yes*** | Yes*** | 6 | 612 | 0.49*** | Reject |
| BR soybeans | Yes*** | Yes*** | 6 | 471 | 1.05*** | Reject |
| BR Sugar | Yes*** | Yes*** | 6 | 471 | 0.40*** | Reject |
| US Corn | Yes*** | Yes*** | 6 | 699 | 1.24*** | Reject |
| US soybeans | Yes*** | Yes*** | 6 | 699 | 0.87*** | Reject |
| US wheat | Yes*** | Yes*** | 6 | 699 | 0.34*** | Reject |
| IT Corn | Yes*** | Yes*** | 6 | 543 | 0.26*** | Reject |
| IT wheat 2 | Yes*** | Yes*** | 6 | 647 | 0.51*** | Reject |
| FR wheat | Yes*** | Yes*** | 6 | 699 | 0.27*** | Reject |
| FR Corn | Yes*** | Yes*** | 6 | 381 | 0.41*** | Reject |
| Biodiesel no vat | Yes*** | Yes*** | 6 | 307 | 0.37*** | Reject |
| US oil | Yes*** | Yes*** | 6 | 699 | 0.29*** | Reject |
| Oil Brent | Yes*** | Yes*** | 6 | 699 | 0.25*** | Reject |

Source: own elaborations.
*, **, *** denote 10, 5, 1% significance level respectively.
Null hypothesis: (trend) stationarity.

Even though in some cases the ADF test allowed to reject the null of unit root, the fact that the KPSS always rejected the null of (trend) stationarity, induced to treat all variables as being non-stationary. First differencing was enough to transform all series in stationary ones. Since all variables are integrated of the same order it is possible to investigate whether exists a linear combination of them that is stationary.

### *6.1.3.1 Ethanol and agricultural commodity prices in the United States.*

In the case of the US it has been investigated the extent to which ethanol prices affect agricultural prices, namely corn (main ethanol feedstock) and soybeans and wheat, which compete with corn for land. Eq. 2 has been modified such as:

$$p_{it} = \alpha + \beta p_t^{eth} + \varepsilon_t$$

**Eq. 4**

Where $p_{it}$ is the price of the commodity $i$ (either corn, soybeans or wheat) at time $t$, $p_t^{eth}$ is the price of US ethanol at time $t$, $\alpha$ and $\beta$ are parameters to be estimated and $\varepsilon_t$ is the error term. The model can be augmented with a linear time trend, if significant. The relationship in Eq. 4 represents a long-run equilibrium and can be safely estimated through OLS provided the residuals are white noise or, in other words, the series are cointegrated. Results from the cointegration tests are reported in Table 6.4.

**Table 6.4. Engle-Granger cointegration test between ethanol and agricultural commodity prices in the US (ethanol independent variable)**

| Variables | US Corn | US Soybeans |
|---|---|---|
| Constant | 4.764*** | 5.431*** |
| Ethanol | 0.913*** | 0.457*** |
| Time | 0.001*** | 0.001*** |
| Observations | 268 | 268 |
| Start | 13/04/2007 | 13/04/2007 |
| End | 25/05/2012 | 25/05/2012 |
| R squared | 0.899 | 0.678 |
| DW | 0.3 | 0.15 |
| ADF | -2.89 | -3.36 |
| Cointegration | No | No |

Source: own calculations.
*, **, *** denote 10, 5, 1% significance level respectively.

In none of the cases it was possible to reject the null of no-cointegration, meaning that, in the time span considered, it is not possible to detect a long-run relationship between ethanol and single agricultural commodity prices in the US, or, put differently, changes in ethanol prices do not influence agricultural commodity prices in the long run. This is not surprising since it is more likely that agricultural prices are more influenced by ethanol production, which increases the demand for corn and therefore, in presence of a rigid supply in the short-run, contributes in increasing prices.

The same regression has been estimated substituting the price of oil to that of ethanol, to see the extent to which agricultural commodity prices are affected by oil prices. In neither case it was possible to reject the null of no cointegration (results not reported for the sake of brevity), meaning that the influence of changes in oil prices on agricultural prices is limited, at least in the time span considered (from January

1999 to May 2012). Even limiting the analysis to the last 5 years (from 2007 to 2012), since it is more likely interdependencies between energy and agricultural prices increased during the last price bubbles, it was not possible to reject the null of no-cointegration.

When the variables are not cointegrated it is still possible to investigate price relationship using the first differences, which are stationary series. However, in this case, estimated parameters cannot be interpreted as valid in the long-run anymore. Using first differences implies modeling just the short-run effects. Results from such exercise are reported in Table 6.5.

**Table 6.5. OLS on first differences between ethanol, oil, and agricultural prices in the US.**

| Variables | Δ US Corn | Δ US Soybeans | Δ US Corn | Δ US Soybeans | Δ US Corn | Δ US Soybeans |
|---|---|---|---|---|---|---|
| Constant | No | No | No | No | No | No |
| Δ Ethanol | 0.457*** | 0.412*** | | | | |
| Δ Biodiesel | | | | | | |
| Δ Oil | | | 0.123*** | 0.132*** | 0.230*** | 0.219*** |
| Time | No | No | No | No | No | No |
| Observations | 267 | 267 | 698 | 698 | 268 | 268 |
| Start | 13/04/2007 | 13/04/2007 | 08/01/1999 | 08/01/1999 | 13/04/2007 | 13/04/2007 |
| End | 25/05/2012 | 25/05/2012 | 25/05/2012 | 25/05/2012 | 25/05/2012 | 25/05/2012 |
| R squared | 0.11 | 0.11 | 0.02 | 0.02 | 0.06 | 0.07 |
| DW | 2.37 | 2.21 | 2.16 | 2.2 | 2.27 | 2.04 |

Source: own calculations.
*, **, *** denote 10, 5, 1% significance level respectively.

From the results it can be inferred that ethanol prices have an effect on both corn and soybean prices in the short run. A 1% change in ethanol price triggers a 0.457 and a 0.412% change in corn and soybean prices respectively. However, in both cases the explanatory power of the regression (expressed by the R-squared) is rather low (just 0.11) even for a regression in the first differences (which typically has relatively low R-squared values).

In the case of oil the effect is lower in absolute terms even though the influence of oil prices on agricultural prices seems to increase when the analysis is restricted to the post-2007 period. Nonetheless, the value of the R-squared is always close to zero, meaning that the influence of oil prices on agricultural prices, in the short terms, is almost negligible.

When ethanol is treated as the dependent variable the picture changes quite substantially. In this case four regressions have been estimated. In the first one ethanol price was regressed on US oil price only, in the second it was included also the price of corn, in the third the price of soybeans, and in the fourth the price of wheat. Only when the prices of all major agricultural commodities are included it was possible to detect a cointegrating relationship, meaning that energy and agricultural prices move together in the long-run. Results are shown in Table 6.6.

**Table 6.6. Engle-Granger cointegration test between ethanol and agricultural commodity prices in the US (ethanol dependent variable).**

| Variable | Regression 1 | Regression 2 | Regression 3 | Regression 4 |
|---|---|---|---|---|
| Constant | -3.040*** | -4.474*** | -4.150*** | -4.383*** |
| US oil | 0.673*** | 0.278*** | 0.285*** | 0.272*** |
| Soybeans | | | -0.114*** | -0.141*** |
| Corn | | 0.609*** | 0.667*** | 0.631*** |
| Wheat | | | | 0.119*** |
| R-squared | 0.59 | 0.91 | 0.91 | 0.92 |
| DW | 0.07 | 0.29 | 0.32 | 0.35 |
| ADF | -2.21 | -3.05 | -3.36 | -4.42** |
| Cointegration | No | No | No | Yes |

Source: own calculations.
*, **, *** denote 10, 5, 1% significance level respectively.

Therefore the long run-relationship between the variables is:

$$p_t^{eth} = -4.38 + 0.631p_t^{corn} + 0.272p_t^{oil} + 0.119p_t^{wheat} - 0.141p_t^{soy} + \varepsilon_t$$

The Durbin-Watson statistic is always very low indicating a high level of positive autocorrelation. This could be solved by adding lags of the dependent and independent variables, in order to obtain an autoregressive distributed lag (ADL) model, which coefficients, however, would be of difficult interpretation. One way to provide a nice economic interpretation of the regression coefficients of the static model is to use the error correction representation of the model itself (see Eq. 3). The ECM does not suffer from serial correlation of the residuals (because of the presence of the error-correction term) and yet its coefficients can be easily interpreted. the error-correction terms provides information about the long-run equilibrium, while the other parameters on the short-term effects.

The ECM is estimated regressing the change in the log US of ethanol price on the change in the log of oil, corn, soybean, and wheat prices as well as on the residuals of the cointegrating regression. Table 6.7 shows the estimated parameters of the ECM.

**Table 6.7. US ethanol, estimated error-correction model.**

| Variable | Δ_Ethanol |
|---|---|
| Δ_oil_t | 0.169*** |
| Δ_corn_t | 0.117** |
| Δ_soybeans_t | 0.125*** |
| Δ_wheat_t | 0.112** |
| Error corr. term | -0.122*** |
| R-squared | 0.29 |
| DW | 2.12 |

Source: own calculations.
*, **, *** denote 10, 5, 1% significance level respectively.

Amongst the parameters of the ECM the most important one is the error correction term, which gives a measure of the speed of adjustment of the system after a shock. The error-correction term also incorporates information from the long-run relationship in the short-run model. A coefficient of -0.122 means that if the ethanol price, in the previous period was higher than what the long-run equilibrium relationship predicts by 1%, then there will be an adjustment to reduce the ethanol price by 0.112% in the current period to re-establish the long-run equilibrium between the variables. The higher the error-correction term, the quicker the speed of adjustment to the long run equilibrium after a shock. The fact that the error-correction term is significant, is a further proof that there is a cointegrating relationship between the price series.

Since only 12% of last period's error is "corrected" in the current period, the speed of adjustment is rather low, meaning that the system takes a long time to go back to the long run equilibrium. In the short-run the impact of a change in either oil, corn, soybean or wheat prices has a positive impact on ethanol prices. Change in oil price have the greater impact on ethanol prices (0.169), followed by soybeans (0.125). In the case of corn, a 1% increase in corn price is translated into a 0.117% increase in ethanol price. Wheat price is the one that has the lower impact on ethanol prices (0.112).

From this exercise one can infer that, in the time span considered (from 2007 to 2012) the price of ethanol, and those of oil and the major commodities, moved together in the US, that is some force – arguably US policies in favor of biofuels – created a new link between energy and agricultural prices, with important implications for stakeholders, also in third countries, since American commodity prices are often regarded as reference prices at international level.

#### *6.1.3.2 Ethanol and agricultural commodity prices in Brazil.*

Also in the case of Brazil it has been investigated first whether ethanol price affects the price of the main agricultural commodities produced in the country: corn, soybeans, and sugar, which is used as feedstock for ethanol production. Since all the variables are not stationary, the relationship between the variables can be estimated, similarly to the US case, without incurring in the spurious regression problem,

only if the variables are cointegrated. Therefore the price of corn, soybeans, and sugar in Brazil are regressed on the price of Brazilian ethanol (3 separate equations). Results are illustrated in Table 6.8.

**Table 6.8. Engle-Granger cointegration test between ethanol and agricultural commodity prices in Brazil (ethanol and oil independent variables).**

| Variables | Commodities vs. Ethanol | | |
|---|---|---|---|
| | Corn | Soybeans | Sugar |
| Constant | 5.482*** | 5.876*** | 6.89*** |
| Ethanol | 0.554*** | 0.367*** | 1.128*** |
| Oil | | | |
| Time | No | No | No |
| Obs. | 497 | 497 | 471 |
| Start | 22/11/2002 | 22/11/2002 | 23/05/2003 |
| End | 25/05/2012 | 25/05/2012 | 25/05/2012 |
| R squared | 0.49 | 0.28 | 0.80 |
| DW | 0.03 | 0.02 | 0.07 |
| ADF | -2.91 | -2.10 | -4.24*** |
| Cointegration | No | No | Yes |

Source: own calculations.
*, **, *** denote 10, 5, 1% significance level respectively.

The estimation results show that only sugar cane price has a long run-relationship with the price of ethanol, since only in that case it is possible to reject the null of no-cointegration. In other words, in the period between May 2003 and May 2012 the price of sugar cane and the price of ethanol moved together. This is not surprising since the Brazilian ethanol sector is much more developed than in other countries. The South American country started to subsidize the sector already in the 70s, a period characterized by high crude oil prices and low sugar prices.

Also in this case it has been estimated the relative ECM, in this case using a lag of both the dependent and independent variable to resolve autocorrelation problems (Table 6.9).

**Table 6.9. Error-correction model for Brazilian sugar.**

| Variable | Δ_sugar_BRA |
|---|---|
| Δ_sugar_t-1 | 0.613*** |
| Δ_ethanol_t | 0.022 |
| Δ_ethanol_t-1 | 0.140*** |
| Error_corr_term | -0.010* |
| R-squared | 0.48 |
| D'h | 1.66 |

Source: own calculations.
*, **, *** denote 10, 5, 1% significance level respectively.

In this case the error-correction term is very low (and significant just at 10% significance level) meaning a very low speed of adjustment to the long-run equilibrium after a shock.

One might argue that the interdependence between ethanol, crude oil and agricultural commodity prices have increased in recent years, due to the strong increase in biofuel production. Therefore, in the case of corn and soybeans, the fact that the null of no-cointegration could not be rejected might have depended on the fact that a structural break took place sometime during the time span examined. A plausible date could be the beginning of the 2007, when ethanol production in the US really took off and Brazil re-enforced its policies in favor of biofuels[13]. Consequently the long-run relationship between ethanol and corn and soybean prices has been re-estimated augmenting the model with a dummy variable representing a structural break, that is to say a point after which the relationship between the variables changed. The estimated equation is:

$$p_{it} = \alpha_1 + \alpha_2 D + \beta_1 p_t^{eth} + \beta_2 p_t^{eth} D + \varepsilon_t$$

**Eq. 5**

Where $p_{it}$ is the price, alternatively, of corn and soybeans, $D$ is a dummy variable that takes the value 1 after January 2007 and zero otherwise, $\alpha_1$ and $\alpha_1 + \alpha_2$ are the value of the intercept before and after the break, and $\beta_1$ and $\beta_1 + \beta_2$ are the slope coefficients before and after the break. Estimation results are shown in Table 6.10.

**Table 6.10. Engle-Granger cointegration test between ethanol and agricultural commodity prices in Brazil (ethanol independent variable) allowing for a structural break (Jan 2007).**

| Variables | BR Corn (HAC se) | BR Soybeans (HAC se) |
|---|---|---|
| Constant | 4.787*** | 4.900*** |
| Biofuel_D | 0.707*** | 1.070*** |
| Ethanol | 0.146*** | -0.226*** |
| Eth_Biofuel_D | 0.316*** | 0.566*** |
| Obs | 497 | 497 |
| Chow | 97.5*** | 367.5*** |
| R squared | 0.72 | 0.76 |
| DW | 0.05 | 0.08 |
| Breusch-P. | 17.8*** | 78.2*** |
| ADF | -4.21** | -3.53 |
| Cointegration | Yes | No |

Source: own calculations.
*, **, *** denote 10, 5, 1% significance level respectively.

Allowing for a structural break it is possible to detect a long-run relationship also between ethanol and corn prices. If before 2007 a 1% change in ethanol price triggered a 0.146% increase in corn price, after

[13] Other break dates have been nonetheless tested but the only one that produced significant results.

the break, the same change in ethanol price affected corn price by 0.462%. In the case of soybeans the null of no-cointegration could not be rejected even allowing for a structural break.

Similarly to what has been done in the case of the US, also for Brazil it has been investigated the impact of changes in crude oil price on agricultural commodity prices.

Eq. 5 has been estimated also using crude oil as independent variable, to see whether biofuel expansion modified the long-run relationships between crude oil and agricultural commodity prices. Changes in crude oil prices are expected to influence, at least indirectly (through production cost) the price of agricultural commodities. The *a priori* hypothesis is that biofuel expansion increased the extent to which energy and agricultural markets interact. Also in this case January 2007 has been chosen as break date (Table 6.11).

**Table 6.11. Engle-Granger cointegration test between crude oil and agricultural commodity prices in Brazil (ethanol independent variable) allowing for a structural break (Jan 2007).**

| Variables | BR Corn (HAC se) | BR Soybeans (HAC se) | BR Sugar (HAC) |
|---|---|---|---|
| Constant | 4.108*** | 5.106*** | 0.785* |
| Biofuel_D | -1.869*** | -1.270*** | 3.134*** |
| Oil | 0.134** | 0.027 | 1.226*** |
| Oil_Biofuel_D | 0.560*** | 0.419*** | -0.751*** |
| Obs | 612 | 699 | 471 |
| Chow | 191.2*** | 130.5*** | 24.3*** |
| R squared | 0.74 | | 0.51 |
| DW | 0.06 | 0.05 | 0.02 |
| Breusch-P. | 1.83 | 86.2*** | 119.5*** |
| ADF | -5.03*** | -3.92* | -2.08 |
| Cointegration | Yes | Yes | No |

Source: own calculations.
*, **, *** denote 10, 5, 1% significance level respectively.

It is possible to reject the null of no-cointegration (meaning no interaction between prices) in the case of corn and in the case of soybeans, even tough, in the latter case just at 10% confidence level. In the case of corn, a 1% change in crude oil price implied a 0.134% change in corn price before the break, while after the same change in oil price triggered a 0.694% increase. In the case of soybeans, before the break the crude oil coefficient was not even significant, while after it increased to 0.419, meaning that an increase (decrease) in crude oil price implies a 0.419% increase (decrease) in soybean price in the long-run. These results have important implications since they show how the relationships between energy and agricultural markets have been increasing in the last few years.

Similarly to what has been done in the case of the US, one could argue that also crude oil and agricultural commodity prices might have an effect on ethanol price. Therefore the price of Brazilian

ethanol has been regressed on the price of crude oil and of its main feedstock, sugar cane, and then it has been tested for stationarity of the residuals to see whether the series are cointegrated (Table 6.12).

**Table 6.12. Engle-Granger cointegration test between ethanol price and crude oil and sugar cane prices in Brazil (ethanol dependent variable).**

| Variable | Ethanol |
|---|---|
| Constant | -5.737*** |
| US oil | 0.403*** |
| Sugar | 0.541*** |
| R-squared | 0.86 |
| DW | 0.12 |
| ADF | -5.12*** |
| Cointegration | Yes |

Source: own calculations.
*, **, *** denote 10, 5, 1% significance level respectively.

It was possible to reject the null of no-cointegration at 1% significance level, meaning that in the period considered (May 2003 to May 2012) the price of ethanol and those of crude oil and sugar were tied by a long-run relationship. In the long run a 1% change in crude oil price implies a change in ethanol price by 0.403, while the same change in sugar cane price means a 0.541% increase in ethanol price. The short term dynamics are described by the ECM reported in Table 6.13.

**Table 6.13. Error-correction model for Brazilian ethanol.**

| Variable | Ethanol |
|---|---|
| Δ_ethanol_t-1 | 0.473*** |
| Δ_oil_t | -0.012 |
| Δ_sugar_t | 0.065 |
| Δ_oil_t-1 | -0.047 |
| Δ_sugar_t-1 | 0.023 |
| Error_corr_term | -0.078*** |
| R-squared | 0.26 |
| D'h | 0.94 |
| Obs | 470 |
| Start | 30/05/2003 |
| End | 25/05/2012 |

Source: own calculations.
*, **, *** denote 10, 5, 1% significance level respectively.

The ECM (the model has been augmented with one lag of the dependent and independent variables according to the Hannan-Quinn and the Akaike criterion) tells us that the speed of adjustment to the long-run equilibrium is very slow (7% of last period's error is corrected in the current period) and that the short-run impact of changes in the price of sugar cane and crude oil is not significantly different from zero (none of the parameters is significant).

Summarizing, one can say that in Brazil, the price of ethanol is significantly affects by the price of sugar, also produced from sugarcane. Moreover, biofuel expansion modified the relationships between energy (crude oil) and agricultural markets the country: in the late 2000s the effect of changes in crude oil price on corn and soybean prices increased with respect to the first part of the decade. This has important policy implications since agricultural markers, in Brazil, could not only be affected by agricultural policies but also by policies implemented in the energy sector, which, until a few years ago had little effect. Policy makers must take these aspects into account when designing and implementing new policies in the future. In particular, it is desirable that policies affecting the energy and the agricultural sectors will be the result of an inter-disciplinary confrontation in order to avoid undesirable side effects on food production and security.

Finally, also the price of ethanol, in Brazil, is affected, to a certain extent by feedstock (sugar cane) and crude oil prices, highlighting once more the close interdependencies that have arisen between these markets in last years.

#### *6.1.3.3 Biodiesel and agricultural commodity prices in the EU (France and Italy).*

In the case of the European Union it is not so straightforward to identify reference prices for biofuels and agricultural commodities since agricultural markets are quite different from a country to another. Another important limiting factor is data availability: it is not easy to find reliable and long enough price series, especially with weekly frequency. Finding price data was particularly difficult in the case of biodiesel (the most important biofuel in the EU), for which it is almost impossible to obtain weekly price series free of charge. A partial solution to the problem was provided by a study by Brummer at al. (2012), which electronic form included a database of German biodiesel prices from July 2002 to June 2008. Using the German price as representative of biodiesel price in the EU seems reasonable since Germany is the leading biodiesel producer in the Union and maybe the only country endowed with an efficient biofuel market.

The main agricultural commodities produced in Europe are corn (for feed purposes) and wheat. In this case it was decided to consider French prices as representative for the whole Union, since France is the leading EU producer of both commodities and often the French price is used as reference price by operators. However, as a term of comparison, additional regressions have been run using Italian corn and wheat prices instead than French ones, to see whether one can draw the same conclusions.

Similarly to the case of the US and Brazil it has been investigated whether the price of corn and wheat depends on the price of the leading biofuel, in this case biodiesel. Results are shown in Table 6.14.

**Table 6.14. Engle-Granger cointegration test between German biodiesel price and corn and wheat price in France and Italy (biodiesel independent variable).**

| Variables | FR Corn | IT Corn | Wheat FR | Wheat IT |
|---|---|---|---|---|
| Constant | 0.425 | 2.435*** | -0.353 | 2.093*** |
| Biodiesel | 0.662*** | 0.385*** | 0.778*** | 0.442*** |
| Time | No | No | No | No |
| Obs. | 174 | 307 | 307 | 307 |
| Start | 11/02/2005 | 26/07/2002 | 26/07/2002 | 26/07/2002 |
| End | 06/06/2008 | 06/06/2008 | 06/06/2008 | 06/06/2008 |
| R squared | 0.04 | 0.06 | 0.10 | 0.05 |
| DW | 0.01 | 0.06 | 0.03 | 0.01 |
| ADF | -1.17 | -1.31 | -1.66 | -1.26 |
| Cointegration | No | No | No | No |

Source: own calculations.
*, **, *** denote 10, 5, 1% significance level respectively.

The null of no-cointegration was not rejected in any case, meaning that French and Italian corn and wheat prices do not move together with biodiesel prices in the period examined. The same exercise has been repeated using US ethanol as independent variable, in order to examine whether the effects of ethanol expansion in the US have direct repercussions also in the other side of the Atlantic. Also in this case, however, it was not possible to reject the null of no-cointegration (Table 6.15).

**Table 6.15. Engle-Granger cointegration test between US ethanol price and corn and wheat price in France and Italy (crude oil independent variable).**

| Variables | FR Corn | IT Corn | Wheat FR | Wheat IT |
|---|---|---|---|---|
| Constant | 5.395*** | 5.463*** | 5.457*** | 5.552*** |
| Ethanol | 0.770*** | 0.822*** | 0.712*** | 0.691*** |
| Time | No | No | No | No |
| Obs. | 268 | 268 | 268 | 268 |
| Start | 13/04/2007 | 13/04/2007 | 13/04/2007 | 13/04/2007 |
| End | 25/05/2012 | 25/05/2012 | 25/05/2012 | 25/05/2012 |
| R squared | 0.53 | 0.55 | 0.33 | 0.49 |
| DW | 0.07 | 0.04 | 0.26 | 0.03 |
| ADF | -2.94 | -2.41 | -1.92 | -2.13 |
| Cointegration | No | No | No | No |

Source: own calculations.
*, **, *** denote 10, 5, 1% significance level respectively.

Again, it has been tested whether corn and wheat prices, in France and Italy, are linked to crude oil prices (Brent), similarly to what happens for some commodities in the US and in Brazil. Again it was not possible to reject the null of no-cointegration in any case (Table 6.16).

**Table 6.16. Engle-Granger cointegration test between crude oil price and corn and wheat price in France and Italy (crude oil independent variable).**

| Variables | FR Corn | IT Corn | Wheat FR | Wheat IT |
|---|---|---|---|---|
| Constant | 2.140*** | 3.766*** | 3.163*** | 3.911*** |
| Oil (Brent) | 0.723*** | 0.346*** | 0.484*** | 0.331*** |
| Time | No | No | No | No |
| Obs | 381 | 543 | 699 | 647 |
| Start | 11/02/2005 | 04/01/2002 | 08/01/1999 | 07/01/2000 |
| End | 25/05/2012 | 25/05/2012 | 25/05/2012 | 25/05/2012 |
| R squared | 0.55 | 0.38 | 0.54 | 0.36 |
| DW | 0.06 | 0.02 | 0.12 | 0.01 |
| ADF | -2.95 | -2.47 | -2.62 | -2.77 |
| Cointegration | No | No | No | No |

Source: own calculations.
*, **, *** denote 10, 5, 1% significance level respectively.

It has been also tried to introduce a structural break in the price relationship to simulate the strong increase in biofuel production that took place in 2007 due to the implementation of EU policies in favour of biofuels. The introduction of the structural break (in the same way it has been done in the case of Brazil) was possible only in the oil regression since the biodiesel price series ends in 2008 and there would have been too few observations to for the results to be reliable (Table 6.17).

**Table 6.17. Engle-Granger cointegration test between crude oil price and corn and wheat price in France and Italy (crude oil independent variable), allowing for a structural break (Jan 2007).**

| Variables | FR Corn | IT Corn | Wheat FR | Wheat IT |
|---|---|---|---|---|
| Constant | 3.982*** | 5.353*** | 4.239*** | 5.679*** |
| Biofuel_D | -1.279*** | -2.716*** | -1.194*** | -2.320*** |
| Oil | 0.206* | -0.113*** | 0.149*** | -0.191*** |
| Oil_B_D | 0.393*** | 0.742*** | 0.386*** | 0.675*** |
| Obs. | 381 | 543 | 699 | 647 |
| Start | 11/02/2005 | 04/01/2002 | 08/01/1999 | 07/01/2000 |
| End | 22/05/2012 | 25/05/2012 | 25/05/2012 | 25/05/2012 |
| Chow | 94.9*** | | | |
| R squared | 0.72 | 0.64 | 0.68 | 0.68 |
| DW | 0.08 | 0.04 | 0.17 | 0.03 |
| ADF | -3.55 | -3.34 | -3.26 | -4.01* |
| Cointegration | No | No | No | Border-line |

Source: own calculations.
*, **, *** denote 10, 5, 1% significance level respectively.

Neither in this case it was possible to reject the null of no-cointegration (except than in the case of Italian wheat, which is border-line).

As pointed out earlier in this chapter, the fact that cointegration is not detected between two or more variables could also mean that the model is not well specified. Nevertheless, it seems not very plausible that crude oil prices do not affect agricultural prices at all since crude oil is used to produce some

very important agricultural inputs such as fertilizers and herbicides. Therefore, it has been tested whether all variables taken together have a long-run equilibrium. Results are show in Table 6.18 (France) and Table 6.19 (Italy).

**Table 6.18. Engle-Granger cointegration test between French corn and wheat prices and crude oil price.**

| Variable | Corn | Wheat |
|---|---|---|
| Constant | 0.810*** | -0.520*** |
| Brent | 0.282*** | -0.189*** |
| Corn | | 1.264*** |
| Wheat | 0.609*** | |
| R-squared | 0.89 | 0.86 |
| DW | 0.55 | 0.64 |
| ADF | -4.04** | -3.55* |
| Cointegration | Yes | No |
| Obs. | 381 | 381 |
| Start | 11/02/2005 | 11/02/2005 |
| End | 25/05/2012 | 25/05/2012 |

Source: own calculations.
*, **, *** denote 10, 5, 1% significance level respectively.

**Table 6.19. Engle-Granger cointegration test between Italian corn and wheat prices and crude oil price.**

| Variable | Wheat | Corn |
|---|---|---|
| Constant | 0.268*** | 0.797 |
| Brent | 0.041*** | 0.061*** |
| Soybeans | | |
| Corn | 0.933*** | |
| Wheat | | 0.785*** |
| R-squared | 0.83 | 0.83 |
| DW | 0.05 | 0.06 |
| ADF | -3.71* | -3.84** |
| Cointegration | No | Yes |
| Obs. | 543 | 543 |
| Start | 04/01/2002 | 04/01/2002 |
| End | 25/05/2012 | 25/05/2012 |

Source: own calculations.
*, **, *** denote 10, 5, 1% significance level respectively.

The null of no-cointegration was rejected in the case of French and Italian corn, meaning that the price of the commodity, in both countries, is a function of oil and wheat prices, that is the price of the main production factor and the price of the other main crop. In the long-run the effect of changes in crude oil price is stronger on French corn price (0.282) than in the case of Italian corn price (0.061). in both cases, however, the effect of a change in wheat prices on corn prices is much stronger. In the case of France, a 1% increase in wheat price leads to a 0.609% increase in corn price in the long run, while in the case of Italy a 1% increase in wheat price implies a 0.785% increase in corn price in the long run.

In both cases the short-run dynamics have been studied estimating the respective ECMs (Table 6.20)

**Table 6.20. Error-correction models for Italian and French corn.**

| Variable | Δ_Corn_IT | Δ_Corn_FR |
|---|---|---|
| Δ_corn_t-1 | 0.437*** | 0.090* |
| Δ_oil_t | 0.031 | 0.049 |
| Δ_wheat_t | 0.347*** | 0.106*** |
| Δ_oil_t-1 | 0.038* | 0.092** |
| Δ_wheat_t-1 | -0.027 | 0.073*** |
| Error_corr_term | -0.042*** | -0.052** |
| R-squared | 0.3 | 0.13 |
| D'h | 4.12*** | 0.96 |

Source: own calculations.
*, **, *** denote 10, 5, 1% significance level respectively.

In both cases the model has been estimated including one lag of both the dependent and the independent variables according to the indications provided by the various information criteria (AIC, BIC, HQ), however, only in the case of France this solved autocorrelation problems. This might be due to the fact that the Italian market is not very efficient since the bargaining modalities are often not fully transparent. For this reason it is advisable to consider results from the Italian ECM with caution. In the case of France the model seems well-specified. In the short-run wheat prices have a greater impact on corn prices than oil prices, similarly to what happens in the long-run equation. The role of crude oil price is much smaller and significant only after one lag. The speed of adjustment of the system towards the long-run equilibrium is rather slow: only 5.2% of last period's error is corrected in the current period.

### 6.1.4 Final considerations.

In this section the relationship between energy and agricultural markets in the three main biofuel producing countries has been analyzed using time series cointegration techniques since all the variables used in the analysis are not stationary. When all the variables contain a unit root, conventional OLS regression results are valid only if a linear combination of the variables is stationary, that is the variables are cointegrated. If so, not only the results of the OLS regression are not spurious (due to the fact that the variables might share a common trend) but represent a long-run equilibrium towards which the variables tend to converge after a shock.

Due to biofuel expansion in the countries under study, it might be the case that new relationships between energy (both fossil and renewable) and agricultural markets have arisen. One can argue that changes in biofuel prices might have an impact on the price of the agricultural commodities used in their production or in the price of commodities that compete for land with those used as biofuel feedstock.

However, one might also argue that it is the price of agricultural commodities that can influence the price of biofuels, especially in countries such as the United States and Brazil, where biofuel markets are quite developed. Furthermore the rapid expansion of the biofuel sector, as well as many other exogenous (to the agriculture sector) factors, might have changed the relationship between crude oil prices and agricultural prices. Changes in crude oil prices might have repercussions on producer prices (typically with some lags of delay) since crude oil is at basis of the production of many agricultural inputs such as fertilizers and herbicides, not to mention the energy needed to move agricultural machinery. The policy-induced expansion of the biofuel sector might have modified the relationship between oil and agricultural prices or, put in other words, might have created a new link between the energy and the agriculture markets.

These hypotheses have been formally tested for each of the three main biofuel producers: the US, Brazil, and the EU.

Commodities examined are corn, soybeans, and wheat in the US, corn, soybeans, and sugar in Brazil and corn and wheat in France and Italy (representative of the EU). In the case of the US and Brazil ethanol price has been considered the reference one for biofuels, while in the case of France and Italy it was used biodiesel price. The time span analyzed varies depending on the prices considered due to data availability.

In the United States, changes in ethanol prices are not able to explain, taken singularly, the long-run evolution of neither corn nor soybean prices, however, in the short run, they do have an impact on corn prices, since corn is the feedstock ethanol is produced from. Also the influence of changes in oil price on corn and soybean prices is limited, even in the short run and in the post-2007 period, when the biofuel sector expanded the most.

However, when regressing the price of ethanol on the prices of the three major agricultural commodities and the price of crude oil it is indeed possible to detect a long-run relationship. This means that the variables move together in the long-run. In the long run the price of ethanol is positively affected by the price of crude oil, wheat, and, especially, corn. Increases in soybean price have a negative effect on ethanol prices. In the short run (as it can be inferred from the error-correction model) changes in the price of oil or agricultural commodities always have a moderate positive effect on ethanol prices. Finally, the speed at which the system goes back to the long-run equilibrium after a shock is not very high (12% of last period's error is corrected in the current period).

In the case of Brazil the price of ethanol has a long-run effect on the price of sugar only. This is explained by the fact that the Brazilian sugar and ethanol markets have been very integrated for years. Ethanol production started to expand in Brazil, at the beginning of the 70s, thanks to major public incentives. In a situation characterized by high oil prices and low international sugar prices, it was a priority, for Brazilian policy-makers, to create an "alternative" market for domestically produced sugar and, at the same time, reduce the country's dependence on imported oil. Currently, ethanol and sugar are produced in

the same production facilities in Brazil and the government can, if the situation requires so, restrict ethanol production if sugar prices increase too much. In the short-run the impact of changes in ethanol price on sugar price is quite high, while the speed of adjustment after a shock to the long-run equilibrium is rather low. Changes in the price of ethanol have repercussions also on the price of corn, if a structural break in correspondence of 2007 (year in which many countries further increased their biofuel consumption mandates) is allowed. In particular, the effect is greater after 2007 than before. This might also be due to the fact that also Brazil, in recent years, started to produce ethanol from corn, such as the US.

The increase in biofuel production affected also the extent to which crude oil price affect agricultural commodity prices in Brazil, especially in the case of corn and soybeans. Before 2007 changes in oil price only marginally affected the price of corn, while did not affect at all the price of soybeans. After the break, the influence grew significantly, especially in the case of corn. Sugar prices are not affected by changes in oil prices. Finally, it must be noted that the relationship between sugar and ethanol prices, in Brazil, is bi-directional. The price of ethanol is itself influenced by changes in the price of crude oil and of sugar in the long run. This shows how policies in favor of biofuels have been having major consequences on agricultural markets by creating new relationship between energy and agricultural prices, which direction of causality is often hard to detect.

In the European Union the situation is much less clear-cut, also because it is more difficult to find reliable data sources, especially in the case of biodiesel, the major biofuel produced in the Union. The analysis has been carried out using German biodiesel prices and French and Italian wheat and corn prices, which have been considered representative of EU prices.

Estimation results show that neither corn nor wheat prices are affected by changes in biodiesel prices, as one would expect *a priori* since biodiesel is mainly produced from rapeseed oil (which only marginally compete for land with cereals) or, especially recently, from increasing quantities of imported palm oil. It was not possible to detect any long-run relationship between the price of crude oil (Brent) and corn and wheat prices neither, not even allowing for a structural break in 2007 (year in which biodiesel production in the EU substantially increased from previous years levels). Nevertheless, estimation results show how the price of corn, one of the most energy-intensive crops, does depend on oil and wheat prices in the long run, especially in France. This shows how energy and agricultural markets are nowadays integrated and how complex relationships between prices are. In France corn price is positively affected by wheat price (which compete with it for land) and, to a lesser extent by oil prices, between 2005 and 2012. In the short run the impact of changes in wheat and crude oil prices on corn prices is lower and in the case of oil significant only for the first lag.

The policy lesson that one can draw from this work is that in recent years the link between energy and agricultural prices has been tightening because of many factors, the most important of which is undoubtedly policies in favor of biofuels implemented by the US and Brazil, and, to a lesser extent the EU.

The fact that the EU has started subsidizing the biodiesel sector seems to have had, at least in the first years of implementation, minor effects on agricultural markets, even though the effects on the environment, especially in developing countries in which the vegetable oil used for biodiesel production is produced, might have been substantial.

In the US and in Brazil ethanol and agricultural prices move together in the long run and the influence of crude oil prices on agricultural prices has been growing over time. This means that in the future policy-makers will have to pay great attention to the effects policies in the energy sector might have on agricultural markets and *vice-versa*. Finally, implications are significant also in the case of the European Union, where the progressive dismantling of the protectionist measures of the PAC that protected for decades domestic farmers from world price fluctuation, has increased the degree to which changes in international prices are transmitted to domestic ones. In other words, EU agricultural markets, now more exposed to world price fluctuations, might be indirectly affected by biofuel policies overseas, through their direct effect on agricultural prices in the US, which are normally considered to be representative of world prices.

These aspects are explored in the next section, in which it will be assessed the extent to which world price signals are transmitted to the European Union and whether the extent to which they are passed through has increased after the implementation of the last reform of the Common Agricultural Policy (CAP), that took place in 2003 and was implemented at the beginning of 2007.

## 6.2 Price transmission mechanisms between EU and international agricultural markets.

This section investigates the extent to which price movements in international agricultural commodity markets are transmitted to the EU domestic market. EU agricultural markets have been almost completely isolated from world ones for many decades thanks to the Common Agricultural Policy (CAP) and its protectionist measures. These policies consisted mainly in market measures aiming at stabilizing domestic prices and keeping them higher that world market ones. In this framework, European farmers could operate in a sort of "protected environment," in which risk and price uncertainty were minimized. The main goal of European policy makers was to guarantee food self-sufficiency and boost farmers' income. Decades later, in the 80s, the system started to show its weaknesses: Europe was overproducing, the CAP expenditure had been increasing correspondingly, and many third countries were complaining that the EU (and the US), with their supporting policies (among which export subsidies), were in fact depressing world prices and impeding producers from other countries to enter the EU market. In the early 90s, pressure from the General Agreement on Tariffs and Trade (GATT) and, later, the WTO, urged the EU to reform the CAP and reduce market protection and import duties. The EU, therefore, started a long process of reform that is still in progress. In 1992 the MacSharry reform removed most market measures and substituted duties with

tariff equivalents and introduced payments to farmers linked to quantities produced. After a relatively minor reform at the end of the 90s (Agenda 2000s, which can be thought as a deepening of the MacSharry reform), in 2003 the Fischler reform decoupled support from production, removed the remaining guaranteed minimum prices (especially in the case of dairy products) and further decreased tariff barriers. The main result of this reform process is that now European agricultural markets are much more integrated to world ones than they used to be in past. This means that farmers have to face higher risk and uncertainty levels and operate in a much more complex context that they were used to. Increased market integration means also that the extent to which changes in world market prices are transmitted to the domestic market has been increasing. This has important implications since, according to many works in the literature, price volatility has been increasing in recent years because of increasing demand, progressive "financialization" of agricultural markets (that is to say an increase in financial transactions concerning agricultural commodities), and biofuel expansion. In the previous sub-section it has been shown that in the last decades biofuel production created (or deepened) a linkage between energy and agricultural markets, this new interdependence might influence agricultural producer prices in the US and in Brazil, which changes are then transmitted to European prices thanks to the progressive dismantling of CAP support measures. In the following subsections econometric time series techniques are used to demonstrate that market integration between world and European prices, and therefore the extent to which international prices are transmitted to European prices. In particular the section estimates the elasticity of price transmission (EPT)[14] between international and European prices. Two approaches have been followed to calculate the EPT. In the first one cointegration techniques are applied to non-stationary weekly price series allowing for a structural break (corresponding to the date of implementation of the Fischler reform) for corn, common wheat and soybeans. In the second approach the EPT has been calculated through OLS on stationary monthly price series always allowing for a structural break in correspondence of the date of full implementation of the Fischler reform (January 2007). An important difference between the two approaches concerns the type of price used to represent European prices. In the first approach French corn and wheat prices and Rotterdam cif[15] soybean prices have been considered representative of European prices, while in the second approach, EU-27 weighted[16] price averages have been employed instead. Moreover, in the second approach, the analysis has been widened to encompass also durum wheat, barley and butter markets.

In both cases results show how the full implementation of the Fischler reform increased the EPT between world and EU markets, even though the magnitude of changes varies with the commodity analyzed, the time-span considered, the data frequency employed and the econometric techniques used. The full implementation of the reform took place in a year, 2007, when strong perturbations interested

[14] A measure of the extent to which prices are transmitted between markets.
[15] Customs, insurance and freight.
[16] On the basis of volumes produced.

agricultural markets, such as the increase in global demand, the increasing interest of investment funds towards agricultural commodities and biofuel production itself, therefore the effects of the reform of the CAP might be "confused" to those of these other factors. Nevertheless, the reform did increase market integration. The case of butter – a commodity that is only marginally affected by speculation and biofuel production – is emblematic.

This section is organized as follows. Sub-section 5.2.1 describes the CAP reform process with special emphasis on the Fischler reform and its implications for price transmission. Sub-section 5.2.2. reviews the existing literature on price transmission in agricultural markets, focusing on studies that have assessed the role of policy reforms on price transmission mechanisms. Sub-section 5.2.3. describes the methodology used in the first approach (weekly non-stationary prices) and illustrates the main results and policy implications. Sub-section 5.2.4. is about the second approach (monthly stationary series) and the main results and policy implications. Sub-section 5.2.5. concludes and provides some hints for future research.

### 6.2.1 The Fischler reform of the CAP.

The Fischler reform of the Common Agricultural Policy (CAP) was agreed between Member States in 2003 and started to be implemented in 2005-07. Main targets of the reform were improving the competitiveness of European agriculture, increase agriculture's sustainability, shift resources from market/production-related measures to structural ones (rural development) and increase member states' role in policy definition and implementation. The competitiveness of European agriculture could be enhanced only by continuing the process of re-alignment of European prices to world ones started with the MacSharry reform in the mid-90s. However, a greater integration of European markets to the world ones also means a greater exposure of European farmers to price volatility, which can, in turn, substantially change agriculture's profitability and trigger deep changes in the structure of European agriculture.

Since the late 50s, when the European Union was established and policies in favor of European farmers started, support to farmers evolved in different ways for different products. In the late 60s, Common Market Organizations (CMOs) were put in place, each governed by its own basic regulation and governing a particular commodity. CMOs existed until 2007, when they were formally unified. Even though different CMOs implied different measures, they all tended to apply the same principles: support the domestic market, protect domestic farmers from imports and favor European exports (through subsidies). This system became out-to-date and politically very difficult to defend at the end of the 80s. Europe was overproducing, crops were not being harvested because of overproduction, and European exports were flooding international markets, consequently depressing prices. Many extra-European countries started to criticize European policies and formally asked, during the GATT (General Agreement on Tariffs and Trade) negotiations, to reduce them because highly discriminatory towards producers in third countries.

Since the conclusion of the Uruguay Round Agreement on Agriculture (URAA) in 1992 (that is the GATT negotiations), EU subsidies to agricultural production and exports have been constrained by WTO rules. Among others, there are restrictions on the total support to agriculture and on both the amount of export subsidies and the volume of exports that can be subsidized (Swinnen, 2001). In other words, the URAA provided the key incentives to convince the EU to reform the CAP. The first step in this respect was the reduction of market support measures and their replacement with direct payments to farmers, linked to production (MacSharry and, later, Agenda 2000 reforms). At the same time price support was reduced and import duties were transformed in tariff-equivalents, considered less trade-distorting. Direct payments were still, to a certain extent, market and trade-distorting and were included by the URAA in the blue box[17]. Even though already the MacSharry and the Agenda 2000 reforms tried to assess problems related to internal market balance and WTO negotiations, these measures were still considered not sufficient (Swinnen, 2001). For example, regarding the Agenda 2000 reform, the cut in cereal support price finally decided by the Council was of 15%, instead than the 30% proposed by the Commission. Burrell (2000) points out that even when the cereal price cuts [as in the Agenda 2000 reform] were complete, it would have been still impossible to export unless world prices (in US dollars) would have been particularly high or the euro particularly weak. During the Doha Round (early 2000s) many EU's trading partners urged the EU to eliminate export subsidies and reduce import barriers, especially for products with tariff peaks (Daugbjerg & Swinbank, 2007). The WTO also requested the EU to reduce production and price supports (amber box) by eliminating export subsidies and guarantee market access by cutting tariffs and other domestic supports by 60-80%. Contextually, the WTO also asked the EU to substantially decrease or abolish direct or coupled payments (blue box) (Lovec & Erjavec, 2012).

Mainly for all these reasons the Commission decided, in 2003, to transform a mid-term review of the CAP into a real reform, the core of which involved a change of policy instruments from those already used in the previous ones. Direct aid payments were decoupled and transformed into a new Single Farm Payment (SFP) scheme. Under the new regime farmers would receive subsidies on the basis of what they received – on average – during a reference period. The aid was guaranteed to farmers irrespective if they produced or not. However, they had to fulfill some basic environment and agricultural conditions (cross-compliance), which meant that the aid was not completely decoupled since land had to be kept in good agricultural conditions and recipients had to be farmers (Daugbjerg & Swinbank, 2007).

The dairy sector is one of those that, with the Fischler reform, underwent the deepest changes. In the case of butter the intervention price was reduced by 25% and market withdrawals were capped to 30,000 tons (Anania, 2007). With respect to cereals, the Fischler reform further decreased intervention

17 The Uruguay Round Agreement on Agriculture (URAA) classified agricultural trade measures under three headings. Amber box support was deemed to impact on production, distorting trade and consequently it has been capped and subject to reduction commitments. The green box contained measures that had not impact on trade. The blue box was an intermediate category of direct payments "under production-limiting programs."

prices (that is the price at which the EU would buy cereals in case market prices fell under a certain threshold) and fixed maximum quantities that could be sold to intervention (3 million tons per year for soft wheat and zero for other cereals). The combination of a very low intervention price (101.31 euro/t) and high market prices drastically reduced the use of this measure, which has been maintained just as "safety net" in case of strong perturbation on international markets. Import tariffs and variable import duties on high quality cereals are still in place, although reduced from previous levels. In case prices in the international market reach a level that might threaten the availability of supply of the European Union, the EU may suspend import duties, last time it happened was during the 2007/08 market year due to very high international prices. Export subsidies, although still in place (even if reduced), have become less and less important because of EU intervention prices have gradually fallen in line with world market prices. In 2008 export subsidies were granted for a total of 10 million euro, while in 1992, before the beginning of the CAP reforming process amounted to 3.1 billion euro. Since September 2006 no export refunds have been granted for cereals (European Commission, 2011).

The Fischler reform came into force in January 2005 but member states had time until the end of 2006 to implement it (notable examples are France and the Netherlands). The end of 2006 was also the last time export subsidies were used for cereals and the reduction in butter intervention price was implemented in the marketing year 2007/08. For all these reasons, January 2007 seems to be the ideal break date to discriminate between the "before" and the "after" reform period and with respect to which investigate changes in price transmission between the world and the domestic market.

### 6.2.2 Literature review on price transmission and policy reform.

Many works have tried to assess the extent to which prices are transmitted either from a market to another (horizontal transmission) or from a stage of the production chain to another (*i.e.* from producer to consumer price, vertical transmission), however much less have focused on price transmission changes due policy reforms, and even less on those (possibly) triggered by CAP reforms. According to Conforti (2004) factors affecting perfect transmission between markets are transport and transaction costs, market power, increasing returns to scale in production, product homogeneity, exchange rates, and border and domestic policies. The second, the third, and the fourth have been commonly studied with reference to vertical price transmission, while the last one has been mostly studied with reference to spatial price transmission (across markets). In recent years horizontal price transmission has been studied using time series econometrics that is a "non-structural approach" in which factors determining transmission are treated as external information, to be confirmed by the results. Still according to Conforti, results from such econometric applications are often controversial and sensitive to the technique employed.

If early works used simple cointegration techniques, more recent contributions have investigated the extent to which transmission is affected by the presence of asymmetric response, thresholds, or a

fractional order of integration of the price series. An interesting review of econometric models of asymmetric price transmission is provided by Frey and Manera (2007).

Amongst the works assessing EPT from world to domestic agricultural markets before and after the implementation of policy reforms, Baffes and Gardner (2003) found that only in a few cases policy reforms (mainly in trade liberalization) significantly increased price transmission from world to domestic markets. They used a simple OLS regression (checking for stationarity of the residuals) to assess whether EPT increased after the implementation of relevant policy reforms in 31 country/commodity pairs. The time span under consideration was from 1970 to the early 90s (depending on the country) and prices used were annual figures. The authors found that changes in world prices do not explain most of the variation in domestic prices. They explain their results by the fact that commodities traded are not perfectly homogenous, because of transport margins, and because the political impulse to insulate domestic markets from world commodity prices is remarkably persistent.

Krivonos (2004) followed the approach proposed by Baffes and Gardner to evaluate the impact of coffee sector reforms during late 80s and early 90s in the main coffee producing countries. Results suggest that the reforms induced a closer cointegrating relationship between grower prices and world market prices. The author also shows, through threshold cointegration techniques, the presence of asymmetries in the way positive and negative world price changes are transmitted into domestic markets.

Listorti (2009) introduces policy regime changes while testing for price transmission in international soft wheat markets, with special focus to the European Union and the CAP. Breaks are identified *a priori* on the basis of policy changes but the decision has also been "validated" by testing for unit-root in the individual series allowing for structural breaks.

A report by the International Food Policy Research Institute (Minot, 2011) assesses the degree to which changes in world food markets influence the price of staple foods in Sub-Saharan Africa. An error-correction model is used to estimate the degree of price transmission during the 2007-2008 period, characterized by a big surge in international commodity prices. The study uses monthly price data for 12 countries, all converted in the same currency (US dollar). Results show how staple food prices rose by 63% in the period under consideration, about three-quarters of the proportional increase in world prices. Moreover, only 13 of the 62 African food prices examined showed to have a long-term relationship with world prices.

Also the Food and Agriculture Organization of the United Nations (FAO) investigated the impact of trade policy reforms on price transmission from the world to the domestic market in the case of developing countries (FAO, 2006), taking into account also the effects of the exchange rate. The study was carried out for 65 country/commodity pairs following the approach proposed by Baffes and Gardner (2003) but augmenting the long-run equation with the real exchange rate, which turned out to significantly improve the model.

Thompson and Bohl (1999) were amongst the first ones to investigate the effects of the CAP on price transmission mechanisms. They estimated the international EPT for Germany over a period of policy regime changes using cointegration techniques. In particular they focused on the effects of the MacSharry reform on producer wheat prices in Germany. They divide the time span under study (from 1976 to 1998) in three policy regime periods. The authors found that EPT increased from 0.18 (during the 70s and the 80s) to 0.30 as a consequence of the URAA, showing that market liberalizing policies increase price transparency.

Listorti (2008) also worked on price transmission mechanisms in the wheat market, specifically, between the United States and the European Union. She uses cointegration analysis to assess the extent to which prices in the two countries were related in the years from 1978 to 2003 (using monthly figures), giving that the wheat market was deeply influenced by the CAP. The analysis was performed in the general framework of the law on one price (LOP) validity. Results show that there is no long-run relation between the US CIF price and the EU domestic price (proxied with the French price). A long-run relation was instead found between the US price and the EU external reference price (the maximum between the US price and the intervention price). This means that domestic and commercial EU policies for soft wheat actually played a strong role in insulating the internal market from the world one, at least before 1993. After this year the degree of integration increased, most probably because of a reduction in the EU intervention price, rather than a change in trade barriers, which instead remained mostly unchanged.

Dawson *et al.* (2006) examine the long-run relationship between the prices of feed barley and feed wheat on the Euronext LIFFE using weekly data for 1996-2002 through the Johansen, Mosconi, and Nielsen's cointegration procedure allowing for structural breaks at known points in time. Results show evidence of cointegration and the presence of a structural break in October 2000. The break correspond to the 15% reduction in cereal intervention price under Agenda 2000 and to the abolishment of barley export intervention. They also find that the barley price Granger-cause the wheat price and that similar price relationships are in place also between other commodity pairs.

Even though the literature on price transmission in agricultural markets is very wide, little has been done to evaluate the impact of CAP reforms on price relationships between world and European markets. The few works on this topic are about old reforms of the CAP and are focused on the cereal market only. In this respect this work is innovative, since it tries quantify the impact on EPT of the Fischler reform on five different agricultural commodities.

### 6.2.3 The first approach, estimating EPT with weekly non-stationary price series.

The aim of this work is to assess whether the price transmission elasticity (EPT, *i.e.* the extent to which world prices are transmitted into domestic markets) from the world market to the European and the Italian ones changed after the implementation of the Fischler reform. The SFP was officially introduced in

January 2005 but member states had time until the end of 2006 to implement it (Cap Monitor, 2009). For this reason January 2007 seems to be the ideal date from to discriminate between the before and after reform period and with respect to which investigate changes in price transmission between the world and the domestic market.

In order to measure EPT between world and domestic prices for corn, wheat, and soybeans cointegration techniques allowing for structural breaks are applied. US prices are considered to be representative of world prices. Prices included in the analysis are Argentinean, French, and Italian in the case of corn, Canadian, French, and Italian for wheat, and *cif* Rotterdam and Italian for soybeans. The *a priori* hypothesis is that the full implementation of the Fischler reform represented a structural break in the long-term relationship between world and European prices. In particular the reform is expected to have increased the extent to which world agricultural prices are transmitted to domestic prices. It also seems reasonable to take into account market perturbations that affected world agricultural markets in the time span taken into consideration: the price bubbles of 2003-04, and 2007-08. Since already the MacSharry and the Agenda 2000 reforms of the CAP addressed the problem of EU market isolation, we expect to find cointegration – that is a certain extent of price transmission – between European and world prices for selected agricultural commodities both before and after the implementation of the Fischler reform and a higher value of the PTE after the reform.

#### *6.2.3.1 Methodology.*

The *law of one price* (LOP) states that the same good cannot be sold for different prices in different countries at the same time, taking into account exchange rates (Mankiw, 2001), and net of transport costs. The LOP holds in the long run even if it might not hold in the short run. If a particular good – say corn – had different prices in different locations, in would be profitable for arbitrageurs to buy corn where it is less expensive and then sell it in the country where it is more expensive. However, by doing so, the price in the "cheap" market would rise due to increased demand, while price in the "expensive" market would decrease as a consequence of increased supply. Therefore, in the long run, prices in the two markets will converge to the same value. Nevertheless, a *conditio sine qua non* for the LOP to hold is that no prohibitive trade restrictions are in place between the two countries.

A direct consequence of the LOP is that – in the long run – world price signals are fully transmitted to domestic prices. However, this is always true only in theory since in the real world many factors impede a full transmission of price fluctuations across markets. The most important among these factors is trade policies implemented by governments, which are aimed at favoring domestic producers over foreign. Nonetheless, even if no trade policies are in place, the LOP might still not hold since there may be quality differences between the goods sold in the two countries. When it comes to (agricultural) commodities

quality differences are very often quite small and therefore goods are treated as homogeneous in this work.

Historically the validity of the LOP has been assessed using the following type of regression (Baffes & Gardner, 2003):

$$p_t^d = \alpha + \beta p_t^w + \varepsilon_t$$

**Eq. 6**

Where $p_t^d$ and $p_t^w$ are domestic and world prices for a given commodity at time $t$, $\alpha$ and $\beta$ are parameters to be estimated and $\varepsilon_t$ is the error term. If the LOP holds, then $\alpha + 1 = \beta = 1$ and Eq. 6 becomes: $p_t^d = p_t^w$, which also means that any price differential at time $t$ is white noise.

When variables are expressed in logs, the slope coefficient $\beta$ can be interpreted as the *elasticity of price transmission* (EPT) that is the extent to which price signals are passed through from world to domestic markets. The EPT can range between $0$ (no transmission/market isolation) and $1$ (perfect transmission/validity of the LOP). The EPT is defined as the percentage change in the domestic price in response to a one-percent change in the world price (Thompson & Bohl, 1999). The EPT can also be thought as a measure of trade barriers in place between two markets. The intercept can be interpreted as a measure of transaction costs that – since the equation is written in logarithmic form – are thought to be a constant proportion of prices (Listorti, 2009).

Eq. 6 represents the long-run equilibrium between two markets but in the short-run prices can diverge – also quite substantially – from the long-run equilibrium. However if the long-run relationship holds, there must be a mechanism that drives back prices to equilibrium. For this reason the vast majority of works studying the LOP apply cointegration techniques.

Usually price series (especially when particularly long) are not stationary[18], which means that they cannot be regressed on each other without occurring in the spurious regression phenomenon[19]. However, even if two (or more) variables are not stationary, it might exist a linear combination of them that is in fact stationary (Engle & Granger, 1987). When this happens the variables are said to be cointegrated. When two variables are cointegrated Eq. 6 can be safely estimated through OLS without incurring in the spurious regression problem. The cointegrating equation, that is the long-run equilibrium is nothing else than Eq. 6, which in turn represents the LOP.

[18] (Weak) stationarity means that the series is characterized by constant mean, variance, and co-variances. That is, after a shock, it tends to return to its long-run equilibrium and do not drift apart.

[19] The spurious regression problem arises when the OLS estimator finds a significant correlation between two variables even if they are completely unrelated. This might be due to the fact that the two variables (i.e. rabbit population in Italy between 1970 and 2000, and nominal GDP in the USA in the same time span) are both characterized by a similar stochastic trend (Verbeek, 2006).

The presence of a cointegration relationship between two or more variables implies the existence of an error-correction model that describes the short-run dynamics consistently with the long run relationship (Verbeek, 2006). Therefore if Eq. 6 is the long-run/cointegrating equation, the error-correction model (ECM) is of the form:

$$\Delta p_t^d = \delta + \theta \Delta p_t^w + \gamma \varepsilon_{t-1} + u_t$$

**Eq. 7**

Where $\theta$ is the short-run effect that is how much of a given change in the world price is transmitted to the domestic price in the current period, while $\gamma$ is the error-correction term representing how much of the price difference between the world and the domestic price occurred in the past period is eliminated in each period thereafter (Baffes & Gardner, 2003). $\varepsilon_{t-1}$ is the residuals of the long-run equation at time $t-1$.

If one is interested only in pair-wise comparisons and one of the process can be treated as exogenous, both the long-run equation and the error correction equation can be estimated using the two-step procedure illustrated in Engle and Granger (1987). The two-step technique consists in estimating the long-run relationship through OLS (after having verified the price series are integrated of the same order) and then testing for stationarity of the residuals. This can be done using the standard Augmented Dickey-Fuller (ADF) unit-root test with modified critical values (Davidson & MacKinnon, 1993) or the Cointegrating Regression Durbin-Watson test[20]. When the null of no-cointegration is rejected the error-correction model can be also estimated through OLS using the residuals from the long-run equation.

The main issue here is that – when it comes to agricultural prices – we might be in presence of structural breaks that is exogenous shocks that might permanently change price relationships. Classic examples are policy changes or structural reforms. Such shocks may alter the behavior of price series and their relationships in different ways. The shock can cause a shift in the mean of the series, the time trend, or the long run cointegration vector. The presence of structural breaks can undermine both the unit-root tests on the single price series, and the cointegration analysis itself. In other words, disregarding the presence of structural breaks in the cointegration relation may lead to wrongly accept the null of non-stationarity of the liner combination of the series when it might be the case that the residuals are indeed stationary around a broken level or trend (Listorti, 2009).

Choosing break dates *a priori* induces a certain degree of arbitrariness but when one wants to investigate the effect of policy changes and/or structural reforms it is a widely accepted practice. In this work the long-run cointegration equation is modified in order to take into account of the potential

[20] The value of the Durbin-Watson statistic from the cointegrating regression is suggestive for the presence or absence of a cointegrating relationship. Critical values for this type of test are given in Banerjee *et al*. (1993).

structural break corresponding to the first week of 2007. Even if in some countries the reform was implemented earlier, it has been decided to choose the beginning of 2007 as breaking date to be sure to capture the effects it might have generated.

Allowing for structural breaks and generalizing Eq. 6 becomes:

$$p_t^d = \alpha_1 + \beta_1 p_t^w + \alpha_2 D^{fisch} + \beta_2 p_t^w D^{fisch} + \varepsilon_t$$

**Eq. 8**

Where all variables are expressed in logs. $p_t^d$ and $p_t^w$ are domestic and world prices at time $t$, and $D^{fisch}$ is a binary variable, which assumes the value 1 if $t > Jan\ 1st, 2007$ and 0 otherwise. The $\alpha$s are constants representing transaction cost before $(\alpha_1)$ and after $(\alpha_1 + \alpha_2)$ the reform, while the slope coefficients $\beta$s are an estimate of the PTE from the world into the domestic price before $(\beta_1)$ and after $(\beta_1 + \beta_2)$ the reform, and $\varepsilon_t$ is the error term.

The model can be further augmented by adding a (broken) time trend and dummies to take into account perturbations in world commodity markets like the price "bubbles" occurred in 2003-04 and 2007-08.

The corresponding error-correction model, which describes the short-term dynamics, is of the form:

$$\Delta p_t^d = \theta_1 \Delta p_t^d + \gamma_1 \varepsilon_{t-1} + \theta_2 \Delta p_t^w D^{fisch} + \gamma_2 \varepsilon_{t-1} D^{fisch} + \upsilon_t$$

**Eq. 9**

Where $\Delta p_t^d$ and $\Delta p_t^w$ are first differences of the domestic and the world prices and $\varepsilon_{t-1}$ are the lagged residuals from Eq. 8. The $\theta$s are the short-term (or immediate) responses of the domestic price to movements of the world price before $(\theta_1)$ and after $(\theta_1 + \theta_2)$ the Fischler reform, while the $\gamma$s capture the *pre* $(\gamma_1)$ and *post* $(\gamma_1 + \gamma_2)$ speed of adjustment to the long-term equilibrium of domestic prices. When the cointegration equation contains a time trend then an intercept is included in the ECM.

After estimating the equations and ascertained the existence of a cointegration relationship between the variables, it is possible to compute the degree of adjustment $m$ of the domestic price, relative to full adjustment, $n$ periods after the change in the world price (Krivonos, 2004):

$$m_n = 1 - \frac{(\beta - \alpha)(1 + \gamma)^n}{\beta}$$

**Eq. 10**

The higher $m$, the quicker domestic prices adjust to changes in the world price.

#### *6.2.3.2 Data.*

Data used in this sub-section are weekly prices for the three main agricultural commodities used for either food or animal consumption: corn, wheat, and soybeans.

The time span under consideration is from January 1st 2002 up to September 30th 2011, for a total of 509 observations (except than for Corn Bordeaux and Soybeans Rotterdam, whose series starts in 2005 and are made up by only 348 observations). Even if it were technically possible to obtain data older than 2002 (at least for wheat and corn) it was decided to limit the analysis to 2002 in order to be able to translate all prices in euro. Even though exchange rates between the euro and the US dollar were available also before 2002, it was only after than they were effectively determined by real currency market transactions.

For corn, prices considered are American, Argentinean, French, and Italian ones. The US *fob* price at the Gulf of Mexico (considered to be representative of the world price) and the Argentinean *fob* Up River prices are from the FAO international prices database[21], French price (Bordeaux) is from the *Marché à Terme International de France* (MATIF), and the Italian one from the Chamber of Commerce of Milan.

The world wheat price is considered to be the US No.2, hard Red Winter, always *fob* at the Gulf of Mexico, and it is from the FAO database, the Italian baking wheat price is from the Bologna's *Borsa Merci*, while the Canadian CWRS No1 and the French (Rouen) prices were kindly provided by the Canadian Market Analysis Division of Agriculture and Agri-Food Canada.

Analogously to wheat and corn, also for soybeans the US *fob* at the Gulf of Mexico price provided by the FAO is considered to be the world price. For soybeans EU and Italian prices are respectively the Rotterdam *cif* price for US soybeans and the soybeans price at the Chamber of commerce of Milan.

US prices have been considered to be representative of the world price since the United States heavily dominates global corn (60%) and wheat (25%) exports, and have been for decades the largest soybean exporter (now third-largest behind Brazil and Argentina). Therefore US grain prices are typically quoted as international prices for all grains except rice, where Thai prices are typically quoted (Headey & Shenggen, 2010).

#### *6.2.3.3 Results.*

After establishing the order of integration of the each price series and that they are cointegration-compatible, it has been tested for cointegration without structural breaks for all price pairs and all commodities using Eq. 6 for the whole sample. For those price pairs for which the null of no-cointegration

[21] http://www.fao.org/economic/est/prices?lang=en

was not rejected, the presence of cointegration has been tested allowing for a structural break in the cointegration vector corresponding to the full implementation of the Fischler reform in 2007.

Results from the Augmented Dickey-Fuller (ADF) unit root test on the levels of the variables are reported in Table 6.21. In all the cases it is possible to reject the null of unit root. The same test repeated to the first difference of the variables always rejects the null, meaning that the variables are integrated of order 1 and are therefore cointegration-compatible.

**Table 6.21: Augmented Dickey-Fuller test for unit root in the variables in levels.**

| Price series | Constant | Trend | Lags | DF statistic | Verdict |
|---|---|---|---|---|---|
| Corn fob US | Yes** | Yes** | 14 | -2.32 | do not reject |
| Corn Argentina | Yes* | Yes** | 10 | -2.01 | do not reject |
| Corn Bordeaux, FR | Yes** | No | 7 | -2.08 | do not reject |
| Corn Milan, ITA | Yes** | No | 4 | -2.16 | do not reject |
| Wheat Hard Red, US | Yes** | Yes* | 2 | -2.56 | do not reject |
| Wheat CWRS n.1, CAN | Yes*** | Yes** | 18 | -2.71 | do not reject |
| Wheat Rouen, FRA | Yes** | Yes* | 10 | -2.43 | do not reject |
| Wheat Milan, ITA | Yes*** | Yes* | 17 | -3.15 | do not reject |
| Soybeans fob, US | Yes** | Yes* | 17 | -2.48 | do not reject |
| Soybeans cif Rotterdam | No | No | 12 | 0.90 | do not reject |
| Soybeans Milan, ITA | Yes*** | Yes** | 9 | -2.67 | do not reject |

Source: own elaborations.
*,**,*** indicate respectively 10, 5, and 1% significance level.
Null hypothesis: unit root.

As a robustness check the stationarity of the price series has been checked also with the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) stationarity test (results not reported), which differs from the ADF test because the null hypothesis is the (trend) stationarity of the series. The results from the KPSS test confirm that all the variables in levels are not stationary (the null is always rejected), while the first differences indeed are.

The presence of a long-run/cointegration relationship between the variables has been investigated using the Engle-Granger (1987) two-step procedure: the null of no-cointegration is rejected when the residuals from the OLS estimation of the long-run equation do not contain a unit root. Testing for a unit root in the cointegration equation residuals has been done with the standard ADF unit-root test. However, when testing for no-cointegration, the appropriate critical values are more negative than those for the standard unit-root test. Asymptotic critical values for residual-based cointegration tests are provided by MacKinnon (2010). Critical values also depend on the number of variables included in the cointegration regression: Hassler (2004) states that both step dummies and interaction terms (step dummy times the regressor) should be counted as additional I(1) regressors when it comes to testing.

Table 6.22 shows the estimates of the cointegration equations calculated over the full sample. Cointegration has been detected only between the Argentinean and the US fob corn prices, and between the Canadian CWRS and the hard red US fob wheat prices. This is like one would expect *a priori* since the Argentinean and the Canadian markets are less protected than the European ones. In both cases the price transmission elasticity is one, meaning perfect price transmission. In the Canadian case the constant is very close to zero and not significant (and was therefore dropped from the equation) meaning zero transaction costs. This can be explained by the fact that the Wheat Canadian board detains the monopoly of the national cereal market: the absence of intermediaries means zero transaction cost. Since the Board will be

dismantled in August 2012[22], it would be interesting to see whether transaction cost will rise or not for Canadian traders.

**Table 6.22. Cointegration equations – Full sample without structural breaks.**

| Parameters/Price Series | Corn Argentina | Corn Bordeaux, FR | Corn Milan, ITA | Wheat CWRS n.1, CAN | Wheat Rouen, FRA | Wheat Milan, ITA | Soybeans cif Rotterdam | Soybeans Milan, ITA |
|---|---|---|---|---|---|---|---|---|
| Constant | -0.22*** | 1.14*** | 1.95*** | | | 0.61*** | 0.64*** | 1.49*** |
| Time trend | | -0.0005*** | -0.0002** | 0.0003*** | 0.0003*** | | | 0.0002*** |
| World price | 1.04*** | 0.84*** | 0.67*** | 1.00*** | 0.96*** | 0.89*** | 0.90*** | 0.76*** |
| T= | 509 | 348 | 509 | 509 | 509 | 509 | 348 | 509 |
| CRDW | 0.24** | 0.11 | 0.05 | 0.19** | 0.26** | 0.06 | 0.72** | 0.25** |
| ADF on residuals | -3.46** | -2.48 | -2.92 | -3.78** | -2.41 | -2.80 | -3.00 | -2.62 |
| Cointegration | Yes | No | No | Yes | No | No | No | No |

Source: own elaborations.
*,**,*** indicate respectively 10, 5, and 1% significance level, Null hypothesis: no cointegration.

The null of no cointegration was not rejected for any of the price pairs involving a European price, neither for corn, wheat, nor soybeans. It might mean that there is not a long-run relationship between world and European prices or that, more likely, the presence of a structural break modifies the long-run relationship between prices. In other words it might be the case that not allowing for the presence of structural breaks does not allow to reject the null of no-cointegration when in fact there is.

When structural breaks are accounted for, the picture changes (see Table 6.23). In the case of corn a cointegration relationship is found between the Italian and the world price. Before the full implementation of the Fischler reform, PTE between the Italian and the world corn prices was about 0.42, meaning that, in the long-run, only 42% of a change in the world price is transmitted to domestic prices. After the reform, PTE more than doubled reaching 0.87, meaning a higher degree of integration between the Italian and the world price. After the reform also the value of the constant – a measure of transaction cost – decreased. Before January 2007 it was as high as 3.00, while after reform decreased to 0.77, showing how decoupling payments to farmers from production helped decreasing transaction cost. It must be stressed that the null of cointegration between the Italian and the world price is rejected only if the price bubbles of 2003-04 and 2007-08 are accounted for. The 2003-04 price bubble was triggered by a demand shock: demand (especially by emerging economies) increased so quickly to catch producers unaware. The situation was made worse by low inventory levels. The increase in demand was substantially due to fast macroeconomic expansion in OECD countries as well as in emerging economies such as China and Brazil (Radetzki, 2006).

[22] Source: Financial Times, October 19th 2011.

**Table 6.23. Cointegration equation allowing for a structural break (Jan 2007) and accounting for 2003-04 and 2007-08 price bubbles.**

| Parameters/Price series | Corn Bordeaux, FR† | Corn Milan, ITA | Wheat Rouen, FRA | Wheat Milan, ITA | Soybeans cif Rotterdam† | Soybeans Milan, ITA |
|---|---|---|---|---|---|---|
| Constant | 1.36*** | 3.00*** | 2.36*** | 3.20*** | 1.50*** | 3.14*** |
| Fischler dummy | -0.14*** | -2.23*** | -2.59*** | -3.07*** | -0.62* | -1.44*** |
| Time | 0.0004*** | 0.0002*** | | | -0.0002*** | -0.0002*** |
| Time*Fischler | | | | -0.0002*** | | |
| World price | 0.74*** | 0.42*** | 0.48*** | 0.35*** | 0.74*** | 0.45*** |
| World p*Fischler | | 0.45*** | 0.56*** | 0.65*** | 0.13* | 0.30*** |
| 2003-04 Dummy | | 0.23*** | 0.27*** | 0.26*** | | 0.07*** |
| 2007-08 Dummy | 0.35*** | 0.36*** | -0.21*** | -0.20*** | -0.09*** | -0.04*** |
| T= | 348 | 509 | 509 | 509 | 348 | 509 |
| CRDW | 0.26 | 0.22 | 0.57 | 0.22 | 1.09** | 0.30* |
| ADF on res. | -3.78 | -4.90** | -4.55** | -5.55*** | -4.76** | -3.40 |
| Cointegration | No | Yes | Yes | Yes | Yes | No |

Source: own elaborations.
*, **, ***, indicate respectively 10, 5, and 1% significance level.
†Series start in 2005, therefore the 2003-04 dummy was not included in the estimation.
Corn : 2003-04 dummy= 1 if 23/8/02<t<27/08/04, 0 otherwise. 2007-08 dummy = 1 if 4/5/07<t<18/4/08, 0 otherwise.
Wheat and Soybeans: 2003-04 dummy = 1 if 7/7/2003<t<28/6/04, 0 otherwise. 2007-08 dummy = 1 if 29/9/08<t<31/8/09, 0 otherwise.

The 2007-08 price bubble was also triggered by a sharp and quick increase in demand but worsened by the increasing importance acquired by biofuels – which are mostly produced from agricultural commodities such as corn – and by problems on the supply side. In some regions yields are growing at a much lower rate than used to be in the past (also because of climate change) struggling in meeting new demand needs. In the corn regressions, the 2007-08 dummy represents the ascending phase of the "bubble" (starting in May 2007 and ending in April 2008) that is the period when domestic prices diverged most from the world price. Even accounting for the structural break and the price bubbles, the null of no-cointegration is not rejected for the French price. A possible explanation is that the series is shorter than the Italian one: a long-run relationship might exist but the too short time span considered does not allow detecting it.

The null of no-cointegration – when the implementation of the Fischler reform and the price bubbles are accounted for – is rejected also for the Italian and the French wheat prices with respect to the world price. Before the reform PTE between the French and the world price was about 0.48 meaning a relatively low level of price transmission. Before the reform also the intercept, measuring transaction costs, was quite high (2.36). The Italian market appears to be even less integrated to world one before the reform. The Italian PTE was 0.35 before 2007 and the constant about 3.20. After the implementation of the Fischler reform integration to the world market increased for both France and Italy. After the reform PTE computed between the French and the world price is equal to unity (0.48+0.56 = 1.04) and the constant becomes almost zero. The same happens to Italy: also in this case post-reform PTE is almost unity – meaning perfect transmission – and transaction cost substantially go down after the 2007 (intercept drops from 3.20 to 0.13).

Also in the case of wheat the cointegration equations have been augmented with dummies accounting for the turbulences that affected commodity markets in 2003-04 and 2007-08. However, in this and the soybeans case, the 2007-08 dummy is not the same as in the corn regression. While, in the case of corn the trend of world and EU prices diverges during the ascending phase of the bubble, in the wheat and the soybeans cases, the discrepancy grows in the descending phase. Therefore, the 2007-08 bubble dummy in the wheat/soybeans case ranges from September 2008 up to August 2009 instead than May 2007 – April 2008.

Finally, cointegration equations allowing for structural breaks were computed also for the soybean market. The null of no-cointegration has been rejected for the *cif* Rotterdam series while for the Italian price has been not. Before the reform PTE between the Rotterdam and the world price was already quite high, almost 0.74, meaning that the soybean market was much more integrated than the wheat and the corn ones before the Fischler reform. This might be explained by the fact that Europe is a net importer of the commodity: since there was no need of protecting domestic producers, trade barriers (direct and indirect) have always been low therefore keeping market integration high. Transaction cost was also quite low already before the reform (intercept almost 1.50) with respect to those affecting both corn and wheat markets. Despite all that, the reform did have an effect also on the soybean market. After 2007 PTE increased up to 0.87, a relatively high level but surprisingly lower than unity. If it is true that the European soybean market has historically been more integrated to the world one than those of other commodities, it seems that after the reform it became less integrated than the main cereal ones.

The null of no-cointegration was not rejected for the Italian soybean price. This might be due to the fact that the Italian soybean market is not very developed and prices are not always established on the basis of actual transactions.

**Table 6.24. Error-Correction Models.**

| Parameters/Price series | Corn Argentina | Corn Milan, ITA | Wheat CWRS n.1, CAN | Wheat Rouen, FRA | Wheat Milan, ITA | Soybeans cif Rotterdam |
|---|---|---|---|---|---|---|
| Constant | n.a. | 0.0007 | 0.0007 | n.a. | n.a. | 0.0007 |
| Short-run effect | 0.76*** | 0.08* | 0.57*** | 0.1 | 0.05 | 0.44*** |
| Short-run effect after Fischler | n.a. | 0.08-0.01 | n.a. | 0.10+0.59*** | 0.05+0.15*** | 0.44-0.01 |
| Adj. Coeff. | -0.10*** | -0.03 | -0.08*** | -0.07 | -0.01 | -0.17* |
| Adj. Coeff. After Fischler | n.a. | -0.03+0.02 | n.a. | -0.07-0.31 | -0.01-0.03* | -0.17-0.24 |
| DW | 2.21 | 1.1 | 1.87 | 2.32 | 0.88 | 2.21 |
| 3-month adjustment | | | | | | |
| Before Fischler | 92% | 44% | 84% | 67% | 24% | 96% |
| After Fischler | 92% | 18% | 84% | 100% | 51% | 100% |

Source: own elaborations.
*, **, ***, indicate respectively 10, 5, and 1% significance level.

When cointegration has been found between a price pair (either with or without structural breaks and bubble dummies) the respective error-correction model (ECM) has been estimated (Table 6.24). The ECM describes the short-term dynamics of price relationships and gives information on how and how fast

prices re-align to the long-run equilibrium after a shock. The ECM contains two important parameters: a short-run and an adjustment coefficient. The short-run parameter gives a measure of how much of a given change in the world price is transmitted to the domestic price in the current period, while the adjustment coefficient indicates how much of the past difference between domestic and world prices is eliminated in each period thereafter. The closer to unity are these two parameters, the higher the speed changes in the world price are transmitted to domestic prices (Baffes & Gardner, 2003). The adjustment coefficient is expected to be negative, since it would imply correction downward if the domestic price exceeds world price at time $t$ and correction upwards when domestic price falls short of world price (Krivonos, 2004). Following Krivonos (2004) it has also been calculated the "amount of adjustment" that takes place after 12 periods, that is three months.

In the case of the Argentinean corn price the short-run effect is 0.76 and the adjustment coefficient -0.10 meaning that the 76% of a change in the world price is immediately transmitted to the domestic market and that in every period 10% of the difference between the domestic and world prices at $t-1$ is adjusted in the current period. After 12 weeks the amount of adjustment that takes place is 92%. Between the Italian and the world corn prices is estimated an ECM allowing for structural break. The short-run coefficient is 0.08 and is significant only at 10%. Moreover it does not change after the Fischler reform. The adjustment coefficient is negative but it is not significant and is decreasing (in absolute value) after the reform, meaning that there might be some problem in the cointegration equation. Nevertheless, the 3-month adjustment has been computed also in this case and turned out to be 44% before the reform and 18% after.

Results concerning wheat markets are better. Both the short-run and the adjustment coefficients estimated for the Canadian market are significant and consistent with the *a priori* hypothesis. The immediate response is 0.57, while the amount of adjustment taking place in every period is 0.08. The three-month adjustment is 84%. In the ECMs for France and Italy the short run coefficient is significant only after the reform and, while it is quite high in the case of France (0.10 before and 0.69 after the reform) it is surprisingly low for Italy (0.05 before and 0.20 after). The adjustment coefficients are both barely significant even though they are increasing in absolute value after reform. Before 2007 the three-month adjustment was 67 and 24% for France and Italy respectively, while after 2007 it increases to 100 and 51%.

The only ECM model estimated for the soybean market is the one regarding the *cif* Rotterdam series. The short-run effect is 0.44 both before and after the reform meaning that the introduction of the new CAP regulations did not affected immediate price transmission mechanisms between the EU and the world price. Also the adjustment coefficient does not significantly change after the reform, being 0.17 both before and after 2007. The amount of adjustment taking place in 3 months is more or less 100% both before and after the implementation of the Fischler reform.

#### *6.2.3.4 Discussion and policy implications.*

This sub-section assessed whether the full implementation of the Fischler reform positively affected price transmission elasticity (EPT) between the world and some European agricultural markets and therefore increased market integration. Commodities considered were corn, wheat, and soybeans, the most important for human consumption and animal feed. Whether and the extent to which EPT changed after the Fischler reform has been investigated through cointegration techniques allowing for structural breaks.

The impact of the Fischler reform was greater for corn and wheat markets, while it was negligible for soybeans. The EPT between the world and the Italian corn prices more than doubled after the Fischler reform increasing from 0.42 to 0.87, meanwhile the intercept term (a proxy for transaction costs) decreased from 3.00 to 0.77. The Fischler reform appears to have had a positive effect also on the EPT between the world and both the French and Italian wheat prices. The EPT between the French and the world wheat prices increased from 0.48 to almost unity (meaning perfect transmission) after the reform. More or less the same occurred to the Italian wheat market: in this case EPT before the reform was as low as 0.35, becoming almost 1 after. Also in this case the intercept term decreased from 3.20 to 0.13 meaning a reduction in transaction costs.

The null of no-cointegration was rejected also for the *cif* Rotterdam soybean price, when allowing for a structural break at the beginning of 2007. In this case, however, the reform exerted a much lower effect on the EPT between the world and the European market. The extent to which world price signals were passed through to the EU market was already quite high before the reform (EPT almost 0.74) and transaction cost was already quite low (intercept of 1.50). After the reform the EPT for the Rotterdam price did increase (up to 0.87) but not as much as for wheat. A possible explanation is that Europe has historically been a net importer of the commodity: since there was no need of protecting domestic producers, trade barriers (direct and indirect) have always been low therefore keeping market integration high. Moreover since the soybean market has always been scarcely protected, it was not affected by the Fischler reform.

Cointegration has been detected also between the Argentinean and the US corn prices as well as between the Canadian and the US hard red wheat price. In both cases EPT is almost 1 – meaning perfect transmission – and the intercept is almost zero (no transaction costs).

The null of no-cointegration, even allowing for structural breaks, has not been rejected for the French corn and the Italian soybean prices. In the French corn case, a possible explanation is that the series is not long enough to allow cointegration to be detected, while for the Italian soybean price it is likely that the lack of co-movement between the Italian and the world price is due to the fact that the domestic market is very inefficient and not based on real transactions.

It has to be stressed that in the cointegration equations between the world and various European prices it was needed to take into account the price bubbles of 2003-04 and 2007-08. During these periods

the difference between domestic and world prices was substantially higher than in the rest of the time span considered. It might be the case that when turbulences – either due to demand or supply shocks, low stocks, speculating behavior or bad weather – affect agricultural commodity markets the long-run relationship between the variables changes. If the effect of the 2003-04 bubble was more or less the same for all the variables considered, the 2007-08 one had very different effects. In the case of corn, domestic and world prices substantially differ during the price ascending phase, while in the case of wheat and soybeans during the descending phase. These aspects could represent the starting point for further research, maybe applying cointegration models that allow for asymmetric price transmission.

Finally, when cointegration was found between a price pair, error-correction models were estimated. These models are well specified only for the Argentinean corn price and the Canadian wheat price series. In the case of European prices, for which cointegration is present only taking into account structural breaks and price bubble dummies, the estimated ECMs not always perform well, especially in the case of corn. However, in the case of wheat, they show how the Fischler reform not only increased long-term price transmission between world and European markets but also increased the speed at which domestic prices adjusts to changes in the world price.

### 6.2.4 The second approach, estimating EPT with monthly-stationary price series.

The Fischler reform, by decoupling most of CAP support, induced a market reorientation of domestic prices and production decisions by EU farmers. This led to a significant reduction in domestic and world market distortions associated with the CAP. The reform triggered a market reorientation of EU domestic prices but did not significantly reduce border protection: as a consequence imports, on the EU market, lost price competitiveness. However, the reform technically removed export subsidies and the selling of intervention stocks on the world market, therefore contributing to an increase in world prices (Anania, 2007).

In this context, the aim of this sub-section is to assess, similarly to the previous sub-section, whether the price transmission elasticity (EPT, *i.e.* the extent to which world prices are transmitted into domestic markets) from the world market to the European one changed after the implementation of the Fischler reform but using different price series. Furthermore, by using a different econometric technique and different price series it will be possible to see whether results depend upon the methodology or the data frequency used.

This sub-section focuses on corn, soft wheat, durum wheat, feed barley and butter markets. Corn, soft wheat, and feed barley are among the most widely used agricultural commodities for human consumption and animal feed, while butter and durum wheat have historically been amongst most protected markets. Data used are monthly figures, as in most of the literature on price transmission, from January 1999 to March 2012. Monthly figures have been used instead than weekly ones since less affected

by short-term market turbulences that might affect the long-run relationship between the variables and because easier to gather. Moreover, by using monthly figures it is possible to employ official EU-27 averages computed by Eurostat, therefore reducing the degree of subjectivity implied by choosing the price of one of the EU member states as representative of price levels in the entire Union.

#### *6.2.4.1 Methodology.*

The *law of one price* (LOP) states that the same good cannot be sold for different prices in different countries at the same time, taking into account exchange rates (Mankiw, 2001), and in absence of transport costs. The LOP holds in the long run even if it might not in the short run. If a particular good – say corn – had different prices in different locations, in would be profitable for arbitrageurs to buy corn where it is less expensive and then sell it in the country where it is more expensive. However, by doing so, the price in the "cheap" market would rise due to increased demand, while price in the "expensive" market would decrease as a consequence of increased supply. Therefore, in the long run, prices in the two markets will converge to the same value (Listorti, 2009). Nevertheless, a *conditio sine qua non* for the LOP to hold is that no prohibitive trade restrictions are in place between the two countries.

A direct consequence of the LOP is that – in the long run – world price signals are fully transmitted to domestic prices. However, this is always true only in theory since in real world many factors impede full transmission of price fluctuations across markets. The most important among these factors is trade policies implemented by governments, which are aimed at favoring domestic producers over foreign. It must be noted that, even if no trade policies are in place, the LOP might still not hold since there may be quality differences between the goods sold in the two countries. Nonetheless, when it comes to (agricultural) commodities quality differences are very often quite small and therefore, in this work, goods are treated as homogeneous.

Historically the validity of the LOP has been assessed using the following type of regression (Baffes & Gardner, 2003):

$$p_t^d = \alpha + \beta p_t^w + \varepsilon_t$$

**Eq. 11**

Where $p_t^d$ and $p_t^w$ are domestic and world prices for a given commodity at time $t$, $\alpha$ and $\beta$ are parameters to be estimated and $\varepsilon_t$ is the error term. If the LOP holds, then $\alpha + 1 = \beta = 1$ and Eq. 11 becomes: $p_t^d = p_t^w$, which also means that any price differential at time $t$ is white noise.

When variables are expressed in logs, the slope coefficient $\beta$ can be interpreted as the *elasticity of price transmission* (EPT) that is the extent to which price signals are passed through from world to domestic markets. The EPT can range between $0$ (no transmission/market isolation) and $1$ (perfect

transmission/validity of the LOP). The EPT is defined as the percentage change in the domestic price in response to a one-percent change in the world price (Thompson & Bohl, 1999). The EPT can also be thought as a measure of trade barriers in place between two markets. The intercept can be interpreted as a measure of transaction cost that – since the equation is written in logarithmic form – is thought to be a constant proportion of prices (Listorti, 2009). Nevertheless, during the time span considered (1999-2012) transaction cost is likely not to have remained constant. Therefore, it has been tried to model transaction cost variability by augmenting the model with freight rates data, for the commodities for which such data were available (corn and wheat). Freight rates are a positive function of oil prices, and, during the 1999-2012 period, they have been characterized by an upward trend, which only in the very last years matched the path followed by agricultural prices. Since it was possible to find freight rates data for the Gulf of Mexico – Rotterdam route only, and because they did not significantly increased the performance of the model, it was eventually decided not to take them into account.

Eq. 11 can be estimated through OLS as long as the variables are stationary[23]. If they are not, OLS is still valid as long as they are cointegrated, that is there is a linear combination of the variables that is, indeed, stationary (Engle & Granger, 1987). However, West (1988) shows that OLS and linear instrumental variable estimators with a single right-hand side non-stationary variable are asymptotically normal, even in presence of heteroskedasticity and autocorrelation. Test statistics and confidence intervals yield asymptotically correct inferences whether or not the regressor is non-stationary. This applies also to hypotheses about the model as a whole.

In order to measure the ETP between world and domestic prices, this work uses static OLS regression methods allowing for structural breaks. It is well-know that if time series exhibit a non-stationary behavior, but the simple static regression is not spurious, dynamic misspecification is not necessarily a problem. However, in this case one of the two prices, contrary from the cointegration approach, is assumed to be exogenous (the world price) (Listorti, 2008). More sophisticated econometric techniques might be applied as well (threshold cointegration, asymmetric cointegration, or smooth transition error correction models) but since only price series are available (and not, for example, data on freight rates or other transaction cost that might also affect the EPT) it has been preferred to start with a very simple specification.

The *a priori* hypothesis is that the full implementation of the Fischler reform represented a structural break in the long-term relationship between world and European prices. In particular the reform is expected to have increased the extent to which world agricultural prices are transmitted to domestic ones. Since already the MacSharry and the Agenda 2000 reforms of the CAP addressed the problem of EU

[23] (Weak) stationarity means that the series is characterized by constant mean, variance, and co-variances. That is, after a shock, it tends to return to its long-run equilibrium and do not drift apart.

market isolation, it seems reasonable to expect to find a certain extent of price transmission also before the implementation of the Fischler reform but lower than after.

Price relationships may have been affected also by other factors such as biofuel production, increased demand, and the progressive "financialization" of agricultural markets, which have in turn increased prices and price volatility: Headey and Shenggen (2010) provide a good review. Even though it was not possible to take into account all these factors in the analysis, they will be considered when interpreting the results.

In this work the long-run equation (Eq. 11) is modified in order to take into account a potential structural break corresponding to January 2007. Choosing break dates *a priori* induces a certain degree of arbitrariness but when one wants to investigate the effect of policy changes and/or structural reforms it is a widely accepted practice. Examples in the literature are many: Baffes and Gardner (2003), Krivonos (2004), and Listorti (2009). The majority of member states implemented the reform already in 2005 but some very important ones, like France, the Netherlands, Greece, Finland, and Spain, did it in 2006 only. Since this study refers to the EU as a whole, it seems that January 2007 is the best option to fix the break date. It this way one is sure to capture all possible effects of the change in policy on price relationships. 2007 was an important year also because the reduction in the intervention price for butter came into force in that year and because September 2006 was the last time export subsidies were used for cereals.

Allowing for structural breaks Eq. 11 becomes:

$$p_t^d = \alpha_1 + \beta_1 p_t^w + \alpha_2 D^{fisch} + \beta_2 p_t^w D^{fisch} + \gamma_1 T + \gamma_2 T D^{fisch} + \varepsilon_t$$

**Eq. 12**

Where all variables are expressed in logs. $p_t^d$ and $p_t^w$ are domestic and world prices at time $t$, $D^{fisch}$ is a binary variable, which assumes the value $1$ if $t > Jan\ 1st, 2007$ and $0$ otherwise and $T$ is a deterministic time trend. The $\alpha$s are constants representing transaction cost before $(\alpha_1)$ and after $(\alpha_1 + \alpha_2)$ the reform, the slope coefficients $\beta$s are an estimate of the PTE from the world into the domestic price before $(\beta_1)$ and after $(\beta_1 + \beta_2)$ the reform, the $\gamma$s are coefficients for the time trend before $(\gamma_1)$ and after $(\gamma_1 + \gamma_2)$ the reform, and $\varepsilon_t$ is the error term. The conventional Chow test for structural change is then used to verify whether $\alpha_2$, $\beta_2$, and $\gamma_2$ are jointly different from zero. The time trend terms have been included in the equation only when significant either before or after 2007.

#### *6.2.4.2 Data.*

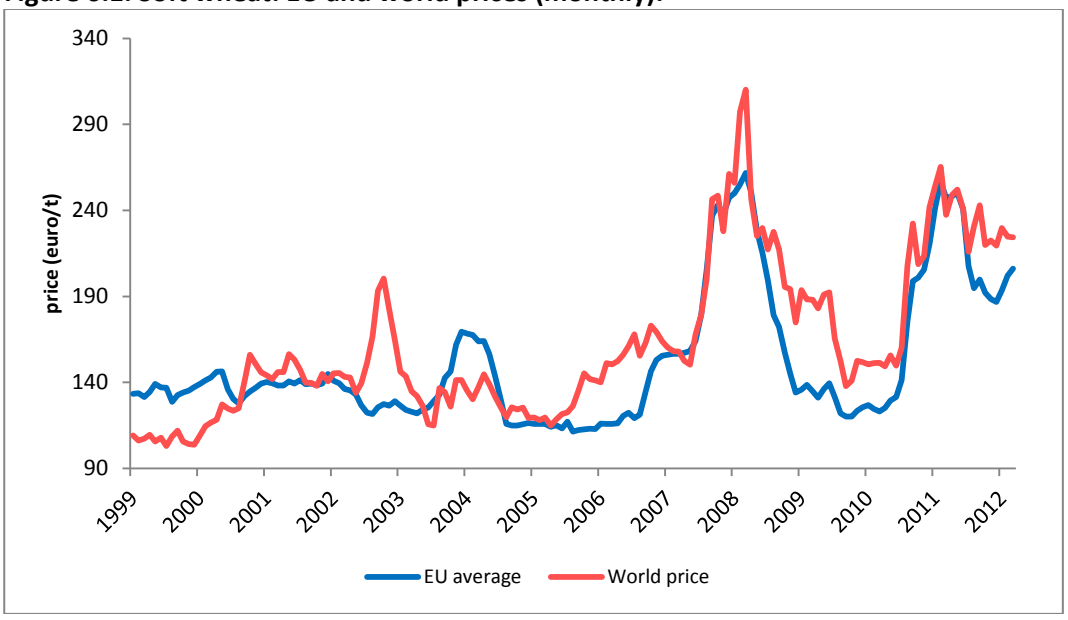
Data used in this work are monthly prices for five major agricultural commodities: soft wheat, corn, durum wheat, barley, and butter. The time span considered is from January 1999 up to March 2012 for a total of 159 observations. Even though older data were available, it has been decided to start from 1999

because of the need to express prices in the same currency: euro exchange rates are available only from January 1999, when the euro started to be effectively traded on international monetary markets. Previous works (Mela and Canali 2011, and Mela and Canali 2012) used higher frequency data (weekly figures) and cointegration techniques to measure the ETP between the world and some selected European agricultural prices. However, here monthly figures are preferred over weekly data since the latter are more prone to short-term perturbations, which can, in turn, alter price relationships. Furthermore, weekly figures were not available for all commodities analyzed. Kristoufek et *al.* (2011) analyzed correlations between many food and fuel commodities both in the EU and the US. Results indicate that the dynamic interactions between different commodities change when assessed with weekly, monthly, and quarterly data. Besides, when available, weekly data did not refer to the EU as a whole but to individual countries. For example, France is for sure the most important corn producer in Europe but still accounting for just 24% of total production (FAO, 2012). However, the decision to consider the price in the major producing country representative of European prices would have been arbitrary and, in some cases, also questionable, therefore it has been decided to use EU monthly averages.

For corn and soft wheat (Hard Red Winter) the US free-on-board (fob) price at the Gulf of Mexico are considered to be representative of world prices, while for butter the reference price is the fob Oceania export price. Figures are from the FAO international prices database. For feed barley and durum wheat world prices are considered to be the US fob price at Portland harbor and the Canada fob export price respectively. These two series have been kindly provided by the Canadian Market Analysis Division of Agriculture and Agri-Food Canada. Average European prices (production weighted averages among all 27 member states) are provided by the European Commission.

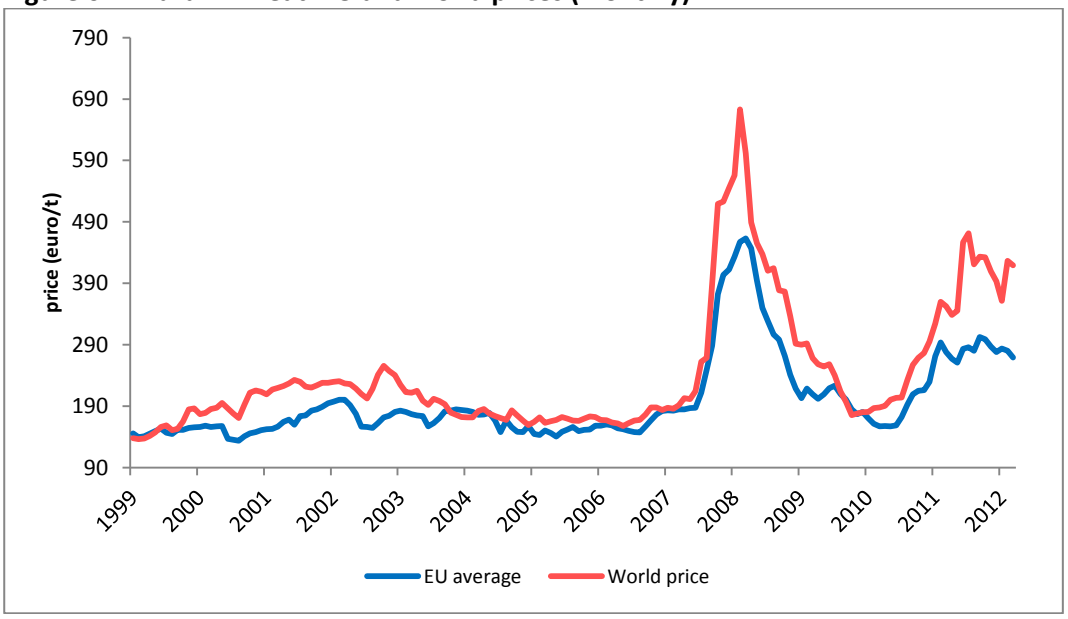
Graphical comparisons between world and European prices are provided by Figure 6.1, Figure 6.2, Figure 6.3, Figure 6.4 and Figure 6.5.

**Figure 6.1. Soft wheat: EU and world prices (monthly).**



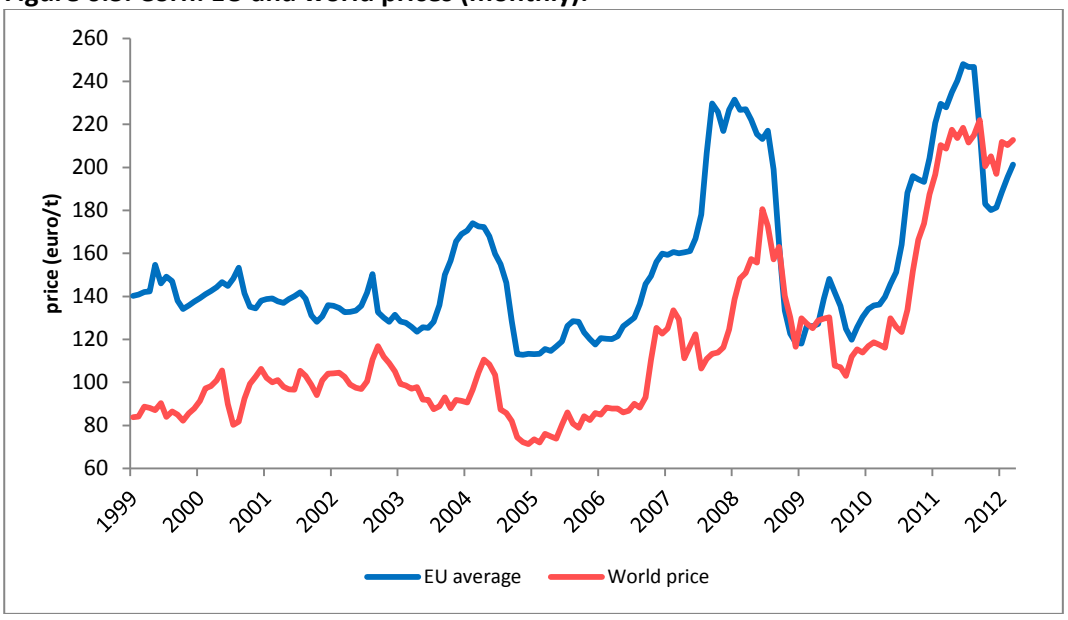

Source: own elaboration on European Commission and FAO data.

**Figure 6.2. Durum wheat: EU and world prices (monthly).**



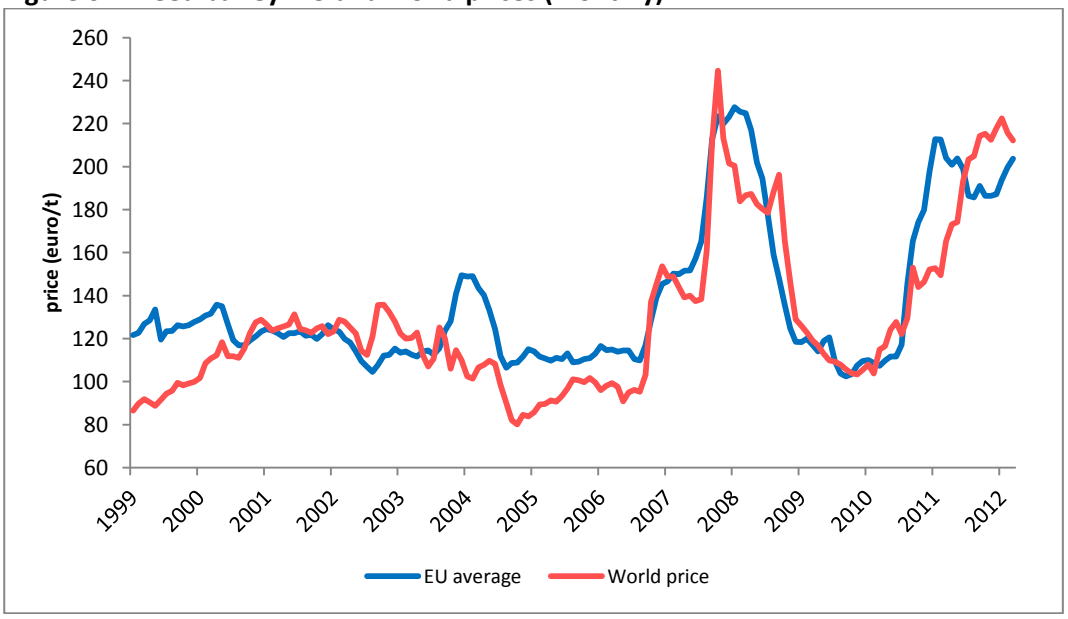

Source: own elaboration on European Commission and Agriculture Canada data.

**Figure 6.3. Corn: EU and world prices (monthly).**



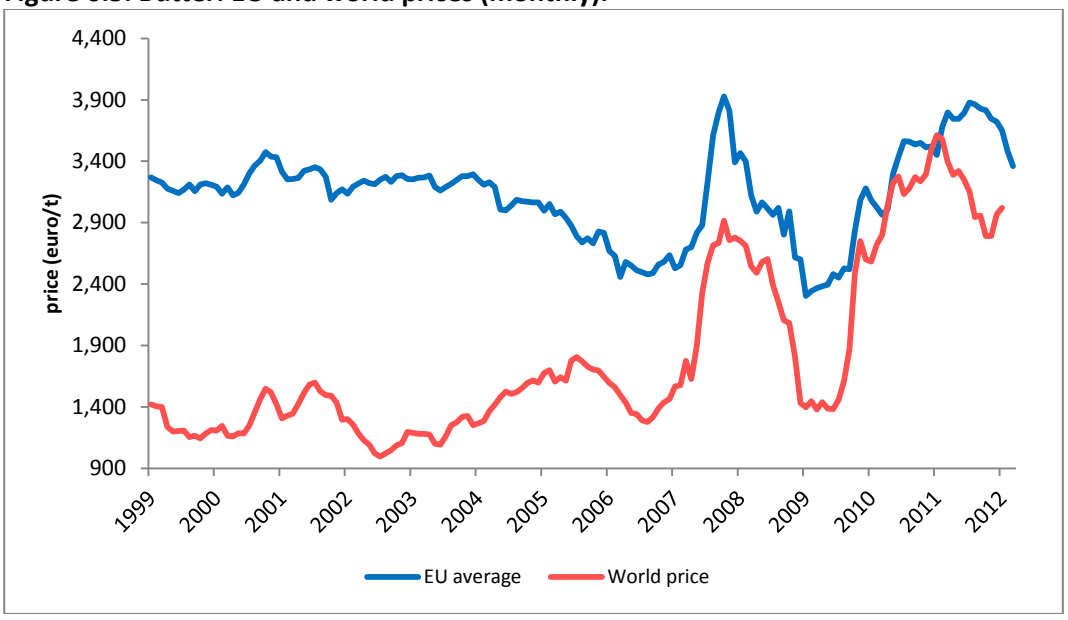

Source: own elaboration on European Commission and FAO data.

**Figure 6.4. Feed barley: EU and world prices (monthly).**




Source: own elaboration on European Commission and Agriculture Canada data.

**Figure 6.5. Butter: EU and world prices (monthly).**




Source: own elaboration on European Commission and FAO data.

In all cases it is possible to see how world and European prices tend to follow the same path, especially from 2007 onwards, after the Fischler reform was fully implemented. The difference in price patterns before and after 2007 is particularly evident for butter (which had historically been one of the most protected markets), feed barley, and soft wheat. For corn and durum wheat the difference seems to be less relevant. In the case of butter it is clear that, before reform, the European market was isolated from the world one because of the high intervention price (reduced by 25% in 2007), while for the other commodities it seems that before reform a certain degree of co-movement between world and domestic prices was also present, even if to a lesser extent than after. For barley and soft wheat, before 2007, the European market seemed to respond to changes in the world price with some lags of delay.

### *6.2.4.3 Results.*

The standard Augmented Dickey-Fuller unit root test has been performed on the variables in levels, in order to assess whether they are stationary or not (Table 6.25). Results show that most of the variables are (trend) stationary, even if sometimes at a relatively low significance level (10 percent). The null of unit root has been rejected in all cases, except than for corn and soft wheat prices, in favor of the trend-stationary alternative hypothesis.

**Table 6.25. Augmented Dickey-Fuller test on the variables in logs.**

| Variable | Constant | Trend | Lags | ADF | Verdict |
|---|---|---|---|---|---|
| Wheat EU | Yes*** | Yes** | 12 | -3.23* | Reject |
| Durum EU | Yes*** | Yes** | 12 | -3.54** | Reject |
| Corn EU | Yes*** | Yes** | 11 | -3.67** | Reject |
| Barley EU | Yes*** | Yes** | 4 | -3.39* | Reject |
| Butter EU | Yes*** | No | 2 | -2.85* | Reject |
| Wheat US | Yes*** | Yes** | 10 | -2.67 | Do not reject |
| Durum CAN | Yes*** | Yes** | 10 | -3.18* | Reject |
| Corn US | Yes | Yes* | 10 | -1.5 | Do not reject |
| Butter AUS | Yes*** | Yes*** | 7 | -4.09*** | Reject |
| Barley US | Yes*** | Yes*** | 11 | -3.74** | Reject |

Source: own elaborations.
*,**,*** denote 10, 5, 1% significance level respectively.
Null hypothesis: unit root.

In the cases of durum wheat, barley, and butter, since both the world and the European prices are (trend) stationary, the long-run relationship between world and domestic prices can be safely estimated through OLS, without incurring in the "spurious regression" problem. Conventional statistical measures are inapplicable when all regressors are non-stationary and, on the other hand, cointegration techniques are not appropriate if the variables are integrated of different orders (Baffes J. , 1997). Even though it was not possible to reject the null of unit root for neither soft wheat nor corn world prices, the long-run relationship between variables (and therefore the ETP) has been estimated anyway. In this case the dependent variables – EU corn and soft wheat – are stationary variables, while the independent ones – US soft wheat and corn – are not. West (1988) shows that, under fairly general conditions, the OLS estimator is asymptotically normal when it can be transformed to have a single non-stationary right-hand side variable and that, in estimating such a model, there is no need to take special steps to handle the assumed non-stationarity. Nevertheless, in the soft wheat and corn regressions it has been checked for the stationarity of the residuals (ADF test) and in both cases it was possible to reject the null of unit root.

The long-run relationship between price pairs has been estimated with and without taking into account structural breaks. All regressions were affected by positive autocorrelation (the Durbin-Watson test always rejected the null of no-autocorrelation) and heteroskedasticity (Breusch-Pagan test) problems. In presence of autocorrelation and heteroskedasticity, even if OLS estimates can still be asymptotically consistent, OLS standard errors underestimate the true uncertainty in parameters estimates. Therefore all equations have been estimated with heteroskedasticity-autocorrelation standard errors (HAC), which are robust with respect to deviations from the independent and identically distributed error term assumptions.

As a robustness check, the long-run relationships between price pairs had been estimated also using the Prais-Winsten estimator (PW), an alternative method to HAC robust standard errors to deal with heteroskedasticity and – especially – autocorrelation. The PW estimator is a Feasible Geneneralized Least Squares (FGLS) estimation method assuming that the autocorrelation of the error terms is due to a time-series dependence. The HAC method is usually preferred since using a FGLS methodology implies making

additional statistical assumptions, which may not be justified and that may threat estimator efficiency. Therefore OLS (with HAC standard errors) results must be regarded as reference ones.

For all commodities considered, the Fischler reform seems to have significantly modified the long-run relationship between price series. In all cases there is evidence in favor of the *a priori* hypothesis that the Fischler reform increased price transmission elasticity between world and European markets and decreased transaction cost. The Chow test for structural change rejects the null that coefficients from the unrestricted model (allowing for a structural break corresponding to the Fischler reform) are equal to zero in all regressions, meaning that the change in EU policy changed the relationship between the variables. However, the magnitude of such increase is different when estimated with OLS (HAC standard errors) and the PW technique. In the case of corn and barley while the OLS estimator finds the structural break to be significant, the PW one does not.Table 6.26 shows the estimation results regarding the long-run price relationship between European and US (world price) soft wheat prices.

**Table 6.26. Soft wheat: long-run relationship between world and European prices.**

| Parameter | OLS | | OLS (HAC std. errors) | | Prais-Winsten | |
|---|---|---|---|---|---|---|
| | No break | Break | No break | Break | No break | Break |
| Constant | 0.318*** | 1.772*** | 0.318 | 1.772*** | 1.309*** | 1.809*** |
| Time trend | -0.0005*** | -0.001*** | -0.0005* | -0.001*** | No | No |
| World price | 0.862*** | 0.180** | 0.862*** | 0.18 | 0.399*** | 0.161** |
| Fischler dummy | | -2.09*** | | -2.09*** | | -0.843*** |
| Fischler*world price | | 0.967*** | | 0.967*** | | 0.385*** |
| Fischler*time | | 0.0002 | | 0.0002 | | No |
| Observations | 159 | 159 | 159 | 159 | 159 | 159 |
| Adj R-squared | 0.62 | 0.81 | 0.65 | 0.81 | 0.97 | 0.97 |
| Chow test | | 45.69*** | | 45.69*** | | |
| DW | 0.14*** | 0.26*** | 0.14*** | 0.26*** | 0.99 | 1.12 |
| Breusch-Pagan | 11.68*** | 20.59*** | 11.68*** | 20.59*** | | |

Source: own elaborations.
*,**,*** denote 10, 5, 1% significance level respectively.

Before the full implementation of the Fischler reform EPT between the world market and the European one was almost zero (no transmission). The world price coefficient, before the break, was equal to 0.180 and not significant. After reform, price transmission grew to almost one (perfect transmission). After January 2007 (break date) the intercept – a measure of transaction cost – assumed a slightly negative value, which can be interpreted as a substantial reduction in transaction cost.

Results from the PW estimation are similar, even though they suggest that the impact of the Fischler reform on the soft wheat market was lower. In particular, EPT increased from 0.161 (before) to 0.546 meaning that, in the long-run, almost 55% of a change in the world price is transmitted to the domestic one. Also in this case transaction cost decreased, but not as much as estimated by the OLS regression. The intercept declines from 1.809 to 0.966 meaning that a certain degree of transaction cost is still present.

**Table 6.27: Durum wheat: long-run relationship between world and European prices.**

| Parameter | OLS | | OLS (HAC std. errors) | | Prais-Winsten | |
|---|---|---|---|---|---|---|
| | No break | Break | No break | Break | No break | Break |
| Constant | 0.579*** | 1.281*** | 0.579*** | 1.281*** | 1.160*** | 3.299*** |
| Time trend | 0.0003*** | 0.0003** | 0.0003* | 0.0003* | No | No |
| World price | 0.712*** | 0.401*** | 0.712*** | 0.401*** | 0.476*** | 0.058 |
| Fischler dummy | | -0.653*** | | -0.653*** | | -0.800*** |
| Fischler*world price | | 0.364*** | | 0.364*** | | 0.243*** |
| Fischler*time | | -0.001*** | | -0.001*** | | No |
| Observations | 159 | 159 | 159 | 159 | 159 | 157 |
| Adj R-squared | 0.89 | 0.93 | 0.89 | 0.93 | 0.97 | 0.94 |
| Chow test | | 24.15*** | | 24.15*** | | |
| DW | 0.31*** | 0.45*** | 0.31*** | 0.45*** | 1.76 | 2.01 |
| Breusch-Pagan | 14.80*** | 2.41 | 14.80*** | 2.41 | | |

Source: own elaborations.
*,**,*** denote 10, 5, 1% significance level respectively.

Table 6.27 shows the results regarding durum wheat, the essential ingredient for making pasta. The world reference price is the Canadian export price. It must be stressed that the average European price mainly reflects the Italian price, being Italy the leading producer of the cereal and of pasta. Also in this case the Fischer reform increased price transmission and decreased transaction cost, even if the magnitude of changes is different when estimated with OLS or PW. According to the OLS coefficients, EPT increased from 0.401 to 0.765 after January 2007. This is probably the result of Italy's decision to fully decouple payments from production, therefore exposing domestic producers to wider market fluctuations. Transaction cost almost halved, decreasing from 1.281 to 0.628. The EPT estimated with the PW technique is significantly lower, being 0.058 before reform and 0.301 after. Also transaction cost decreased less (from 3.299 to 2.499). Nevertheless, PW estimates are consistent with OLS in measuring an increase in market integration after January 2007.

**Table 6.28: Corn: long-run relationship between world and European prices.**

| Parameter | OLS | | OLS (HAC std. errors) | | Prais-Winsten | |
|---|---|---|---|---|---|---|
| | No break | Break | No break | Break | No break | Break |
| Constant | 0.885*** | 1.349*** | 0.885*** | 1.349*** | 1.641*** | 1.829*** |
| Time trend | -0.0003*** | -0.0003* | -0.0003 | -0.0003 | No | No |
| World price | 0.645*** | 0.408*** | 0.645*** | 0.408*** | 0.265*** | 0.169* |
| Fischler dummy | | -0.776*** | | -0.776** | | -0.384 |
| Fischler*world price | | 0.529*** | | 0.529*** | | 0.185 |
| Fischler*time | | -0.002*** | | -0.002** | | No |
| Observations | 159 | 159 | 159 | 159 | 159 | 159 |
| Adj R-squared | 0.59 | 0.66 | 0.59 | 0.66 | 0.95 | 0.95 |
| Chow test | | 10.25*** | | 10.25*** | | |
| DW | 0.17*** | 0.24*** | 0.17*** | 0.24*** | 1.01 | 1.03 |
| Breusch-Pagan | 10.32*** | 57.67*** | 10.32*** | 57.67*** | | |

Source: own elaborations.
*,**,*** denote 10, 5, 1% significance level respectively.

Also in the case of corn, the Fischler reform might have had a positive effect on market integration (Table 6.28), at least according with the OLS results. In fact, corn and barley are the only cases in which results from OLS and PW differ in detecting the presence of a structural break. According to the OLS

estimator, after the break, EPT more than doubled, increasing from 0.408 to almost unity. At the same time transaction cost decreased (but not totally disappeared) from 1.349 to 0.820. However, according to the PW estimation, the role of the Fischler reform in increasing market integration is negligible. The dummy variable representing the reform and the interaction term are, in fact, non-significant, indicating that price transmission between the world and the European market did not change after January 2007 and remained quite low, just 0.169.

**Table 6.29. Feed barley: long-run relationship between world and European prices.**

| Parameter | OLS | | OLS (HAC std. Errors) | | Prais-Winsten | |
|---|---|---|---|---|---|---|
| | No break | Break | No break | Break | No break | Break |
| Constant | 0.643*** | 1.815*** | 0.643*** | 1.815*** | 1.513*** | 1.683*** |
| Time trend | No | No | No | No | No | No |
| World price | 0.708*** | 0.130* | 0.708*** | 0.13 | 0.302*** | 0.216*** |
| Fischler dummy | | -1.662*** | | -1.662*** | | -0.347 |
| Fischler*world price | | 0.804*** | | 0.804*** | | 0.165 |
| Fischler*time | | No | | No | | No |
| Observations | 159 | 159 | 159 | 159 | 159 | 159 |
| Adj R-squared | 0.67 | 0.78 | 0.67 | 0.79 | 0.97 | 0.97 |
| Chow test | | 41.59*** | | 41.59*** | | |
| DW | 0.14*** | 0.24*** | 0.14*** | 0.24*** | 0.99 | 1.00 |
| Breusch-Pagan | 2.87* | 23.17*** | 2.87* | 23.17*** | | |

Source: own elaborations.
*,**,*** denote 10, 5, 1% significance level respectively.

Table 6.29 illustrates the results of the feed barley regressions. Also in this case OLS estimates support the *a priori* hypothesis that the Fischler reform contributed in increasing market integration between the world and the European markets, while the PW estimates do not. According to the OLS regression, EPT increased from almost zero before reform to 0.817 after, at the same time transaction cost decreased to almost zero. These results are in sharp contrast with those provided by the PW estimation, which do not support the *a priori* hypothesis.

**Table 6.30. Butter: long-run relationship between world and European prices.**

| Parameter | OLS | | OLS (HAC std. errors) | | Prais-Winsten | |
|---|---|---|---|---|---|---|
| | No break | Break | No break | Break | No break | Break |
| Constant | 2.298*** | 3.599*** | 2.298*** | 3.599*** | 2.787*** | 3.299*** |
| Time trend | -0.001*** | -0.001*** | -0.001*** | -0.001*** | No | No |
| World price | 0.398*** | -0.020 | 0.398*** | -0.020 | 0.220*** | 0.058 |
| Fischler dummy | | -1.766*** | | -1.766*** | | -0.800*** |
| Fischler*world price | | 0.509*** | | 0.509*** | | 0.243*** |
| Fischler*time | | 0.001*** | | 0.001* | | No |
| Observations | 157 | 157 | 157 | 157 | 157 | 157 |
| Adj R-squared | 0.49 | 0.74 | 0.49 | 0.74 | 0.93 | 0.94 |
| Chow test | | 50.70*** | | 50.70*** | | |
| DW | 0.13*** | 0.28*** | 0.13*** | 0.28*** | 1.97 | 2.01 |
| Breusch-Pagan | 14.84*** | 16.31*** | 14.84*** | 16.31*** | | |

Source: own elaborations.
*,**,*** denote 10, 5, 1% significance level respectively.

Table 6.30 shows the results from the butter regressions. World price is the indicative export price of main producer countries such as Australia and New Zealand. In this case, the Fischler reform increased market integration between European and world markets according to both the OLS and the PW estimators. Also in this case the magnitude of changes is greater in the OLS regression but both estimators agree in saying that before the reform the European market was isolated to the world one: EPT, before Fischler, was not significantly different from zero in neither case and transaction cost was quite high. After reform EPT increased to almost 0.5 according to the OLS estimator and to almost 0.3 according to PW. In both cases transaction cost declined but remained high, maybe reflecting the long distance between the main places of production (Oceania) and of destination (Europe). The increase in butter market integration seems confirmed by the growing attention paid by European operators to price movements overseas.

Finally it must be acknowledged the fact that the extent to which world prices are transmitted to the EU domestic market might have been influenced also by exchange rate fluctuations. Liefert and Persaud (2009) argue that the extent to which both world prices and exchange rate fluctuations are transmitted to domestic prices depends on a country's trade policies, therefore it might be the case that the reforms of the CAP not only increased price transmission but also exchange rate pass-through. For that reason, if exchange rate fluctuations did have an impact on price transmission elasticity, this might be as well traced back to reforms of the PAC. This aspect, which has not been taken into account explicitly and that is of great interest, might be further explored in next versions of the paper.

#### *6.2.4.4 Discussion and Policy Implications.*

This sub-section assessed whether the full implementation of the Fischler reform positively affected price transmission elasticity (EPT) between the world and some European agricultural markets and therefore increased market integration. Commodities considered were soft and durum wheat, corn, barley, and butter: amongst the most important ones for human consumption and animal feed. Whether and the extent to which EPT changed after the Fischler reform has been investigated through both OLS regression techniques allowing for structural breaks (controlling for heteroskedasticity and autocorrelation) and the Prais-Winsten (PW) estimator. Data used are monthly figures, less prone to be subjected to short-term market fluctuations that may alter long-run relationships between price pairs, and easier to gather.

The OLS results show that before the full implementation of the Fischler reform (January 2007 chosen as break date), EPT was almost zero for soft wheat, feed barley, and butter. In all these cases the degree to which prices are transmitted from the world to the domestic market increased: to almost unity (perfect transmission) for soft wheat and feed barley and to almost 0.5 in the case of butter, which market has historically been strongly protected by the European Union. For durum wheat and corn, it has been detected that a certain degree of price transmission was present also before the full implementation of the

Fischler reform: before 2007 EPT was almost 0.4 for both. Also in these two cases the reform increased market integration: the EPT of durum wheat increased to almost 0.8, while that of corn to almost 0.9. The Fischler reform also had an effect on transaction cost, approximated by the intercept. They have decreased in all cases, dropping to almost zero for soft wheat and barley. Transaction cost declined also for durum, corn, and butter but relatively less than the other two commodities. In absolute terms the highest transaction cost is that affecting butter, probably because of the great distance between the main area of production (Oceania) and the fact that the European market had been isolated from the world one for a long time, meaning that maybe trade practices still have room for improvement. It must be highlighted that, over such a long time span, transaction cost are unlikely to have remained constant, however, the inclusion of freight rates data (when available) did not significantly improve the model.

Results from the PW estimator confirmed the fact that the full implementation of the Fischler reform increased the EPT between international and European agricultural market for soft and durum wheat and butter, even though the magnitude of the change was lower than that estimated through OLS. In the case of corn and barley no change in ETP was detected after the Fischler reform.

Two lessons can be learned from this work. The first is a methodological one. Results seem to be sensitive to the methodology used (OLS vs. PW), the length of the time span considered, and data frequency in accordance to what pointed out by Conforti (2004). The time series properties of the series might change if one varies the time span considered, consequently affecting the type of econometric techniques that can be used to measure EPT changes (cointegration vs. conventional OLS, inclusion of lagged values of the variables, *etc.*).

The second lesson is a policy one. The Fischler reform seems to have played an active and positive role in increasing market integration between world and European markets, even though many other factors may have played a role as well. First of all, the sharp increase in biofuel production in the US that inflated the demand for corn, which in turn triggered an increase in the price of other agricultural commodities because of substitution effect, and the progressive financialization of agricultural markets, which increased the number of transactions on future markets. Nowadays agricultural commodities are not traded only by sector operators anymore but have become like any other commodity (like gold or silver or oil) and are being the target of financial operators and investment funds as well. The full implementation of the Fischler reform took place almost exactly at the same time as the price bubble of 2007-08, which might have represented the beginning of a new kind of relationship between agricultural prices. One might argue that the change in ETP was something that could have happened also if the Fischler reform did not take place. However, results from the butter equation show that the reform did have an effect and also a quite strong one. Analyzing the butter market allows to “isolate” the effects of the Fischler reform from those of other factors, since butter is much less affected by speculation, rising global demand, and biofuel production than cereals. Also in the case of grains, however, it is likely that the reform had a positive effect

on market integration, acting as a "magnifier" in transmitting the effects of increased global demand, financialization, and biofuel production, from the world to European producers.

It must be stressed that also changes in the exchange rate could have played a role in the relationship between international and EU prices. Even if it can be excluded that speculative behavior in currency markets played a role, since the euro and the dollar are global currencies exchanged on a daily basis by a great number of operators, it might be the case that changes in the CAP have changed the role played by the exchange rate. Similarly to what happens for price changes, also the extent to which exchange rate fluctuations are transmitted to domestic prices depend on a country's trade policies. Therefore it might have been the case that reforms of the CAP not only increased price transmission but also the exchange-rate pass-through, which in turn can affect the EPT. This aspect, which has not been taken into account explicitly is of great interest and might be further explored in the future.

Further research would benefit from both a wider dataset and the use of more advanced econometric techniques. It would be interesting to widen the analysis taking into account biofuel production (and prices) and other factors that might have been affecting price relationships in the last decade such as financial transactions, and changes in the exchange rate. However, such data are far from easy to obtain, when available at all. Better and most sophisticated econometric methods could also be employed on the current dataset but it is likely that the data availability problem is a much more limiting factor than the methodological one.

### 6.2.5 Final considerations.

From the results obtained in the previous sub-sections, it seems clear that the Fischler reform played a key-role in increasing the extent to which changes in international prices are transmitted to EU agricultural markets. In a few years European agricultural markets passed from being almost isolated from world markets to be almost fully integrated with them. Since the speed of change has been very rapid, the consequences for farmers and operators of the agro-food industry have been significant. Until some years ago to be a farmer, in the EU, was an activity characterized by a relatively low level of risk, since EU policies protected the domestic market from world price fluctuations. The progressive dismantling of protectionist policies increased the level of risk and uncertainty of the environment in which farmers and other operators of the food supply chain operate. Agricultural prices, at international level, have always been volatile (even though in recent years volatility has indeed increased), however, the complex market measures and production subsidy schemes put in place by the EU had always protected the domestic agriculture sector from market fluctuations. It is not like this anymore. Nowadays the extent to which price movements on international markets are transmitted to the EU is almost complete, especially for grains, amongst the most traded commodities. European farmers have been suddenly exposed to international market forces, like a boat that has been harbored for a long time and for the first time sails to the open sea,

and have to learn, very quickly how to cope with the new market conditions since high commodity prices and high volatility, according to the FAO and other international organizations, will be a constant in the next few years. Furthermore, biofuel expansion has created a new, direct, link between energy and agricultural markets in the US and in Brazil, meaning that policy design and implementation will have to take these new relationships into account. Also farmers will have to adapt to the new situation: European agriculture, in such a context can survive only if able to differentiate its products from those produced, at lower unit-cost, in countries like the US, Brazil, Argentina or Australia. Moreover farmers will have to cluster in big production cooperatives or consortia to better stand market fluctuations and increase their bargaining power. Finally it would be desirable a strong development in insurance instruments and future markets in Europe (especially in Mediterranean countries, such as Italy) which farmers could resort to lower the effects of price uncertainty.

# 7 Conclusions.

This thesis dealt with three main topics all related to the recent expansion in biofuel production worldwide. First, it analyzed biofuel and biofuel feedstock production in the world, with special emphasis on the economic, social and environmental sustainability of biofuel policies. Second, it empirically assessed the extent to which biofuel expansion affected the relationships between energy and agricultural prices in the key biofuel producing countries. And third, measured the extent to which changes in international commodity prices are transmitted to the European Union.

The main conclusion is that the strong expansion of biofuel production that took place in the last decade was mainly policy-driven or, put it in another way, it would not have happened without strong government intervention in few key countries (the US, Brazil and the EU). The problem is that such policies, even if very successful in boosting biofuel production, proved to be bad-designed since they did not take into account, more or less consciously, the several side-effects that the creation, *ex novo*, of this new market might have had.

Biofuels started to be subsidized for several reasons, at least officially. These included the fact that biofuels would enhance a country's energy security, contribute decreasing GHG emissions (since biofuels were considered carbon-neutral), create an alternative market for agricultural commodities (in a period of relatively low international prices) and boost rural development, especially in developing countries. Unfortunately only a few studies addressed this topic before governments started their support programs, while the majority of them were carried out only very recently, well after policy implementation.

Biofuel expansion took place through the promotion, by governments, of the so-called first-generation biofuels, which means produced from food crops, such as corn, sugarcane and vegetable oils. At the end of the 2000s more than 40% of the US corn production was employed to produce ethanol. Since the US is the largest corn producer and exporter in the world it would be naïve to think that such increase in corn demand would not imply serious consequences for agricultural commodity markets. The most evident, and undesirable, consequence that biofuel expansion had was a strong and sudden increase in the demand for agricultural commodities, which in turn, increased prices. Even though many other factors might have influenced agricultural prices in the last decade, among which increased demand by emerging economies, increased financial transactions on agricultural markers and bad weather conditions, it might be affirmed that the role of biofuel expansion was not marginal and have exacerbated an already critical situation. Even though not all main agricultural commodities are used as feedstock in the biofuel industry, biofuel expansion had repercussions also on those not interested directly by biofuel production. The main reason is the high level of integration agricultural markets have nowadays, thanks to reduced trade barriers and better information flows. Furthermore, since land supply is inelastic in the short term, competition among crops for land increased due to biofuel expansion. In the United States, for example, where corn is

the main biofuel feedstock, the sharp increase in corn prices that took place in the last decade induced farmers to sow more corn at the expenses of soybean, which price in turn increased because of lower supply. It has also been argued that biofuels created a new, more direct, relationship between energy and agricultural markets, once only indirectly linked through the cost of agrochemical agricultural inputs such as fertilizers. This research brings evidence in favor of both hypotheses. Time series econometrics have been used to analyze price relationships between energy and agricultural prices in the main biofuel producing countries. In the US and in Brazil ethanol and agricultural prices move together in the long-run and the influence of oil prices has been growing over time. This means that policy-makers, in the future, will have to pay great attention to the mutual influence energy and agricultural policies can have on each other. In Europe this close relationship between energy and agricultural prices was not detected, however European agricultural markets have been influenced by biofuel policies in the US, and to a lesser extent Brazil, indirectly, through their effects on international commodity prices.

Biofuel expansion had repercussions on agricultural prices not only in countries characterized by a developed biofuel sector but also in those where biofuel production is limited, provided at least partial transmission between international and domestic prices is present. The United States, and to a lesser extent Brazil, countries where the biofuel sector is more developed, are big enough, in terms of agricultural production, to influence international prices (often US prices are taken as reference ones), which in turn can transmit to domestic ones provided they are sufficiently integrated to the world market. The European Union is an emblematic case in this sense. In the EU the biofuel sector is not so developed like in the US and Brazil and since it is focused on biodiesel (produced from vegetable oils such as rapeseed oil and palm oil) its repercussions on agricultural markets within the Union are limited. However, the process of reform of the Common Agriculture Policy, in the last 20 years, has progressively reduced the level of protection of European agricultural markets, increasing the level to which changes in international prices were transmitted into domestic ones. In this research it is shown that the elasticity of price transmission (EPT) between the EU and the world market increased substantially after the last major reform of the CAP (Fischler's, which entered into force in 2005-07) meaning a higher degree of integration between the EU and international agricultural commodity markets. This is very important because full transmission between EU and world prices, implies that also the European agricultural sector can be affected by biofuel policies in third countries (the US) through their effect on international prices. Even if not tested empirically in this research, it is very likely that, similarly to what happened in the EU, biofuel expansion in the US and Brazil affected agricultural prices in many other countries.

Higher agricultural prices often translate into higher consumer food prices, one of the main drivers of inflation. In developing countries, where people spend a large portion of their income in food, the effects of food price increases are particularly serious. The first price bubble of 2007-08, for example, triggered the so-called *tortilla* riots in Mexico, where the price of corn reached sky-high levels in a very short lap of time.

In 2010-11 the strong increase in cereal prices (also due to poor harvests in some key producer countries) was the main reason at the basis of the *Arab Spring*, a series of riots in many North African and Middle East countries, which eventually led to the collapse of several decade-old regimes in the region.

Biofuels not only had unexpected and undesired effects on agricultural prices: they also proved to be less efficient in reducing GHG emissions than it was thought to. At international level there is not concordance on the modalities that should be used to compute the GHG balance of biofuel production and some scientists argue that, contrary to what the initial intentions were, biofuels expansion is, in fact, increasing GHG emissions. However, they are thought to be carbon-neutral because plants while growing, are assumed to absorb the same amount of carbon that will be released when the fuel is consumed. This is true only in theory since many other factors play a role and they are not always accounted for by carbon accounting mechanisms. First of all the strong increase in agricultural prices induced farmers to increase production, something that can be done in two ways: increasing productivity or expanding cultivated area. Both methods imply an increase in carbon emissions, which not always is taken into account. Increasing productivity means producing more from the same unit of land but, by doing so, an increase in the amount of energy-intensive inputs (fertilizers, herbicides, etc.) is needed. Increasing acreage is the other solution but it is difficult to realize in the short-term and can generate serious consequences for the environment.

In this thesis it has been estimated the amount of agricultural commodities that has been needed to produce biofuels in the last decade in the three major biofuel producing countries: the US, Brazil and the EU. Assuming that agricultural productivity will not change in the near future, it has also been forecasted the quantities that will be needed in the future to achieve the biofuel consumption mandates of the US, Brazil, and the EU. The US and Brazil have been assumed to use (now and in the future) domestically produced feedstocks to produce ethanol (from corn in the US and from sugarcane in Brazil) and biodiesel (from soybean oil in both cases). In the case of the EU it has been hypothesized that a mix of domestically produced rapeseed oil and imported palm oil will be employed in biodiesel production in changing proportions. In 2011, 51.8% of Brazilian sugarcane production and 42.2% of US corn production were used to produce ethanol, for a total of 4.2 and 15.5 million hectares respectively, which in turn correspond to 1.5% and 16% of total agricultural area. By 2021 ethanol production will absorb almost 61% of Brazilian sugarcane production and 57% of US corn production, *ceteris paribus*. In 2021 the amount of land needed to grow all sugarcane needed to produce ethanol in Brazil will be more than 8 million hectares, almost equal to the entire current sugarcane area in the South American country (3% of total current Brazilian agricultural area). In the US the area that will be needed to cultivate corn for ethanol production will grow to slightly less than 20 million hectares, equal to 53% of current corn area in the US, and 20% of current agricultural area. Both in Brazil and in the US biodiesel production (from soybean oil) is increasing rapidly. In 2011, 13.4 million tons of soybean were used for biodiesel production in Brazil, corresponding to 16.9% of total production. The increase, with respect to the previous years was quite dramatic given that only in

2005 biodiesel production was almost zero. In order to crop the soybean needed for biodiesel production, were needed, in 2011, 4.4 million ha, almost 17% of total Brazilian soybean area harvested and 1.7% of total agricultural area. This quantity will grow to 16 million tons by 2021 and the area needed to crop soybean for biodiesel production will reach 5.2 million, 3.3% of total current agricultural area (more than the amount that will be needed to crop sugarcane for ethanol production). In the United States, in 2011, 9.8 million ha were needed to produce soybean necessary for biodiesel (2.4% of total agricultural area), 116 times more than in 2001. By 2021 this quantity will reach 35.1 million tons of soybeans will be employed in the biodiesel sector in the US, or 30.9% of total production. The area needed to grow soybeans used for biofuel production will be slightly less than 12 million hectares, 2.9% of current total agricultural area.

These data highlight the different impact sugarcane- and corn-based ethanol have on agricultural production. Brazilian and American ethanol was 22.9 and 52.8 million $m^3$ in 2011 respectively, implying an "ethanol yield" of 5.5 $m^3$/hectare for sugarcane ethanol and of 3.4 $m^3$/hectare for corn-ethanol. This means that producing ethanol from sugarcane is more productive and less consuming in terms of land than corn ethanol. On the whole, considering both ethanol and biodiesel, 3% of total Brazilian agricultural area and 18.4% of total American agricultural area were used for biofuel feedstock production. These quantities are forecasted to grow to 6.3 and 23% by 2021, implying an increasing competition for land.

In the EU, where the most important biofuel is biodiesel, the impact of biofuel expansion on agricultural production has been much harder to estimate since the EU does not produce vegetable oils enough to produce all biodiesel that is consumed within the Union. In 2011 the EU used 5.4 million tons of domestically produced rapeseed oil and at least 3.9 million tons of palm oil to make biodiesel. The amount of land needed to grow rapeseed within the Union and oil palm in third countries (mainly Indonesia and Malaysia) was 5.2 and 1.3 million hectares respectively. The area needed to crop rapeseed for biodiesel production, in the EU was equal to 5.2% of total agriculture area. Assuming that the percentage of rapeseed oil on total vegetable oil production in the EU will remain the same of 2011 and that the share of it employed in the food sector will also remain unchanged, it is possible to forecast that, in 2021, the EU will need 6.6 million tons of rapeseed oil and at least 10 million tons of palm oil from third countries to meet its consumption targets. This means that at least 3.4 million hectares of land, in South East Asia will be needed to produce palm oil destined to the EU. The European Union will depend, for its biodiesel production, more and more from palm oil imports from tropical countries since the domestic vegetable oil production capacity is limited.

Nevertheless, expanding cropped area is not a trivial task and can have negative repercussions in terms of carbon released into the atmosphere. Land use changes due to the expansion of biofuel crops can take place at the expenses of wild areas or forest land rich in vegetation and in biodiversity. If a forest is cleared to make room for oil palm plantations, for instance, a significant amount of carbon, previously stored in the trees will be released into the atmosphere and it might take decades to biofuels to

counterbalance this effect. It is not clear from where the land necessary to meet biofuel consumption targets in the US, Brazil and the EU will come from and how this will be done.

Similarly to what happens in the case of higher food prices, it is in developing countries where the consequences of land use changes are more serious and more difficult to assess. Forest area has been declining in emerging countries like Brazil and Indonesia in the last twenty years, while it has been increasing in developed countries. This is due to the rapid expansion of the agricultural sector in developing countries (fostered only in some cases by biofuels since most of the expansion is spurred by increased domestic demand for food, like in China) but also to weaker environmental regulations, and poor law enforcement. The lack of internationally agreed sustainability criteria for the biofuel (and the agricultural) sector is maybe the most important cause of land use changes and the main matter of concern for the future development of the biofuel sector as well as of the agricultural sector itself.

Even though methodologies and guidelines to calculate GHG emissions from biofuels and their sustainability are present in the main biofuel producing countries, they are often not appropriate, incomplete or applied in the wrong way. The case of the European Union is emblematic in this respect. In the EU, like in most of the other biofuel producing countries, GHG emissions from biofuels are computed through partial life-cycle analysis. However results are heavily dependent on the inputs considered and the boundaries of the analysis itself. The EU methodology, amongst the other things, does not account for indirect land use changes (both in the EU and in third countries) triggered by biofuel expansion in the Union. Even though it is very difficult to calculate them and to discriminate between those induced by biofuels and those by other agricultural activities, they have a strong impact, especially in developing countries, as it can be inferred by palm oil consumption estimates. Also economic models, both partial and general equilibrium ones, are not suitable for computing GHG emissions, land use changes or the impact on food prices triggered by biofuel expansion. They are very complex models but still not complex enough to approximate the real world. Results from studies using such economic models yielded very different results, also when analyzing the same fuel in the same country. Results, like in life-cycle analyses depend crucially on initial assumptions, like the calibration year, the temporal horizon of the model and, more importantly, parameters such as elasticities, which are often best-guessed by researchers or, in the best-case scenario, drawn from the literature.

In many studies indicate, as a solution to the biofuel problem, the development of second- and third-generation biofuels that, according to the literature, should be a sort of *panacea* for all side-effects of first-generation biofuels. It is true that second-generation biofuels are produced from non-food crops and that, consequently, their expansion should not directly affect food prices. However they would still compete with food crops for land and water (70% of world's freshwater is currently used in agriculture). Cultivating feedstock for second-generation biofuels in marginal or idle land can be an option but also in this case the tendency is towards an over-simplification of the problem.

First: converting marginal land might be troublesome and economically not convenient, unless substantial public subsidies are granted to farmers. Second: the process of converting marginal land not necessarily mean that the GHG balance of such conversion will be positive since also cultivating more efficient second-generation feedstock like switchgrass is an agricultural activity, even if less intensive than conventional agricultural commodities. Third: by converting marginal land into cropland it is possible that biodiversity will be negatively affected also because plants used as second-generation biofuel feedstock might escape from cultivation and become invasive species. Fourth: second-generation biofuels, not to mention third-generation ones, are still far from being commercially available at a large scale. In the US, the Environment Protection Agency has been waiving cellulosic ethanol consumption mandates since when they were established because production is almost non-existent. The use of waste or agricultural residues for biofuel production would not have any impact on GHG emission since they would decompose anyway, however this would nevertheless require major investments to convert production facilities.

What emerges from this work is that biofuels, in the current political, economic demographic, situation are, for many aspects, not sustainable. Side-effects of biofuel production are many and often even difficult to quantify. Solutions provided are often utopic or, even if good in theory, very difficult to implement. Biofuel production has been having negative effects on food production and prices, biodiversity and social welfare in the last decade, inside and outside the countries of production. The “original sin” was the initial lack of coordination between policies issued unilaterally by different countries, something that now seems extremely difficult to fix. Governments should, as it has been recently suggested by the United Nations, consider the option of modify their biofuel programs because of their negative consequences on food security in many low-income countries. Also the promotion and implementation of biofuel policies in developing countries should be avoided as a measure for fostering development. It is very unlikely that rural poor will benefit from policies subsidizing the biofuel sector since most of the land in developing countries is owned by big multinational companies or by foreign states (land grabbing). The development of the biofuel sector would also increase food prices even in countries where such increase has been marginal so far because of scarce price transmission from the world market. Poor people living in urban areas would be worse off by higher food prices as well as small farmers who, in developing countries, are often net-purchasers of food.

It has been suggested by many scholars and international organizations that, in order to become sustainable, biofuel production should shift from first-generation to second-generation technologies (those that allow the use of non-food crops or wastes for biofuel production). This will not be easy to achieve. Current second-generation biofuel production is still very small and will not grow substantially unless major investments are made by governments and, under the right conditions, private companies. Moreover it is not governments nor policy-makers who decides whether is profitable to put marginal land under cultivation and to crop non-food biofuel crops on it. Farmers are those making such decisions and they will

not do it unless it is profitable. Current record-high agricultural commodity prices raise many doubts on the fact that farmers will shift from food to non-food crops without substantial government subsidies. An increase in subsidies to the agricultural sector, even just for energy crops, is unlikely to happen anytime soon because of the financial and economic crisis that hit many countries around the world and because of pressure by the WTO and other international organizations to reduce the degree of protection.

In case it will be decided to keep subsidizing biofuels, new polices will have to be designed and implemented at world level, needing a very high degree of coordination between countries and flexibility, which is difficult to imagine can be reached in the short or even the medium term. An emblematic case, in this sense, is GHG emission accounting mechanisms that currently are based on life-cycle assessment analysis and that are often incomplete (i.e. limited to a single country or region) or unable to take all factors into account (i.e. indirect land-use changes).

Research, in the next years, will have to focus on two main topics. On one hand second- and third-generation techniques for biofuel production will have to be refined and made economically (but also environmentally and socially) viable, possibly together with progressive reduction in the support in favor of first-generation biofuels. On the other hand, a better definition of the methodologies to assess the environmental, economic and social impacts of biofuel production will be crucial in order to correctly evaluate the sustainability of biofuel programs. In particular, the development of reliable methodologies to assess the environmental impact of biofuel production is very important since, in the future, subsidies could be calculated in a way to reward the production of biofuels able to provide (proved) positive externalities to the environment as well as increase social welfare.

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