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Hedging price risk of agricultural commodities: feasibility, effectiveness, and farmers' behaviour.

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Copertura del rischio di prezzo delle commodities agricole: fattibilità, efficacia e comportamento degli agricoltori.

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Preface

This thesis has been prepared in fulfilment of the requirements for the PhD degree at the Department of Land, Environment, Agriculture and Forestry (LEAF), School of Agriculture and Veterinary Medicine, University of Padua. The work has been carried out under the supervision of Professor Samuele Trestini and Doctor Elisa Giampietri from LEAF department in the period from October 1, 2018, to December 31, 2021. The main body of the thesis consists of an introduction to the overall work and four chapters on the thesis topic. Each chapter is written as an individual scientific paper. Finally a concluding chapter summarize the results of the four scientific papers.

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Contents

	Preface	
	Acknowledgments	
	Contents	1
	List of Papers	2
	List of Figures	3
	List of Tables	4
	Summary	5
	Riassunto	7
1	Introduction	9
2	Futures-Spot price transmission in EU corn markets	37
3	Testing for asymmetric cointegration of Italian agricultural commodities prices: evidence from the futures-spot market relationship	67
4	Hedging effectiveness of commodity futures contracts to minimise price risk: empirical evidence from the Italian field crop sector	83
5	Analysing farmers' intention to adopt marketing contracts as an innovative strategy to tackle income risk at the farm level	109
6	Conclusion	133

List of Papers

This thesis is based on four papers:

Carlotta Penone, Elisa Giampietri, Samuele Trestini (2022). **Futures-Spot price transmission in EU corn markets.** *Agribusiness.*

Carlotta Penone, Samuele Trestini (2022). **Testing for asymmetric cointegration of Italian agricultural commodities prices: evidence from the futures-spot market relationship.** *Agricultural Economics Czech, 68: 50–58.*

Carlotta Penone, Elisa Giampietri, Samuele Trestini (2021). **Hedging effectiveness of commodity futures contracts to minimise price risk: empirical evidence from the Italian field crop sector.** *Risks*, 9(12), 213.

Carlotta Penone, Elisa Giampietri, Samuele Trestini. **Analysing farmers' intention to adopt marketing contracts as an innovative strategy to tackle income risk at the farm level.** (*In preparation for Agricultural Finance Review*).

List of Figures

Figure 1:1	*Agricultural commodities prices volatility.*	11
Figure 1:2	*Stele depicting an agreement for a futures delivery of barley.*	19
Figure 2:1	*Corn futures and spot prices.*	42
Figure 3:1	*The futures prices (CBOT and Euronext).*	70
Figure 4:1	*Probability density function of risks and measures of hedging effectiveness.*	92
Figure 5:1	*Indicators structural map.*	115
Figure 5:2	*Structural model and path analysis of the hypotheses.*	118

List of Tables

Table 2:1	*Descriptive statistics of futures and spot prices (€/t)*	41
Table 2:2	*Stationarity tests for the selected futures markets and the Member States*	45
Table 2:3	*Cointegration test for corn futures and spot prices of the selected Member States*	46
Table 2:4	*Gregory Hansen's cointegration test*	47
Table 2:5	*Toda-Yamamoto Granger causality test statistics for the selected Member States*	49
Table 2:6a	*Results of the VECM between Euronext futures contract and MS spot prices*	52
Table 2:6b	*Results of the VECM between CBOT futures contract and Member States spot prices*	53
Table 2:AA1	*Results of the VECM with dummy between Euronext futures contract and Member States spot prices*	62
Table 2:AA2	*Results of the VECM with dummy and with interaction dummy between Euronext futures contract and Member States spot price*	63
Table 2:AA3	*Results of the VECM with dummy between CBOT futures contract and Member States spot prices*	64
Table2:AA4	*Results of the VECM with dummy and with interaction dummy between CBOT futures contract and Member States spot price*	65
Table 2:AB1	*Result of the Phillips-Perron stationarity tests*	66
Table 3:1	*Summary statistics of the futures and spot prices*	71
Table 3:2	*Unit root test on spot and futures prices of designated agricultural commodities*	73
Table 3:3	*Cointegration of designated agricultural commodities*	74
Table 3:4a	*VECM of designated agricultural commodities*	76
Table 3:4b	*TVECM of designated agricultural commodities*	77
Table 4:1	*Returns descriptive statistics and stationarity tests*	93
Table 4:2	*Estimates of the Optimal Hedging Ratio for all the considered commodities*	95
Table 4:3	*Estimates of the Hedging Effectiveness through variance reduction, for all the considered commodities*	97
Table 4:4	*Estimates of the Hedging Effectiveness through risk indexes, for all the considered commodities*	98
Table 5:1	*Latent variables, related indicators, and statements for each indicator*	118
Table 5:2	*Descriptive statistics of the sample*	121
Table 5:3	*Outer model evaluation criteria*	123
Table 5:4	*Outer model evaluation criteria (HTMT ratios for the discriminant validity)*	124
Table 5:5	*Inner model evaluation*	125
Table 5:6	*Goodness of fit*	125
Table 5:7	*Results of the inner model*	127

Summary

Farmers face risks. Indeed, agriculture is a risky business, and nowadays this is mainly due to the persisting price volatility and uncertain events (i.e., weather and climate adverse events, the COVID-19 pandemic) causing both price and production risks. As a consequence, the income risk affects farmers resilience in the long run. Numerous risk management strategies are available for handling price risk (i.e., farms' self-coping strategies, subsidized and non-subsidized instruments as insurance, mutual funds, derivatives, etc.). Among these, hedging with agricultural contracts (forward and futures contracts) shows a limited adoption rate by farmers. This thesis aims at evaluating the feasibility of hedging with international futures markets for farmers, and the measure of the effectiveness of these market instruments in reducing farmers' income volatility. Moreover, another research objective of this thesis is the understanding of the determinants of farmers' adoption of agricultural contracts to manage price risk at the farm level. The broader objective lies in the provision of insights that are instrumental to the development of such promising risk management tools among both European and Italian farmers. Indeed, the most recent reforms of the Common Agricultural Policy led to reducing farmers' income support; hence studying new strategies for protecting farmers' income is of paramount importance.

This thesis is a collection of four papers and consists of an introduction, followed by four chapters (papers) and the conclusions. Accordingly, each paper is presented in a separate chapter, and hence the chapters are self-contained and may be read individually.

Chapters 2 presents the study of price transmission between futures and spot prices. This examines the degree of transmission for the corn commodity between global futures price in either the Chicago Board of Trade (CBOT) or Euronext and the spot prices for a selection of the Member States of the European Union. Indeed, given the volatility characterizing agricultural commodity prices and the decreasing level of income support granted by the Common Agricultural Policy, the development of new market strategies is of the utmost importance for European farmers.

Similarly, in Chapter 3, the relationship between the CBOT and Euronext futures prices and the spot prices for the Italian agricultural markets of soybean, corn, and milling wheat is examined. The chapter presents the results of a symmetric and asymmetric vector error

correction model (VECM), confirming the presence of a non-linear cointegration relationship for all the agricultural commodity prices.

Chapter 4 presents the analysis of the hedging effectiveness in reducing Italian farmers' income volatility through CBOT and Euronext futures contracts. The analysis focused on soybean, corn, and milling wheat prices. Different hedging horizons are considered for the estimation of the hedge portfolio then compared to an unhedged portfolio for assessing the granted price risk reduction.

Chapter 5 analyses farmers' characteristics influencing the adoption of marketing contracts within an innovation adoption framework, given the scarce adoption of marketing contracts among farmers.

As before mentioned, the thesis ends with some main conclusions.

Riassunto

L’agricoltura è una attività rischiosa. Oggigiorno ciò è principalmente dovuto alla persistente volatilità dei prezzi ed agli eventi incerti (ad esempio eventi avversi meteorologici e climatici, la pandemia di COVID-19) che causano rischi sia di prezzo che di produzione. Il rischio di reddito incide sulla resilienza degli agricoltori nel lungo periodo. Gli agricoltori Europei hanno a loro disposizione numerose strategie di gestione del rischio di prezzo (es. strategie di auto-coping delle aziende agricole, strumenti sovvenzionati e non sovvenzionati come assicurazioni, fondi comuni di investimento, derivati, ecc.). Fra tutti, la gestione del rischio tramite contratti agricoli (contratti forward e futures) mostra un limitato tasso di adozione a livello Europeo ed Italiano. Nel contesto dell’agricoltura Europea ed Italiana, questa Tesi mira a valutare la fattibilità delle strategie di hedging con contratti futures e la misura dell'efficacia nel ridurre la volatilità dei redditi degli agricoltori. Inoltre, un altro obiettivo di ricerca di questa tesi è la comprensione di quali attributi influenzano l'adozione dei contratti per la gestione del rischio di prezzo a livello aziendale. L'obiettivo più ampio risiede nella fornitura di approfondimenti che sono strumentali allo sviluppo di strumenti di gestione del rischio promettenti tra gli agricoltori Europei e Italiani. Le più recenti riforme della Politica Agricola Comune, infatti, hanno portato a ridurre il sostegno al reddito degli agricoltori; pertanto, è di fondamentale importanza studiare nuove strategie per la tutela del reddito degli agricoltori.

La presente tesi è strutturata in quattro articoli scientifici, presentando le problematiche generali nell’introduzione, sviluppandosi in quattro capitoli (articoli scientifici) e traendo delle conclusioni finali alla luce di quanto emerso da questa ricerca.

Il capitolo 2 presenta lo studio della trasmissione dei prezzi tra i contratti futures e i prezzi spot. Nel contesto del mercato maidicolo, il capitolo esamina il grado di trasmissione tra il prezzo dei contratti futures quotati nel Chicago Board of Trade e nell’Euronext, e tra i prezzi spot di una selezione di Stati Membri dell'Unione Europea. Analogamente, nel Capitolo 3, viene esaminata la relazione tra i prezzi dei contratti futures quotati nel CBOT ed Euronext ei prezzi spot per i mercati agricoli italiani della soia, del mais e del grano macinato. Il capitolo presenta i risultati dell’analisi di trasmissione simmetrica e asimmetrica dei prezzi, confermando la presenza di una relazione di cointegrazione non lineare per le materie prime agricole considerate. Il capitolo 4 presenta l'analisi

dell'efficacia della copertura del rischio di prezzo tramite contratti futures nel ridurre la volatilità del reddito degli agricoltori italiani. L'analisi considera i prezzi dei contratti futures quotati nel CBOT e nell’Euronext e per soia, mais e grano tenero. Attraverso il confronto di un portafoglio con e senza strumenti di hedging, è stata valutata la riduzione del rischio di prezzo connessa con l’utilizzo di questi strumenti. In fine, il capitolo 5, sviluppando un framework di analisi per l’adozione di innovazioni, analizza quali caratteristiche influenzano l'adozione dei contratti da parte degli agricoltori.

1

INTRODUCTION

This chapter provides an overview of the thesis's following four chapters covering feasibility, effectiveness, and farmers' behaviour on financial price risk management instruments. Initially, the concept of risk for agricultural commodities is introduced, followed by an overview of the European and Italian commodity sector. Then the topic of price risk management and its tools is analysed before focusing on price risk management with hedging instruments. Finally, the description of the research gaps and the steps which brought to the completion of the subsequent four chapters is described.

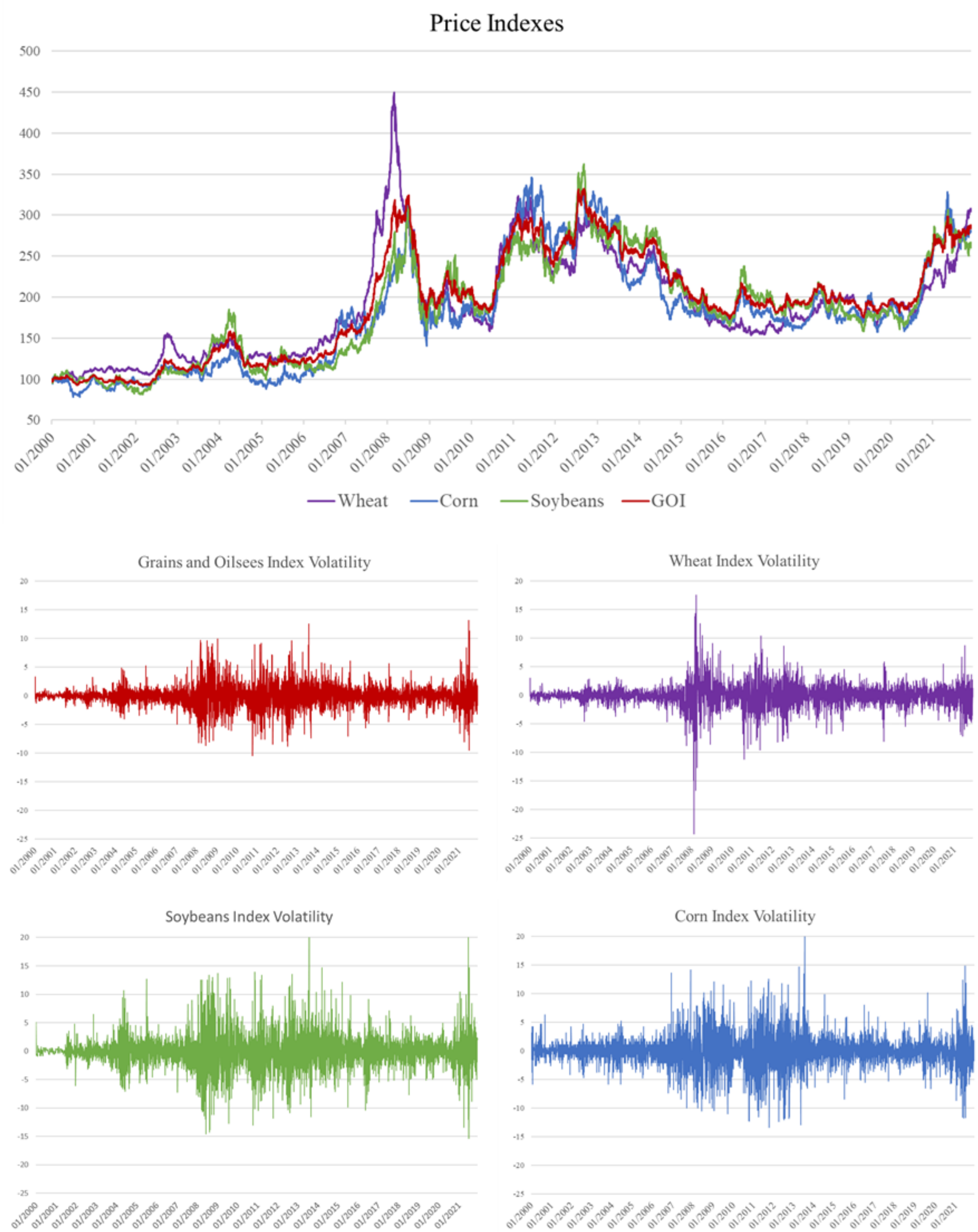
Price risk for agricultural commodities

Farmers are constantly exposed to and must manage different types of risks. Uncertainty originates from decisions sets' random consequences, while risk originates from the exposure to uncertain adverse economic results numerically defined (Hardaker et al., 2015). More straightforwardly, risk generates from the possibility of adverse outcomes due to uncertainty and imperfect knowledge in decision-making. Therefore, the issue of risk in farming activity attracted considerable interest among agricultural economists, and policymakers, given the importance of managing risk in the agricultural sector.

The risks that affect this sector can be divided into five categories, namely production, market, institutional, financial, and personal risk. Recent literature on farmers risk management focused on production risks (Komarek et al., 2020). However, farmers' perceived importance of each type of risk shows that also market risk (or price risk) engenders the greatest concerns (Angelucci and Conforti, 2010; Chand et al., 2018; Jankelova et al., 2017; Meuwissen et al., 2019; Thompson et al., 2019). Farmers' decisions on what and how much to produce are based on price expectation, not price realisation, implying uncertainty (Moschini and Hennessy, 2001). The natural level of risk associated with this time difference between decision making and the selling of the output is heightened by the uncertain circumstances in which farmers operate.

Indeed, markets for agricultural commodities have an inherent tendency to be volatile (Bobenrieth et al., 2013; Wright, 201; Baffes and Haniotis, 2016). As it is possible to observe in figure 1:1, the price volatility of agricultural commodities has been particularly high in the last twenty years, showing periods of increased instability: see, for instance, the prices increase in 2006/2008 (Baffes and Haniotis, 2016) and the following spikes in 2011 (Tadesse et al., 2014). Similar increases are registered today in commodity markets worldwide (USDA, 2021). As these price changes are unpredictable, price volatility has compound negative consequences in all parts of the world (Tadesse et al., 2014; Höhler and Lansink, 2021). Several factors impact agricultural price volatility, and understanding its determinants represents a relevant issue.

Figure 1:1. Agricultural commodities prices volatility.



Note: The grains and oilseed index (GOI)comprise prices for different agricultural commodities (wheat, corn, barley, sorghum, rice, soybean, and rapeseed) measured in 34 world trade location, then weighted for the share of global trade. The wheat index comprise whet prices quoted in 10 different markets (Argentina: variety, Trigo Pan; location, Up River. Australia: variety, ASW; location, Port Adelaide. Black Sea: variety, Milling wheat. Canada: variety, No. 1 CWRS, 13.5%; location, St. Lawrence and Vancouver. EU France : variety, Standard Grade; location, Rouen. US: variety, No. 2 HRW Ordinary and No. 2 SRW; location, Gulf. US: variety, No. 2 DNS 14% and No. 2 SW; location, PNW). The corn index comprise corn prices quoted in 4 different markets(Argentina, Black Sea, Brazil and US). The soybean index comprise soybean prices quoted in 3 different markets(Argentina, Brazil and US).

Factors affecting agricultural commodity prices can be distinguished as endogenous and exogenous. First of all, high levels of price and income volatility for farmers are related to the endogenous conditions of the supply and demand balance for agricultural products. Indeed, the supply response to demand increases, decreases, or shock is slow. Moreover, agricultural commodities are essential to consumers implying limited demand changes in response to prices increases. Thus, short-term inelastic demand and supply conditions intrinsically indicate that, for a slight shift in one of the two curves, prices respond with high swings, thus resulting in high price volatility (Samuelson et al., 2010; Goodwin et al., 2012; Guerra et al., 2015).

Especially for commodity markets, the relative importance of supply and demand developments has a global perspective. Agricultural commodities are primary agricultural products in their original form or have undergone only primary processing trough that has not attained any distinguishing characteristics or attributes (Crawford, 1997). Thus, within a considerable grade, and for a given variety, commodities coming from different suppliers, and even different countries or continents, are ready substitutes for one another (Roberts and Schlenker, 2013).

The tradability of agricultural commodities and the convergence of commodity prices worldwide are irrefutable evidence of a globalised market (O'rourke and Williamson, 2002), bringing strong repercussions on the volatility of commodities prices. The globalisation of agricultural commodities markets, prompted by the World Trade Organisation (WTO), concurrently affected prices dynamics and volatility, especially agricultural horizontal price transmission among markets. As examples, Mundlak and Larson (1992) highlighted an almost unitary transmission of world prices to multiple domestic markets, contradicting general arguments that policy intervention in agricultural markets limited information flows among markets. Similarly, Conforti (2004) revealed varying levels of price transmission in developing countries, including in several highly regulated markets. On the other hand, Baffes and Gardner (2003) reported that, for developing countries, only 3 of 8 markets were integrated with world prices, without any improvement after policy reforms. While the volatility of world agricultural commodity prices and its effect on domestic prices increased governments' application of restrictive policies (Cordier, 2014), trade restrictions have been linked with supply shocks, resulting in increased volatility (Martin and Anderson 2012; Santeramo et al., 2017).

Finally, the theoretical framework of competitive storage (Wright and Williams, 1984) shows that storage effectively stabilises prices, creating a buffer effect on price shocks (Bobenrieth et al., 2013; Gilbert and Mugera,2020; Bobenrieth et al., 2021). Moreover, also the presence of additional stocks can mitigate the volatility of agricultural prices within a year in which production is deficient. Contrariwise, if there is a lack of this buffering effect (low levels of storage or stocks), paired with a less than expected production, impacts on price volatility are strong domestically and (possibly) worldwide. An example is what happened during summer 2021 when the global stocks for durum wheat were low, Canadian production decreased considerably, and prices spiked worldwide (USDA 2021).

Exogenous drivers also affect agricultural commodity prices as environmental and macroeconomic variables and the broad political and legislative environment. First and foremost, the overall risk of agricultural activity is amplified by climate change. Moderate increases in world temperatures will substantially negatively impact cereal crop production and prices (Morton JF. 2007; Olesen and Bindi 2002). Moreover, the COVID-19 pandemic influenced the production and prices of agricultural commodities (Beckman and Countryman, 2021; Höhler and Lansink, 2021), inflating the general level of uncertainty for farmers. This, linked with the challenges due to a growing world population and changing diets (Gilbert and Morgan, 2010), make managing risks for farmers more important than ever.

One last mention which attracted considerable research. Financialisation, i.e., the trading of agricultural derivatives contracts, developed especially within the last 20 years, allows exchanging agricultural commodities as financial assets (Baines, 2017). Consequently, theoretical and empirical research about the positive or negative effects of speculation in derivatives exchanges increased in the last decades. However, researchers have found no evidence for predominantly weakening or reinforcing effects (Haase et al., 2016). Thus, the effect of speculation in agricultural commodity prices, associated with both an increase in prices volatility and the stabilising effect given by price discovery practices, is longer for being concluded (Tadesse et al., 2014; Will et al., 2015).

Several endogenous and exogenous factors affect agricultural commodity prices, strongly impacting European and Italian farm households (Santeramo et al., 2017). The understanding of the determinants and the regulation of their negative consequences are necessary steps for the forthcoming unstable economic scenario (European Commission, 2020)

The European and Italian agricultural commodity sector

The price volatility in the food supply chain threatens the long-term competitiveness of agriculture. Thus, farmers' income threat is crucial for both farmers and policymakers (OECD, 1988; Tangermann, 2011). According to the European Farm Structure Survey for 2016, there were 10.5 million agricultural holdings (farms) in the EU in 2016, of which 10.9% are located in Italy (the third European MS for the number of farms) (Eurostat, 2021). Two-thirds of these farms are less than 5 hectares and play an essential role in reducing the risk of rural poverty providing additional income and food to rural areas (Eurostat, 2018). On the opposite, large agricultural enterprises represented 2.9% of the EU total farms and produced a standard output of EUR 250 000 per year each (Eurostat, 2018), counting for more than half of the EU's total agricultural economic output. More than half of the standard output generated by agriculture across the EU derived from France (16.8 %), Italy (14.2 %), Germany (13.5 %), and Spain (10.5 %) in 2016 (Eurostat, 2018). Among these farms, about one half (52,5%) could be categorised as crop specialists' farms, i.e., crop represented at least two-thirds of the production of the farms. Even if the total agricultural area dedicated to arable crops decreased by 1 million hectares since 2011, European cereal production reached almost 60 million tons in 2021. In the same year, the total oilseed production (rapeseed, sunflower, soybeans) reached almost 30 million tons. Italian agriculture accounts for nearly 11% of EU farms, counting 1,144 million crop farms in 2016. The overall Italian cereal and oilseed (rapeseed, sunflower, soybeans) crop production in 2021 reached almost 15 million tons and 1,2 million tons, respectively (ISTAT, 2021). European and Italian farmers in the field crop sector show, on average, the lowest income and the higher volatility compared to other agricultural products, both at the European and Italian levels (European Commission, 2019), increasing the importance of reducing price and income volatility.

Price risk management for farmers

Against this background, the European Union (EU) supports farmers facing risks. The Common Agricultural Policy (CAP) comprises several policy instruments that help farmers deal with price and income volatility. These instruments progressed significantly over time. One of the objectives of the CAP from its institution was to ensure a fair standard of living for farmers by stabilising and increasing the corresponded prices for the major agricultural products through both domestic (e.g. intervention prices and storage) and border measures (e.g. export subsidies and variable levies on imports). These price support policies, which continued throughout the following decades, effectively support farmers income even if they had critical negative consequences (Tangermann, 2011). Since the development of unmanageable surplus, and after the Uruguay Round of the GATT negotiations, these policies have been progressively reformed. Starting with the 1992 MacSharry's reform, which reduced the level of price intervention, import/export tariffs, and switched the original price support guarantees to direct payment; progressing with the Mid-Term Review in 2005, which decoupled the payment from the production (Single Payment Scheme - SPS), to CAP 2014-2020 which limited market measures to a small share of the CAP budget. Direct payment played an essential role in stabilising farmers' income (Enjolras et al. 2014; Severini et al., 2016); thus, the positive effect of surplus management resulted in inflation in farmers' exposure to price risks (Cordier, 2014).

The increased farmers' exposure to price risk represents a stimulus for the adoption of risk management tools (RMT). Although the European Member States historically provided risk management programmes for markets stabilisation (for instance, the Italian National solidarity Found and the French FNGRA - Fonds National de Gestion des Risques en Agriculture), the CAP presented, with Reg. 73/2009, the possibility for MS to allocate part of the budget to RMT. As a result, the farmers' risk management toolkit substantially improved under the CAP 2014-2020 reform, which entrusts an even more important role to risk management tools, with broader purposes and greater financial endowments than in the previous period. Indeed, with the CAP 2014-2020, farmers' risk management became one of the new EU priorities, and its funding was shifted from the first to the second pillar. As described in Regulation (EU) No 1305/2013, RMT incorporated animal and plant insurance

(Art.37), mutual funds for animal and plant diseases and environmental incidents (Art.38), and income stabilisation tools (IST) (Art.39). Notwithstanding that the Italian politics deemed these measures fundamentals, given the large amount of financial resources budgeted, mutual funds and IST adoption was limited (Severini et al., 2018; Trestini et al., 2018).

Among the CAP subsidised tools, only the IST provided a single policy covering production, price risks and their covariates, compensating farmers for severe income losses (if they fall under a certain threshold). Despite these positive characteristics, the IST is still pioneering in the EU, being applied in just three Member States (MS): Spain, Italy and Hungary. Within the Italian agricultural sector, IST has been very slow to be implemented (Giampietri et al., 2020), and, to date, just five different IST funds exist: 2 for the bovine milk sector, 2 for apple production and 1 for fruit and vegetables.

It is worth mentioning that, even if the significant structural differences (farmland and number of farms) in their respective farm sectors have helped to shape differences in their farm policy, for both the United States and the EU, the toolkit of agricultural support is now green box programs (i.e., minimally market-distorting and not subject to WTO disciplines). However, even if both programs historically followed a similar direction, moved by international agreements, US and EU policies and tools are different nowadays. While the EU still provides a form of direct payment (through the single payment scheme), the US focuses on market income while reducing the risks for farmers by promoting insurances. While the US agricultural policy consists of at least 60% insurance tools and no direct payments, the CAP only involves less than 1% insurance instruments and 60% income support through direct payments (García-Azcárate et al., 2016). Indeed, direct payments form about ¼ of the agricultural income in 2017 (European Commission, 2020).

The risk management strategies implemented by farmers develop beyond government policies. As part of their ordinary business management, farmers actively manage multiple risks. They assess the nature and extent of their individual risks and the suitability of different strategies. The decisions on the portfolio of activities of the farm and the techniques to be applied are part of their active management of risks (Komarek et al., 2020). For example, researchers focused on the benefit of applying diversity as a part of risk management for maintaining productivity and thus reducing production risk (Di Falco and Chavas, 2006). Farmers who diversify their cropping systems either implement more diverse crop rotations (that is, more crop species) or more diverse cultivars to manage their production risk better. Moreover, it is a frequently used strategy among farmers to limit possible adverse outcomes by participating in more than one activity (Mishra and El-Osta, 2002), reducing the household income variability throughout off-farm diversification (McNamara and Weiss, 2005; de Mey et al., 2016).

Given that more diverse risk management strategies are associated with higher perceived resilience (Slijper et al., 2020) and that related risk variables explain resilience (Aven, 2019), it is important the spread of collateral risk management instruments also among European and Italian farmers.

Hedging the price risk of agricultural commodities

For the protection against output prices variability, farmers have many marketing options. Marketing strategies can be grouped into three categories: spot market strategies, such as diversifying the frequency of market sells for annually produced crops; the use of forward contracts; and hedging via standardised futures contracts.

In postharvest sales strategies, the transaction is made at the observed price at that specific moment (the spot price), leaving the farmer to bear the price risk fully. However, he can equally benefit from potential prices increases. Moreover, given that no commitment is made with respect to volume or quality prior to harvest, farmers could also not be able to sell the commodity for lack of buyers (Roussy et al., 2017).

Managing risk with marketing or production contracts (referred to as contractual price agreements, contract farming or agricultural contracts) transfers the price and income risks (Rehber, 2018). Broadly speaking, contract farming are practices that allow farmers to fix the price for a commodity before harvest or before the commodity is ready to be marketed (Goodhue and Hoffmann, 2006). Agricultural contracts may specify the date of delivery, product price, product quality and required production practices, depending on the type of contract. Nevertheless, farmers keep full responsibility for all production management

(OECD, 2000). Among the different types of contract farming, the main categories, and the most developed, are forward and futures contracts (Ricome and Reynaud, 2020).

Forward contracts represent an agreement between farmers and the buyer (processor, firms, cooperatives, consortia) for the selling of agricultural products under advance agreements, frequently at predetermined prices. One of the parties to a forward contract assumes a long position and agrees to buy the underlying asset on a specific future date for a certain specified price. The other party assumes a short position and agrees to sell the asset on the same date for the same price (Hull, 2008). Thus, for the farmers, the foundation of such agreements is a commitment to provide a specified commodity quantity, for the buyer the commitment to buy at the specified price. Inherent to forward contract is counter party risk. Both farmers and buyers face default risk (for the farmer that the buyer may not pay for the commodity, for the buyer that the farmer may not deliver the commodity). Default risk for forward contracts is considered reasonable, and this does not deeply affect the adoption (Schaffnit-Chatterjee et al., 2010). To overcome default risk, futures contracts naturally developed from forward contracts.

Indeed, a futures contract is traded on an organised exchange, standardised in terms of quantity, quality, delivery time and location. Futures contracts are traded on derivatives exchanges, thus under the legislation of a clearinghouse (Hull, 2008). Given that the two parties entering the contract (e.g., the seller and the buyer) do not know each other, the clearinghouse also provides a legal mechanism to guarantee that the contract will be honoured. Linked with this, the clearinghouse also asks for collateral margins (initial and variation margin) to address the issue of counterparty risk (Larson et al., 1998). Both buyers and sellers of futures contracts are required, from the clearinghouse, to make an initial deposit with their respective brokers to guarantee their respective commitments (Schaffnit-Chatterjee et al., 2010). The variation margin grants that the losses are covered if futures prices move against the holder of the hedging position. Hedging costs appear modest compared with the risk reduction granted for most farmers (USDA, 1999).

Derivative exchanges date back to the end of the nineteenth century when the Chicago Board of Trade (CBOT) was established in 1848. Even before that, farmers and merchants used to trade products in advance (figure 1:2), but without any regulation. Nowadays, the CBOT derivatives exchange society merged with the Chicago Mercantile Exchange (CME), forming the CME group (which rule on the CBOT derivatives exchange). This market represents the world reference market for agricultural commodity trading (Hull, 2008). Its European counterpart, Euronext, a well-established provider of agricultural commodity futures contracts in Europe, represents the reference exchange for the European agricultural producers. However, this European exchange is less active than its North American counterpart even if the trading activity has increased in the latest years (Algieri, 2018).

Figure 1:2. Stele depicting an agreement for a futures delivery of barley.

Notes:Delivery point Mesopotamia, Anum-pisha and Namran-sharur's warehouse. Delivery date: Month of Ulul, 19th day, the year when King Abieshuh finished a statue of Entemena as god (1700BC).

A farmer aiming to hedge its price risk sells a futures contract on a specific derivatives exchange around the planting season. Afterwards, instead of delivering the commodity, he buys a futures contract for the same delivery date on the same exchange, thus undoing his position on the futures contract exchange. Only later, he will then sell on the cash market. For example, a farmer sells a corn futures contract in May for December delivery through his broker. In December, he will offset his position by buying a December corn futures contract (before the delivery of the December contract). By doing so, he holds a temporary position for hedging and does not physically deliver the commodity. Contracts are usually closed before expiration (Hull, 2008). By using a futures contract, the farmers reduce their risk but retain basis risk, measured by the difference between the cash price and the futures price.

The connection shown by futures contracts and spot prices, instrumental for effective use (Revoredo-Giha and Zuppiroli, 2013), has been of interest in agricultural economics. Since the seminal work of Working (1953), the futures-spot price relationship is explained by: $F_{tT} = S_t e^{(r+u+c)(t-T)}$, where t is the current date, T is the futures contract expiration date, r is the interest rate due for holding the commodity, u is the marginal storage cost rate, c the marginal convenience yield, F and S are the futures contract price and the spot price of the commodity, respectively. It follows that the basis (z_t) results in: $z_t = F_t - S_t = -(r_t + u_t + c)(T - t)$. Within the central concept of the Law of One Price (LOP), the dispersion of prices in two different markets tends to converge as a result of arbitrage (von Cramon-Taubadel and Goodwin, 2021). It follows that, omitted transportation costs, for a storable commodity, arbitrage opportunities may arise if $z_t \neq 0$: if $z_t < 0$ arbitrageurs will buy the spot commodity and sell futures contracts to profit from the difference; alternatively, if $z_t > 0$, arbitrageurs would profit by selling the spot commodity and buying the futures contracts. This assumption implies that if the basis has a stationary behaviour, futures and spot prices are cointegrated and only differ from the transportation and transaction costs.

If futures and spot markets are cointegrated, the evaluation of hedging effectiveness is carried out through the comparison of farmers results with and without hedging. The most general principles for testing the effectiveness of a hedge portfolio refer to the Modern Portfolio Theory (Markowitz 1952), where portfolios of different assets are combined and examined through their mean and variance. Indeed, managing price risk with futures contracts implies opening a position on a specific derivatives exchange (the CBOT or the Euronext), corresponding to the expected brokerage fees. Once the farmer enters a futures contract agreement, he will have a hedge portfolio of a combined natural long spot position and a short hedge position. Given the contrasting nature of the taken position, assuming a reduction in commodity prices (both spot and futures contract prices of a commodity would decrease), farmer's revenues would decrease in the spot market, while it will receive a higher payment from the closure of the futures contract in the derivatives exchange. Contrarily, if prices rise, farmers will gain a higher price for selling the spot commodity but will experience a loss in the futures market. Thus, assessing the volatility of farmers' hedge and unhedged portfolios defines the hedging strategy's effectiveness in reducing prices risk.

Significantly, production risk affects the effectiveness of hedging practices for farmers in the arable crop sector. Indeed, the literature suggests hedging only a fraction of the expected harvest (Moschini and Lapan, 1995). Moreover, as futures and spot prices are positively correlated, profits and losses in the two different markets offset each other (Working, 1953; Ederington, 1979). However, futures and spot prices are not perfectly correlated, i.e., a one-euro increase in the futures market rarely correspond to a one euro increase in the spot markets (Revoredo-Ghia and Zuppiroli, 2013 Wu et al., 2018), resulting in basis risk. This imperfect correlation brings to the application of an optimal hedge ratio (OHR) which usually is less than 1 (Dawson et al., 2000; Kuwornu, 2005). The determination of the optimal OHR depends on the specified objective function (Bekkerman, 2011; Chen et al., 2013; Conlon et al., 2016; Stefani and Tiberti, 2016). Given recent literature within the European agricultural context, which support the assumption that European farmers are risk-averse (Giampietri et al. 2020), the minimisation of the variance of the hedge portfolio is analogous to the maximisation of the producer expected utility. Thus, for farmers, holds the application of the minimum variance hedge ratio (Lence 1995; Chen et al. 2003).

Moreover, important features of financial data, such as volatility and correlation, have specific characteristics in relation to the examined time horizon (Conlon et al., 2016). This variability called for the choice of multiple hedging (time) horizons and affects hedging effectiveness. Authors considered different time intervals, from week-to-week changes to three or six months changes (Conlon et al. 2016), to a specific sowing-harvesting interval (Revoredo-Giha and Zuppiroli 2013).

The concurrent analysis of different optimal hedge ratios and hedge horizons allow for a complete analysis of the effectiveness of multiple hedging strategies for farmers.

Even if the Agricultural Markets Task Force conveys that agricultural futures contracts are a key risk management instrument for European farmers to tackle the increased price volatility (Veermann et al., 2016), limited studies on the overall efficiency of futures markets at a European level are in accordance with the limited adoption of such instrument among European farmers (Michels et al.,2019). Thus, important questions regarding market integration, market efficiency, and the effectiveness of hedging strategies can relate to how exactly prices are transmitted between futures and spot markets and on basis behaviour.

Farmers behaviour toward hedging instruments

Albeit the availability of a large portfolio of risk management strategies for farmers, understanding behavioural reasons that drive the adoption decision of such strategies can help researchers and policymakers alike. The literature analysing the determinants of the adoption of hedging strategies for the protection of farm income shows that farm and farmers characteristics (land size, farm specialisation, age, education, etc.) and farmers risks profile (risk aversion, use of other risk management tools) are all relevant factors (Goodwin and Schroeder, 1994; Sartwelle et al., 2000; Pennings et al., 2008 Franken et al. 2012; Franken et al., 2014; Coffey and Schroeder, 2019). In addition, behavioural preferences towards risk have been recognised to influence the decision-making process (Meraner and Finger 2019), focusing literature on accounting for risk preferences for understanding farmers' decisions for risk management instruments.

However, despite the literature advocating the effectiveness of hedging strategies for risk management, agricultural contracts (futures and forward contracts) are still a novelty for European and Italian farmers (Schaffnit-Chatterjee et al., 2010). By comparison, other forms of risk management practices are more researched and widespread among farmers (Howden et al., 2007; Trestini et al., 2017a, 2017b; Frascarelli et al., 2021). Thus, the adoption of futures and forward contracts among farmers may not depend only on the factor characterising the farms and farmers. Indeed, just recently, literature started analysing farmers' adoption within decision innovation adoption framework (Michel et al., 2019)

Decision on adopting new technologies or strategies is a necessary part of the farming activity (Kumar and Joshi, 2014). Many different innovation diffusion models exist. For example, the technology acceptance model (Davis et al., 1989), the human-organisation-technology model (Yusof et al., 2008), or the decomposed theory of planned behaviour (Taylor and Todd, 1995), all applied to the diffusion of the adoption of new technologies. However, this model focuses on individual intention and behaviour without considering external environmental factors. On the other hand, the technology-organisation-environment (TOE) framework, developed by Tornatzky and Fleisher (1990), hypothesise that all the factors that affect the decision to adopt new technology, i.e., derivatives instrument, can be referred to three categories. The technological context (TC) represents the technology-related internal and external factors that can influence the adoption; the organisational context (OC) including the firm's characteristics as the leader's opinion or the readiness to adopt the innovation; finally, the environmental context (EC) concerning the role of policy, competitors, trading partners and customers.

The adoption of an extended TAM model resulted in interesting results regarding German livestock farmers attitudes toward the adoption of futures contracts, which provided interesting insight for policymakers to develop effective measurements to increase farmers' intention to use commodity futures contracts, thus managing price risk (Michels et al., 2019.

Knowledge gaps, research questions and answers from the thesis

Against this overall background, different steps are needed to prove the feasibility and the effectiveness of hedging strategies, and to analyse farmers the factors that influence farmers to adopt agricultural contracts.

The analysis of price transmission from futures to spot prices represents the first step to foresee the feasibility of hedging strategies with futures contracts. Indeed, if the efficient market hypothesis is confirmed at a European and futures and spot prices move together, European Member States would be able to operate in derivatives exchanges effectively. Given the historical importance and the diffuse adoption by US farmers of futures contracts, the relationship of the CBOT futures prices and North American spot prices for the main agricultural commodities have been largely considered by agricultural economists (Brockman and Tse, 1995; Hernandez and Torero,2010; Adämmer et al., 2015; Dimpfl et al., 2017), confirming cointegrated and efficient markets. Similarly, also Chinese markets have been analysed, demonstrating the critical role of the actor worldwide. Both Li and Li and Zhang (2011) and Zhao et al. (2010) confirmed that national soybean futures prices drove national soybeans oilseed, meal and oil spot prices. However, Zhao et al. (2010) showed how both spot and futures domestic Chinese prices followed the CBOT futures prices, confirming the global leading role of the Chicago exchange. Conversely, European agricultural markets have gained limited attention despite Europe comprising for a large share of global agricultural production (USDA, 2017). Although the Amsterdam Exchange potato market has been analysed and found efficient (Kuiper et al., 2002), similar to the European hog and piglet markets (Adammer et al., 2015), these studies focused on price discovery in thinly traded futures markets, excluding essential grain commodities. An exception is given by Adammer and Bohl (2018), which examined the influence of European agricultural futures contracts (Euronext) on Germany spot price for canola, wheat, and corn. The lack of a comprehensive research within European agricultural commodity sector endorsed the analysis of European Member State prices.

Insufficient or fragmented research on the hypothesis of an efficient futures market for the European Member States has encouraged analysing the European futures and spot markets' connection with the CBOT and the Euronext. The European Union represents an important actor in agricultural commodity production and trade worldwide. While US and Chinese exchanges have been gained attention from researchers, EU markets are still limitedly studied. Moreover, by analysing the corn price transmission, the first chapter of this thesis focused on the commodity with the highest open interest in the Chicago futures exchange, implying high interest from operators worldwide. Thus, the European corn market analysis will provide a comprehensive overview of the European price connection and market efficiency for agricultural commodities.

As mentioned, the basis affects the effectiveness of the hedging activities. According to the no-arbitrage price theory, prices in two different markets should tend to converge (Lence et al., 1995), with symmetric behaviour, regardless of positive or negative variation in prices. The identification of asymmetric behaviour within prices transmission (vertical and horizontal) has attracted considerable research interest among agricultural economists (von Cramon-Taubadel, 1998; Enders and Siklos, 2001; Santeramo and von Cramon-Taubadel, 2016). However, there is close to no evidence of APT within the futures spot market studies, with some limited exceptions (Bacon, 1991; Wu et al., 2018). Thus, the analysis of futures spot asymmetric price transmission for different commodities would increase the precision for the hypothesis of an efficient exchange in which farmers can operate.

To better characterise the price transmission between futures and spot prices, the linearity of the relationship between futures contracts and spot prices has been considered for the Italian agricultural sector. Indeed, the availability of high-frequency data, necessary for the asymmetric analysis, leads to choosing a single Member State for asymmetric analysis. Italy represented an interesting choice both for the country's importance as a commodity producer and because of the strong presence of various agricultural commodities. Italy is characterised by over 400 thousand farms, of which 28.2% specialised in the arable crop sector, managing over 3 million hectares. Moreover, given their intrinsic differences (growing seasons, market destination, …), it is worth emphasising the differences in price transmission level among distinct commodities. Thus, focusing on Italian commodity prices allows for an in-depth analysis of multiple primary agricultural commodities. To do so, Italian spot prices at high observation frequency (weekly) have been analysed for major Italian agricultural commodities, namely soybean, corn and milling wheat, and the shape of price transmission between spot and the CBOT and Euronext futures prices defined.

As described, futures contracts are primarily a risk management instrument. However, the effectiveness of hedging strategies with futures contracts is not a universally accepted concept (Tomek and Peterson, 2000). Wisner, Blue, and Baldwin (1998) argued that using agricultural contracts could increase farmers' average returns, while Zulauf and Irwin (1998) found no concluding evidence. As for futures-spot price transmission, a considerable amount of research exists for agricultural commodities for the North American markets (for a detailed review, see Chen et al., 2003) but, research considering Italian prices is promising but scant, focusing only on the wheat market (Stefani and Tiberti, 2016; Zuppiroli and Revoredo-Ghia, 2016).

Thus, the determination of the OHR, which minimises farmers portfolios' variance and the analysis on the optimal hedge horizons for the major Italian agricultural commodity, will precisely measure the effectiveness of hedging with futures contracts for Italian producers. It will also provide a concluding insight both on the reported heterogeneity in the hedge ratios on the effect of the previously described basis movements and the shape of the connection between futures and spot prices.

Finally, it has been discussed how the use of agricultural contracts to hedge price risk has been an available strategy for quite some time. However, the adoption rate for such instruments is limited in European and Italian agriculture. Though the diversity of studies linking the adoption of agricultural contracts with farm and farmers characteristics and farmers risks profile (for North American farmers (Goodwin and Schroeder, 1994; Franken et al. 2012; Franken et al., 2014; Coffey and Schroeder, 2018), European studies are limited. Given the different conditions related to farm structure and agricultural policies, it follows the importance of analysis at the European level. Some European level studies exist: Pennings and Leuthold (2000) and Pennings and Garcia (2004) examined the impact of farmers' behavioural attitudes toward adopting futures contracts within the Dutch hog industry. Moreover, Italian durum wheat farmers have a very low adoption rate on agricultural contracts because they did not want constraints and revealed a lack of trust in contracts, thus preferring spot sales (Solazzo et al., 2020). However, none of those above analysed the adoption of agricultural contracts as an innovation. Given the reported novelty of contract farming for price risk management in Europe and Italy, applying an innovation adoption framework represents an original contribution to understanding farmers' contracts adoption in Italy. Given the successful application of both TAM (Michels et al., 2019) and TOE (Giampietri and Trestini 2020) model to agricultural holdings, an adapted TOE-TAM model has been applied to Italian farmers representing, to the best of my knowledge, a novelty worldwide.

To summarise, the lack of literature on the use of agricultural contracts for hedging price risk in Europe and Italy has encouraged this research. Firstly, this work explores the feasibility of hedging strategies with futures contracts for European and Italian farmers in the arable crop sector by analysing price transmission and the efficient market hypothesis. Then, the behaviour of the Italian futures spot basis for the major agricultural commodities is tested for asymmetric behaviour, which would affect price transmission and feasibility. Then, the effectiveness of hedging strategies, given prices behaviour, is analysed. Farmer choices to use risk management tools have been conceptualised in an expected utility framework to measure hedging effectiveness according to the risk minimisation objective. Finally, this work analyses which attributes affect farmers' intention to use agricultural contracts as price risk management instruments. These three-year research activities brought to the completion of four papers:

1. Carlotta Penone, Elisa Giampietri, Samuele Trestini (2022). **Futures-Spot price transmission in EU corn markets.** *Agribusiness.*
2. Carlotta Penone, Samuele Trestini (2022). **Testing for asymmetric cointegration of Italian agricultural commodities prices: evidence from the futures-spot market relationship.** *Agricultural Economics Czech*, 68: 50–58.
3. Carlotta Penone, Elisa Giampietri, Samuele Trestini (2021). **Hedging effectiveness of commodity futures contracts to minimise price risk: empirical evidence from the Italian field crop sector.** *Risks*, 9(12), 213.
4. Carlotta Penone, Elisa Giampietri, Samuele Trestini. **Analysing farmers' intention to adopt marketing contracts as an innovative strategy to tackle income risk at the farm level.** (*In preparation for Agricultural Finance Review*).

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2

Futures-Spot price transmission in EU corn markets

Abstract

Price transmission between futures and spot prices is a relevant issue, dealing with derivatives exchange for price management practices and efficient price discovery. Indeed, due to increased market-orientation of the Common Agricultural Policy (CAP), the development of new market strategies is of the utmost importance for European farmers. In this context, this study examines the degree of transmission for the corn commodity between global futures price in either the Chicago Board of Trade or Euronext, and the spot prices for a selection of Member States of the European Union. This research provides critical insights into the shape of the futures-spot price transmission, confirming a long-run relationship and a cointegrating behaviour of price sets.

Keywords

Futures Contract, Price Transmission, European Markets, Error Correction Model, Corn Prices

Introduction

As regards the agricultural commodity sector, futures markets provide two significant advantages, specifically risk transfer and price discovery. Indeed, futures contracts can hedge the price risk for farmers and other operators, by transferring the risk of price volatility to speculators (Shapiro and Brorsen, 1988). Moreover, given the leading role of futures markets compared to spot markets (Garbade and Silber, 1983), futures contract prices are used for informative purposes, e.g., the pricing of commodities in the spot markets. The efficiency of both practices depends on the spread between local spot prices and futures prices, namely the basis. Theoretically, changes in the basis should reflect both transportation and management costs, and local supply and demand conditions. Indeed, if the basis strengthens and becomes more positive (or less negative), it will benefit short hedgers seeking to protect their commodities' selling prices through futures contracts. Conversely, if the basis weakens, the long hedgers will benefit and gain an advantageous price for buying the commodity (Wu *et al.*, 2018).

Several factors affect local spot prices. For instance, growth in local demand (Ajanovic, 2011) and lower crop yields (Adjemaian *et al.*, 2013) will increase local spot prices, thus strengthening the basis. Moreover, raised interest rates, which would increase the cost of storing the commodities, would also strengthen the basis. Besides these, changes in the basis could reflect on futures prices volatility (Wright, 2011). The role of speculation has been analysed as a trigger for futures price volatility, without finding indisputable evidence of predominant reinforcement or weakening (Haase *et al.*, 2016). However, assuming that futures market prices can be unrelated to fundamentals (e.g., demand, supply), it follows that changes in futures prices and spot prices can be poorly correlated. Therefore, the stability of the relationship between agricultural futures and spot prices is of utmost importance, if futures markets are used either for price discovery or hedging practices (Lence, 2009).

Up to now, empirical investigations on this relationship have mainly been dedicated to North American markets, mostly because of the long history and global importance of the Chicago Board of Trade (CBOT) exchange. As regards agricultural commodities, a great deal of research (Brockman and Tse, 1995; Hernandez and Torero, 2010; Adämmer and Bohl, 2018; Dimpfl *et al.*, 2017) suggests the dominant role of futures markets for price discovery activities in North America. Fortenbery and Zapata (1993) also considered the futures-spot price relationship. Their findings confirm that the degree of cointegration might vary across different market locations, due to dissimilar information flows. The relationship between futures and spot prices has also been investigated in the Chinese markets, focusing primarily on soybean. Accordingly, many authors (Zhao *et al*., 2010; Li and Zhang, 2011) reported how domestic spot prices drive the domestic futures prices for soybean, conversely to the dominant theory. Their findings also confirm the leading role of CBOT soybean futures prices with respect to the domestic spot and futures markets.

Concerning European markets for agricultural commodities, evidence is mainly limited to single countries. For instance, Kupier *et al.* (2002) showed how spot prices are driven by futures prices for the Netherlands potato markets, thus confirming the general theory of futures markets' price discovery role. Adämmer and Bohl (2018) also confirmed the leading role of futures prices for the agri-commodity sector in Germany, even during highly volatile periods (specifically 2007-2008 and 2011). Thus, to the best of our knowledge, evidence on price transmission for futures and spot markets at European Union (EU) level, considering different Member States (MS) are rare, preventing holistic empirical insights and related implications. Indeed, there are very few exceptions, e.g., Revoredo-Ghia and Zuppiroli (2013) who tested the connection between wheat futures and spot prices for three EU countries, namely Italy, France, and the UK, supporting the effectiveness of futures contracts for hedging purposes.

In line with this, this paper aims at expanding the literature by examining the relationship between spot and futures markets and comparing them among a selection of EU Member States. To this end, corn spot prices and futures prices retrieved from both the CBOT and Euronext exchanges were analysed within an error correction framework.

The European corn market and data description

Within the arable crop sector, corn is a very relevant commodity at European level, representing up to 25% of the total grain production in Europe. Additionally, EU produces the 6% of the corn produced worldwide (FAOSTAT, 2021).

In this study, spot prices were selected according to different criteria. The Member States were selected based on the availability of a ten consecutive years price series on the European Commission database (European Commission, 2021). As a result, this study considered the following ten MS: Austria, Belgium, France, Germany, Greece, Italy, Portugal, Slovakia, Slovenia and Spain. These represented about half of the total EU corn production and trade value in 2018: in particular, France is by far the largest producer (18%), followed by Italy (10%), Spain, Poland and Germany (5% each) (FAOSTAT, 2021). Monthly corn spot prices were derived from the European Commission database (European Commission, 2021).

This study considers two derivatives exchange: Euronext and the CBOT. The former is the European exchange in which agricultural futures contracts are traded, while the latter is the world reference market for agricultural contracts trading (Hernandez and Torero, 2010). In particular, the North American exchange was chosen for the analysis, given its connection with the European agricultural derivatives exchange (Ledebur and Schmitz, 2009). It is worth noting that the use of both markets for European corn producers and processors might involve some shortcomings. The North American derivatives exchange could be influenced by different market drivers, such as domestic demand for corn for biofuel production, increasing the possibility of a lack of a stationary basis. Consequently, the prices of futures contracts traded on Euronext are expected to show a higher connection with the European spot prices. However, compared to CBOT, the Euronext derivatives exchange may suffer from a liquidity shortage. This is due to the fact that the number of futures contracts traded here is significantly lower. As reported in the Chicago Mercantile Exchange (CME)[1], in 2020 the CBOT open interest (i.e., open contracts) for each deadline were around 500 thousand in the month before the contracts' expiration, compared to 25-30 thousand for Euronext[2]. In line with this, it is worth specifying that both price discovery and hedging practices are more

[1] https://www.cmegroup.com/markets/agriculture.html
[2] https://www.euronext.com/en/for-investors/commodities

effective when the derivatives exchange presents a significant number of traded contracts, reflecting the underlying commodity's actual value (Working, 1953).

Both the Euronext and CBOT nearby futures contracts prices were retrieved from the Agriculture and Horticulture Development Board (AHDB, 2021). To obtain the price of each month, avoiding the problem of averaging daily futures prices, the week that includes the 15th day for each month was chosen (for example, 10-16 December 2018). Moreover, to reduce possible rollover problems, we chose the futures price specific for each month as a reference price, except for the month enclosing the contract expiration, for which the futures price of the following expiring contract was selected.

European futures contract prices are expressed in Euros/Ton, while CBOT futures contract prices are expressed in US Dollars/Bushel. CBOT prices were converted into Euros per Ton, first transforming US dollar prices from Bushels to Tons, then applying the corresponding monthly exchange rate. Descriptive statistics of the considered price series are reported in table 2:1.

Table 2:1. Descriptive statistics of futures and spot prices (€/t).

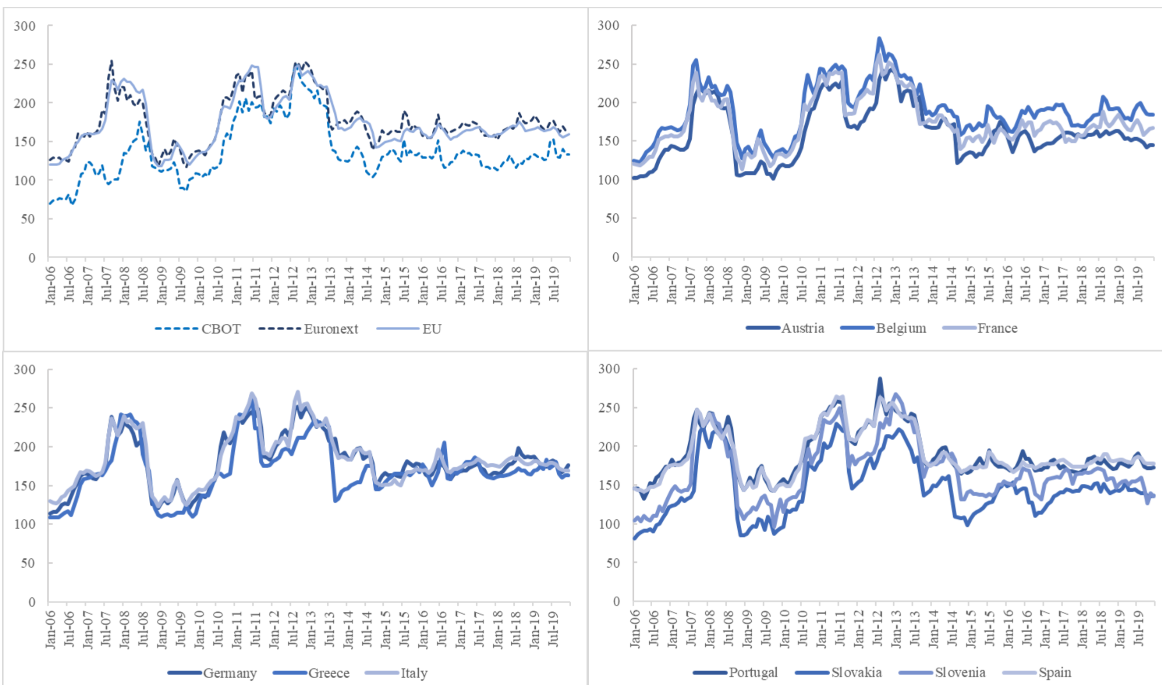
		Obs.	Minimum	Maximum	Mean	Std. deviation
CBOT	-	168	67.9	251.0	136.3	36.6
Euronext	-	168	117.4	254.4	175.7	32.0
EU	EU	168	118.1	248.2	173.6	33.6
Austria	AU	168	101.3	242.5	160.9	35.8
Belgium	BE	168	122.9	283.0	189.3	34.6
France	FR	168	113.2	262.1	174.5	33.5
Germany	GE	168	113.5	251.5	180.3	33.8
Greece	GR	168	109.0	268.1	169.5	35.3
Italy	IT	168	122.8	270.6	183.2	34.3
Portugal	PO	168	132.6	287.9	190.3	32.2
Slovakia	RS	168	81.6	229.1	146.6	38.2
Slovenia	SL	168	96.1	266.9	167.4	40.0
Spain	SP	168	142.0	264.8	190.2	31.7

Source: authors' elaboration

The period under investigation runs from January 2005 to December 2018. Within this time frame, corn prices and other commodities' prices rose dramatically, particularly from late

2006 to mid-2008, and again in 2011 and 2013, as shown by many authors (see for instance Gilbert and Morgan, 2010; Santeramo *et al.*, 2018). Figure 2:1 illustrates the pattern of the futures and spot corn prices over time, showing two periods of higher prices, specifically June-July 2008, and from January 2011 to June 2013. These periods were followed by a more stable period in which prices hovered around a lower mean. For each selected Member State, prices show co-movement with the futures markets.

Figure 2:1. Corn futures and spot prices.



Empirical framework

Several studies have quantified price transmission, defined as a plethora of different information moving among markets (horizontal) or along the supply chain (vertical) (Vavra and Goodwin, 2005). In this study, horizontal price transmission between futures and spot prices is analysed, applying time-series methodologies to ensure the estimators' consistency and avoid spurious regressions (Ng and Pirrong, 1994; Ali and Gupta, 2011; Wu *et al.*, 2018).

According to Working (1953) and Fama and French (1987), the futures-spot price relationship can be explained by:

$$F_{tT} = S_t e^{(r+u+c)(t-T)} \qquad \text{(Eq. 2:1)}$$

where t is the current date, T is the futures contract expiration date, r is the interest rate due for holding the commodity, u is the marginal storage cost rate, c the marginal convenience yield, F and S are the futures contract price and spot price of the commodity, respectively. Taking natural logarithms, the basis (z_t) is defined as the difference between the spot price and futures price of equation 1, resulting as:

$$z_t = F_t - S_t = -(r_t + u_t + c)(T - t) \qquad \text{(Eq. 2:2)}$$

For a storable commodity, arbitrage opportunities may arise if $z_t \neq 0$. Indeed, if $z_t < 0$ arbitrageurs will buy the spot commodity and sell futures contracts to profit from the difference. Alternatively, if $z_t > 0$, arbitrageurs would profit by selling the spot commodity and buying the futures contracts. Under the Law of One Price, arbitrageurs will act symmetrically, so that the spot and futures prices are linearly cointegrated, i.e., the basis is stationary with zero mean, thus implying an efficient market (Hull, 2008). Following Fackler and Goodwin (2001), if the efficient market hypothesis is confirmed, the futures-spot price relationship should be studied within an error correction (EC) framework.

Preliminary analyses are needed to test for an error correction behaviour between futures and spot prices for the selected Member States. Regression involving nonstationary time series results in spurious estimates if the variables appear correlated but are not related to each other.

The first step for the study of price transmission is to test for a unit root in each price series. Therefore, to determine the order of integration of the considered time series, both the Dickey-Fuller (ADF) test (Dickey and Fuller, 1979) and the non-parametric Phillips-Perron (PP) test (Phillips and Perron 1988) were adopted. Moreover, given the possibility of a structural break (i.e., an unexpected change in the time series process), the conventional stationarity tests could be biased, showing over-rejection problems of the null hypothesis of a unit root. Therefore, this study also applied a stationarity test that allows for endogenously determined structural breaks under the alternative hypothesis, namely the Zivot-Andrews (ZA) test (Zivot and Andrews, 2002). After checking for stationary series, cointegration analysis requires the presence of a stationary combination of the futures-spot prices set. Assuming the two-time series processes F_t, and S_t, are integrated of order 1, if there exists z_t such that $S_t - \delta * \mathrm{F_t} = z_t$, where z_t is integrated of order less than 1, then F_t, and S_t are cointegrated. Both Engle-Granger's and Johansen's procedures were applied to test for cointegration among futures and spot prices (Engle and Granger, 1987; Johansen, 1995). Given that the time frame of the investigation comprises some periods of markets instability (Santeramo *et al*., 2018), to allow for potential structural breaks this study also applied the Gregory-Hansen cointegration test (Gregory and Hansen, 1996), which assumes the null hypothesis of no cointegration against the alternative hypothesis of cointegration with one unknown structural break. If a linear combination of the futures spot prices was found to be stationary, it was subsequently tested for the relationship's causality direction through the Toda-Yamamoto approach to Granger causality (Toda and Yamamoto, 1995).

Thus, if price differences are I (0), and the futures-spot price pairs are found to be cointegrated, the price transmission analysis can be conducted applying a vector error-correction model (VECM) (Acosta *et al*., 2014). The model is estimated as follows:

$$\Delta S_{kt} = \alpha + \sum_{i=1}^{I} \beta_j \Delta F_{kt-i} + \sum_{J=1}^{J} \gamma_j \Delta S_{kt-j} + \delta ECT_{t-1} + u_t \qquad \text{(Eq. 2:3a)}$$

$$\Delta F_{kt} = \alpha + \sum_{i=1}^{I} \beta_j \Delta S_{kt-i} + \sum_{J=1}^{J} \gamma_j \Delta F_{kt-j} + \theta ECT_{t-1} + u_t \qquad \text{(Eq. 2:3b)}$$

where ΔS_{kt} and ΔX_{kt} are the differenced spot price and futures price for the k_{th} exchange and Member State at time t, the resulting coefficients are used to assess the extent to which the derivatives' prices are transmitted to the spot prices and vice versa. Specifically, α represents the intercept, β_j captures the short-term effects of futures/spot prices on spot/futures prices. Moreover, δ and θ are the coefficients of the lagged error correction term (ECT), and they represent the speed of adjustment. According to Eq. 3a and 3b, if $\delta > 0$ and $\theta < 0$, the spot price falls and futures price rises during the process of convergence when $z_t < 0$. Conversely, the futures price falls and spot price rises to ensure convergence if $z_t > 0$. If $\delta < 0$ and $\theta = 0$, then the burden of convergence falls on the spot market, while the opposite is true if $\theta > 0$ and $\delta = 0$.

Results and Discussions

The results of the unit root tests for all the prices involved are presented in Table 2:2. For all series, the null hypotheses of a unit root cannot be rejected at their levels. However, the null of unit roots is rejected at the 1% significance level upon taking the first differences. Therefore, all the series are nonstationary and integrated of order one, similarly to what is commonly found in commodity price series (Brockman and Tse, 1995; Ali and Gupta, 2011; Irwin *et al*., 2011).

Table 2:2. Stationarity tests for the selected futures markets and the Member States.

	ADF		PP		ZA	
	Levels	First diff.	Levels	First diff.	Levels	First diff.
CBOT	-2.607	-8.798***	-2.638	-12.316***	-4.079	-12.579***
Euronext	-2.781	-7.062***	-2.724	-11.176***	-3.951	-11.822***
EU	-3.132	-5.123***	-2.702	-6.468***	-4.227	-8.624***
AU	-2.957	-6.409***	-2.570	-9.666***	-3.901	-10.265***
BE	-2.981	-5.681***	-2.812	-8.990***	-4.304	-10.371***
FR	-2.902	-5.711***	-2.705	-10.283***	-4.176	-10.347***
GE	-3.144	-5.058***	-2.816	-8.535***	-4.317	-10.209***
GR	-3.052	-7.517***	-3.270	-15.425***	-4.043	-15.893***
IT	-3.063	-5.097***	-2.683	-7.271***	-4.179	-7.294***
PO	-2.906	-5.674***	-2.638	-8.542***	-4.355	-9.735***
RS	-3.058	-5.900***	-2.777	-8.989***	-3.702	-9.734***
SL	-2.891	-6.889***	-2.630	-11.232***	-3.560	-11.751***
SP	-2.941	-5.139***	-2.491	-7.691***	-4.079	-8.900***

*Note: the optimal lag length was determined using the modified Akaike Information Criterion. *, **, *** indicate significance at the 10%, 5%, and 1% level, respectively.*

Augmented Dickey-Fuller (ADF) test critical values at 1%, 5% and 10% levels are −4.02 −3.44 and −3.14, respectively.

Phillips-Perron (PP) test critical values at 1%, 5% and 10% levels are −4.02, −3.44 and −3.14, respectively.

Zivot-Andrews (ZA) test critical values at 1%, 5% and 10% levels are –5.57 -5.08 and -4.82, respectively.

Given the results from stationarity tests, the presence of a cointegrating relationship is tested. Table 2:3 reports the estimates for the Engle-Granger and Johansen cointegration tests. In line with previous studies (Yang and Leatham, 1998; Alam *et al*., 2016), the results confirm a stable long-run equilibrium relationship between the corn spot prices and futures prices for all the selected Member States.

Table 2:3. Cointegration test for corn futures and spot prices of the selected Member States.

	Engle-Granger		Johansen				
	CBOT	Euronext		CBOT		Euronext	
	z(t)[a]	*z(t)*[a]	Cointegration rank (*r*)	λ_{max}[b]	λ_{trace}[c]	λ_{max}[b]	λ_{trace}[c]
EU	-3.843	-5.565	H_0: r=0	21.12	29.78	39.73	50.01
			H_0: r≤1	8.66	8.66	10.28	10.28
AU	-3.588	-4.435	H_0: r=0	14.27	23.00	25.99	35.60
			H_0: r≤1	8.73	8.73	9.61	9.61
BE	-4.322	-6.468	H_0: r=0	21.81	30.56	45.06	52.46
			H_0: r≤1	8.75	8.75	7.40	7.40
FR	-3.608	-6.184	H_0: r=0	17.34	25.24	53.48	62.43
			H_0: r≤1	7.90	7.90	8.95	8.95
GE	-3.748	-5.874	H_0: r=0	15.75	24.96	41.34	50.61
			H_0: r≤1	9.21	9.21	9.27	9.27
GR	-3.552	-5.430	H_0: r=0	16.29	26.33	25.31	33.77
			H_0: r≤1	10.04	10.04	8.46	8.46
IT	-3.768	-4.670	H_0: r=0	17.63	26.26	29.06	38.91
			H_0: r≤1	8.63	8.63	9.85	9.85
PO	-3.929	-6.017	H_0: r=0	15.87	23.75	32.63	42.29
			H_0: r≤1	7.87	7.87	9.66	9.66
RS	-3.722	-4.701	H_0: r=0	15.63	23.45	40.02	48.80
			H_0: r≤1	7.82	7.82	8.78	8.78
SL	-3.378	-5.217	H_0: r=0	13.24	21.47	64.60	72.79
			H_0: r≤1	8.23	8.23	8.19	8.19
SP	-4.093	-5.778	H_0: r=0	19.48	27.17	37.38	46.34
			H_0: r≤1	7.69	7.69	8.96	8.96

*Note: ***, **, * indicate significance at the 1%, 5%, 10% level respectively.*

[a] *Test critical values: z(t) at 1% and 5% levels are −4.02 and −3.44, respectively.*

[b] *Test critical value: λ_{max} at 1% and 5% levels are 14.07 and 3.76, respectively.*

[c] *Test critical value: λ_{trace} at 1% and 5% levels are 15.41 and 3.76 respectively.*

Table 2:4. Gregory Hansen's cointegration test.

		CBOT			Euronext		
		Test statistic	Break	Date	Test statistic	Break	Date
EU	ADF	-5.43**	29	May 2008	-6.42***	104	August 2014
	Zt	-5.54***	30	June 2008	-6.66***	105	Sept. 2014
	Za	-42.93*	30	June 2008	-66.50***	105	Sept. 2014
AU	ADF	-4.50	29	May 2008	-6.33***	80	August 2012
	Zt	-4.68*	30	June 2008	-6.42***	117	Sept. 2015
	Za	-35.90	30	June 2008	-65.59***	117	Sept. 2015
BE	ADF	-5.67***	29	May 2008	-6.92***	123	March 2016
	Zt	-5.48***	28	April 2008	-6.92***	53	May 2010
	Za	-42.05*	28	April 2008	-72.88***	53	May 2010
FR	ADF	-5.08**	29	May 2008	-8.69***	29	May 2008
	Zt	-5.21**	26	February 2008	-8.79***	26	February 2008
	Za	-43.46*	26	February 2008	-105.80***	26	February 2008
GE	ADF	-5.10**	29	May 2008	-6.89***	51	March 2010
	Zt	-5.03**	28	April 2008	-7.09***	51	March 2010
	Za	-38.29	28	April 2008	-75.25***	51	March 2010
GR	ADF	-5.01**	28	April 2008	-6.83***	104	August 2014
	Zt	-5.13**	28	April 2008	-6.50***	105	Sept. 2014
	Za	-42.55*	28	April 2008	-62.15***	105	Sept. 2014
IT	ADF	-4.69*	29	May 2008	-5.30***	114	June 2015
	Zt	-5.01**	29	May 2008	-5.59***	122	February 2016
	Za	-35.80	29	May 2008	-49.70***	122	February 2016
PO	ADF	-5.61***	29	May 2008	-7.10***	95	Nov. 2013
	Zt	-5.87***	29	May 2008	-7.29***	96	Dec. 2013
	Za	-50.18***	29	May 2008	-76.77***	96	Dec. 2013
RS	ADF	-4.81*	30	June 2008	-6.05***	118	October 2015
	Zt	-5.15**	30	June 2008	-6.29***	140	August 2017
	Za	-39.59	30	June 2008	-59.98***	140	August 2017
SL	ADF	-4.69*	30	June 2008	-5.87***	33	Sept. 2008
	Zt	-4.83*	28	April 2008	-5.92***	33	Sept. 2008
	Za	-38.64	28	April 2008	-58.49***	33	Sept. 2008
SP	ADF	-5.51***	28	April 2008	-6.54***	95	Nov. 2013
	Zt	-5.79***	28	April 2008	-6.85***	95	Nov. 2013
	Za	-46.19*	28	April 2008	-69.67***	95	Nov. 2013

*Note: ***, **, * indicate significance at the 1%, 5%, 10% level, respectively.*
ADF test critical values at 1%, 5% and 10% levels are -5.47, −4.95 and −4.68, respectively.
Zt test critical values at 1%, 5% and 10% levels are -5.47, −4.95 and −4.68, respectively.
Za test critical values at 1%, 5% and 10% levels are -57.17, -47.04 and -41.85, respectively.

To account for possible breaks in the series, the null hypothesis of no cointegration was tested against the alternative hypothesis of cointegration with a single shift at an unknown point in time. The Gregory-Hansen procedure, reported in table 2:4, confirmed the existence of a long-run relation among the set of futures and spot prices. These findings are in line with the above-mentioned results of the Engle-Granger and Johansen test. For the CBOT prices it can be observed that the break date focuses around spring 2008. As shown in figure 2:1, CBOT futures prices were increasing in that specific period, as opposed to Euronext futures prices and spot prices for all the selected EU Member States. The literatures has broadly examined US corn price volatility during the first decade of the twenty-first century, linking it both to financial speculation and the increasing demand of corn for biofuel production (McPhail, 2012; Field, 2016).

Since cointegration tests only indicate the existence of a long-run relationship between futures and spot prices, the Toda-Yamamoto approach to Granger causality (Toda and Yamamoto, 1995) is used to analyse the direction of the relationship among price series. Results are reported in table 2:5. Regarding Euronext futures markets, it can be noted that most pairs of futures spot prices show uni-directional causality from futures to spot prices, as commonly reported in the literature (Mattos and Garcia, 2004; Yan and Reed, 2014). Some MS, specifically Austria, Belgium, France and Portugal, show bi-directional causality, implying a feedback system (Ali and Gupta, 2011). The Granger causality between CBOT futures prices and MS spot prices show different results. Austria, Belgium, Germany, Greece, and Slovenia spot prices are Granger caused by the CBOT futures prices. However, France and Italy, which are the main corn producers at EU level, are shown to Granger cause the CBOT futures prices. These results are somewhat unexpected. However, given that the futures and spot prices show a cointegrating relationship, the analysis of causality could be improved within an error correction framework.

Table 2:5. Toda-Yamamoto Granger causality test statistics for the selected Member States.

Member State			CBOT		Euronext	
	Dependent variable	Lagged coef.	Sig.	Direction of causality	Sig.	Direction of causality
EU	Spot	Futures	0.150	F S	0.000	F ↔ S
	Futures	Spot	0.407		0.013	
Austria	Spot	Futures	0.014	F → S	0.000	F ↔ S
	Futures	Spot	0.221		0.023	
Belgium	Spot	Futures	0.059	F → S	0.000	F ↔ S
	Futures	Spot	0.236		0.003	
France	Spot	Futures	0.376	F ← S	0.000	F ↔ S
	Futures	Spot	0.079		0.002	
Germany	Spot	Futures	0.095	F → S	0.000	F → S
	Futures	Spot	0.457		0.025	
Greece	Spot	Futures	0.000	F → S	0.000	F → S
	Futures	Spot	0.086		0.504	
Italy	Spot	Futures	0.227	F ← S	0.011	F → S
	Futures	Spot	0.059		0.039	
Portugal	Spot	Futures	0.161	F S	0.003	F ↔ S
	Futures	Spot	0.142		0.003	
Slovakia	Spot	Futures	0.136	F S	0.000	F → S
	Futures	Spot	0.121		0.461	
Slovenia	Spot	Futures	0.000	F → S	0.000	F → S
	Futures	Spot	0.516		0.376	
Spain	Spot	Futures	0.790	F S	0.000	F → S
	Futures	Spot	0.700		0.066	

Note. F: futures prices, S: spot prices.
The arrows, when present, show uni-directional (→) and bi-directional (↔) significant effects.

To this end, error correction models (ECMs) are estimated for all futures-spot price pairings. The model allows for the examination of both the long-run dynamics and short-run response to temporary shocks in price relationships. Results are presented in table 2:6a and 2:6b for the Euronext and CBOT analysis, respectively. The cointegration equation (Coint. Eq.) outlines the long-run equilibrium relationship, while the spot (Δs_t) and futures (Δf_t) equation present the short-run dynamics' coefficients and ECT's coefficients of the price transmission. Overall, VECM results for both the CBOT and Euronext derivatives exchanges highlight the presence of a long-run cointegration relationship between the futures and spot prices for all the considered Member States, coherently with the literature (Shawky *et al*., 2003; Bekiros and Diks, 2008; Hernandez and Torero, 2010).

As for the Euronext VECM, ECT's coefficients show high significance with regards to the spot prices equation for all the selected Member States. Given that ECMs allow determining which price between the spot and futures prices reacts to restore the long-run equilibrium after a shock, it is possible to confirm the leading role of Euronext for European spot prices. Indeed, the ECT's coefficient is negative and statistically significant in the Euronext equation for the spot price change (δ in Equation 3a). On the contrary, in the equation for the futures price change (θ in Equation 3b) the ECT's coefficient is statistically insignificant. Interpretation of the ECT's coefficients suggests that, except for France, the spot prices react to restore the long-run equilibrium in the grain markets for all the considered Member States (von Cramon-Taubadel, 1998; Wu *et al*., 2018). The statistical significance of the ECT's coefficient in the spot price equation indicates that the direction of price adjustments runs from the futures to spot prices, whereas the reverse is not valid. Instead, regarding France the coefficients show how both the futures and spot prices react to restore the long-run equilibrium relationship, thus confirming the bi-directional causality found in the Granger causality test. Therefore, we can conclude that in France, which is leader for corn production at EU level, corn spot prices can influence futures prices as a feedback effect (Li and Zhang, 2011). These results validate the Granger-causality results as they allow for the presence of error correction mechanisms between the set of futures-spot prices series (Pala, 2013). Table 2:6a reports the results on short-run dynamics, showing a significant effect of the lagged spot prices in the spot equation for all the selected Member States, except for Slovenia. While, for the futures equation, only the lagged spot prices for Austria, Belgium, Italy and Portugal show a significant effect of the lagged futures prices, overall confirming the results in table 2:5. However, according to table 2:5, no bidirectional causality was found for the Italian spot prices and Euronext futures prices, while the VECM model highlights a short-run effect from the Italian spot prices to futures prices. Error correction models should be used to study cointegrated time series, thus making the results for Italian prices (table 2:6b) more relevant (Fackler and Goodwin; 2001).

The CBOT VECM model also shows a highly significant long-run relationship between futures and spot prices, thus confirming the Engle-Granger results. The spot price equation for the CBOT model showed a significant short-run effect of the lagged value of spot prices for all the selected countries. None of the coefficients reported significance for the futures price equations. Indeed, where the significance exists, this broadly implies that spot prices react to futures prices, while the futures prices only react to variation in the ECT for all the Member States. Specifically, Austria, Belgium, Germany, Greece and Slovenia show a positive short-run causality from futures to spot prices. These results confirm the Toda-Yamamoto approach to Granger causality, implying that futures prices Granger cause the spot prices for the aforementioned countries. Examination of the ECT coefficient for the CBOT model implies that both spot prices and futures prices react to restore the long-run equilibrium for all the selected MS, except for Germany and Italy (Li and Zhang, 2011; Wu *et al.,* 2018).

Both the Euronext and CBOT futures markets show a strong cointegration with the European corn spot prices, as evidenced by tables 2:5, 2:6a and 2:6b. Indeed, the VECM depicted a long-run cointegrating relationship among all the considered MS, and a significant short-run effect and adjustment effect from futures to spot prices for most MS. Overall, price variability explained through price transmission from futures markets is higher for the Euronext futures exchange, given the higher adjusted R^2. Robustness checks confirm the stability of the models. Indeed, for both CBOT and Euronext derivatives exchange and for all the considered countries, residuals are a white noise process with no sign of autocorrelation (Johansen, 1995; Zhu *et al*., 2017).

In addition, given the results presented in table 2:4, which depicted significant structural breaks, we also applied a VECM considering the afore mentioned breaks. Results are presented in the Appendix (table 2:AA1, 2:AA2 and 2:AA3, 2:AA4), and confirm the results from table 2:6a and 2:6b. Indeed, even in the presence of a structural break in the model, the long- run cointegrating relationship is confirmed and the coefficients for both the short-run dynamics and adjustment effect are equal in sign and comparable in magnitude, making the results (table 2:6a and 2:6b) more valid (Dawson *et al*., 2006).

Table 2:6a Results of the VECM between Euronext futures contract and MS spot prices.

		EU	AU	BE	FR	GE	GR	IT	PO	RS	SL	SP
Coint. Eq.	*s*	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	f	-1.041*** (0.042)	-1.251*** (0.055)	-0.994*** (0.034)	-1.052*** (0.028)	-1.037*** (0.042)	-1.044*** (0.098)	-0.996*** (0.054)	-0.908*** (0.049)	-1.414*** (0.089)	-1.310*** (0.074)	-0.924*** (0.039)
	c	0.225	1.386	-0.108	0.277	0.164	0.262	-0.068	-0.557	2.323	1.655	-0.476
Δs_t	*ect*	-0.298*** (0.065)	-0.349* (0.062	-0.475*** (0.095)	-0.390*** (0.115	-0.334*** (0.075)	-0.242**** (0.049)	-0.227*** (0.064)	-0.244*** (0.049)	-0.284*** (0.047)	-0.366*** (0.056)	-0.229*** (0.063)
	Δs_{t-1}	0.640*** (0.097)	0.187* (0.075	0.442*** (0.106)	0.312** (0.113	0.255*** (0.089)	0.235*** (0.071)	0.571*** (0.103)	0.336*** (0.049)	0.253*** (0.065)	n.s.	0.270*** (0.085)
	Δs_{t-2}	-0.140* (0.082)		n.s.			n.s.	-0.182** (0.091)				
	Δf_{t-1}	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Δf_{t-2}	-0.124* (0.066)		n.s.			0.205*** (0.080)	n.s.				
	c	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	R-sq	0.478	0.294	0.290	0.116	0.272	0.370	0.383	0.216	0.373	0.311	0.312
	chi2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Δf_t	*ect.*	n.s.	n.s.	n.s.	0.271** (0.116)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Δf_{t-1}	n.s.	n.s.	n.s.	0.263** (0.113)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Δf_{t-2}			n.s.			n.s.	n.s.				
	Δs_{t-1}	0.488*** (166)	0.166** (0.083)	0.333*** (0.127)	n.s.	n.s.	n.s.	0.376** (0.152)	0.265** (0.129)	n.s.	n.s.	n.s.
	Δs_{t-2}	-0.240* (0.140)		-0.244** (0.120)			n.s.	-0.229* (0.134)				
	c	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	R-sq	0.078	0.050	0.094	0.134	0.035	0.029	0.068	0.057	0.024	0.023	0.030
	chi2	0.035	0.076	0.012	0.000	0.214	0.575	0.070	0.044	0.407	0.425	0.285
	LM	0.702	0.313	0.649	0.409	0.013	0.612	0.737	0.040	0.468	0.092	0.034
	Q	0.708	0.930	0.871	0.353	0.015	0.990	0.741	0.123	0.328	0.601	0.032
	E	0.581	0.605	0.563	0.389	0.440	0.565	0.506	0.583	0.475	0.625	0.526

*Note: the optimal lag length was determined using the modified Akaike Information Criterion. asterisks *, **, and ***, denote level of significance at 10%, 5%* and *1%., respectively. Standard errors are reported within parenthesis. Tests' statistics: Lagrange multiplier (LM) and Portmanteau test (Q), Jarque-Bera (JQ) and Eigenvalue stability condition (E).*

Table 2:6b Results of the VECM between CBOT futures contract and Member States spot prices.

		EU	AU	BE	FR	GE	GR	IT	PO	RS	SL	SP
	s	1	1	1	1	1	1	1	1	1	1	1
Coint. Eq.	*f*	-0.751***	-0.822***	-0.695***	-0.695***	-0.804 ***	-0.580***	-0.739***	-0.580***	-0.875***	-0.918***	-0.602***
		(0.123)	(0.150)	(0.089)	(0.106)	(0.121)	(0.129)	(0.125)	(0.094)	(0.166)	(0.173)	(0.083)
	c	-1.451	-1.025	-1.822	-1.736	-1.236	-2.268	-1.565	-2.385	-0.678	-0.592	-2.280
Δs_t	*ECT*	n.s.	-0.070 *	-0.071*	-0.074*	n.s.	-0.116***	n.s.	-0.079**	-0.091***	-0.077**	-0.055*
			(0.034)	(0.041)	(0.041)		(0.035)		(0.036)	(0.033)	(0.037)	(0.030)
	Δs_{t-1}	0.710***	0.260 ***	0.460***	0.244***	0.435***	0.230***	0.579***	0.362***	0.366***	0.138*	0.457***
		(0.080)	(0.080)	(0.087)	(0.085	(0.081)	(0.076)	(0.082)	(0.081)	(0.077)	(0.077)	(0.078)
	Δs_{t-2}	-0.271***	n.s.	-0.276***		-0.261***	n.s.	-0.266***			n.s.	
		(0.083)		(0.090)		(0.083)		(0.082)				
	Δs_{t-3}			n.s.								
	Δf_{t-1}	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Δf_{t-2}	n.s.	0.144 **	0.097*	n.s.	0.112**	0.190***	n.s.			0.252***	
			(0.063)	(0.058)		(0.053)	(0.060)				(0.075)	
	Δf_{t-3}			n.s.								
	c	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	R-sq	0.401	0.150	0.200	0.063	0.207	0.228	0.315	0.168	0.162	0.134	0.225
	P>chi2	0.000	0.000	0.000	0.027	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Δf_t	*ECT*	0.160***	0.113***	0.200***	0.149***	0.178***	0.082*	0.154***	0.128*	0.073**	0.100***	0.172***
		(0.051)	(0.043)	(0.060)	(0.053)	(0.050)	(0.047)	(0.051)	(0.063)	(0.036)	(0.039)	(0.064)
	Δf_{t-1}	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Δf_{t-2}	n.s.	n.s.	n.s.		n.s.	n.s.	n.s.			n.s.	
	Δf_{t-3}			n.s.								
	Δs_{t-1}	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Δs_{t-2}	n.s.	n.s.	n.s.		n.s.	n.s.	n.s.			n.s.	
	Δs_{t-3}			n.s.								
	c	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	R-sq	0.070	0.064	0.073	0.069	0.085	0.036	0.078	0.038	0.046	0.050	0.046
	P>chi2	0.061	0.092	0.141	0.018	0.022	0.421	0.037	0.167	0.097	0.207	0.096
	LM	0.547	0.916	0.521	0.346	0.631	0.491	0.387	0.086	0.873	0.711	0.099
	Q	0.727	0.967	0.925	0.415	0.588	0.967	0.566	0.244	0.349	0.950	0.207
	E	0.746	0.843	0.744	0.796	0.854	0.811	0.860	0.801	0.788	0.851	0.751

*Note: the optimal lag length was determined using the modified Akaike Information Criterion. asterisks *, **, and ***, denote level of significance at 10%, 5%* and *1%. respectively. Standard errors are reported within parenthesis. Tests' statistics: Lagrange multiplier (LM), Portmanteau test (Q), and Eigenvalue stability condition (E).*

Conclusions

The viability of agricultural commodity futures markets depends on the presence of a stable difference between futures and spot prices. Thus, the co-movement of futures and spot prices, implying a stable basis, is the foundation for its functioning for price discovery and price hedging. This study examines (and compares) the price transmission between two derivatives exchanges (i.e., Euronext and CBOT) and corn spot prices in a selection of EU Member States. The research aims at evaluating the presence of a long-run cointegrating relationship between futures and spot prices, also analysing the short-run dynamics. After conducting some preliminary tests, long-run cointegration was tested through Engle-Granger, Johansen and Gregory-Hansen procedures, confirming a stable relationship. Application of the Toda-Yamamoto approach to Granger causality test allowed to detect the direction of causality in the relationship between CBOT and Euronext futures and spot prices.

Results confirmed highly significant causality from Euronext to all MS spot prices. Additionally, for some MS (Austria, Belgium, France and Portugal), Euronext futures and spot prices also showed bi-directional causality. Alternatively, the CBOT futures contract prices depicted only uni-directional causality, from futures to spot (Austria, Belgium, Germany, Greece and Slovenia) or from spot to futures (France and Italy). Finally, VECM model was performed to assess the futures-spot price transmission within EU corn markets. The long-run cointegration relationship was confirmed for all the considered futures exchange prices and spot prices. Moreover, all the considered EU Member States spot prices are found to react to Euronext futures contract prices to adjust the long-run equilibrium relationship, confirming European futures markets' leading role. The leading role of futures contracts prices is also confirmed for the CBOT derivatives exchange, except for Germany and Italy. However, Germany shows a significant short-run effect from the CBOT futures prices while Italy does not, however displaying a strong cointegrating relationship. For all the considered MS, $AdjR^2$ is greater for the Euronext than for the CBOT.

Our findings have some important implications for EU actors involved in the corn market and for policymakers, providing insights into the connection between derivatives markets and spot prices. Indeed, the possibility of operating in the derivatives exchange represents an additional strategy for European farmers to cope with risks, in the light of the decreased CAP support (e.g., direct payment) and increased global price volatility. Hence, the results on the cointegration between futures and spot prices suggest the possibility for European corn producers to use futures markets (both CBOT and Euronext) to hedge the price risk. In line with this, given the connection between the Euronext futures markets and MS spot prices, the results encourage a further promotion of hedging strategies using the European futures market.

When interpreting these results at EU level, one limitation should be kept in mind, related to the number of selected Member States and not the entire EU, due to problems of data availability. This prevents general considerations on EU price transmission between futures and spot prices. This study remains relevant both because the considered MS cover more than half of EU corn production and due to the lack of similar and more comprehensive studies within the EU corn sector. Thus, the results presented here may have relevance to the EU corn supply chain operators (e.g., farmers, buyers, traders, etc.).

To conclude, this study paves the way for further investigations, e.g., examining the magnitude of basis risk and, therefore, the hedging efficiency of futures markets in reducing price volatility at farm level for a relevant agricultural sector in the EU. Indeed, farmers' resilience nowadays largely depends on the efficiency of hedging in derivatives markets, as well as their ability to understand and adopt such financial tools.

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APPENDIX 2:A

The cointegration analysis reported stable results. However, given the presence of a significant break highlighted by the Gregory-Hansen structural break test in table 2:5, according with Escribano and Arranz (2000)[3], we reported supplemental models with dummy variables and interaction dummy variables.

The variable d (table 2:AA1 to 2:AA4) represents a dummy variable that takes the value 0 before the break and the value 1 after the break. The variables d*Δst-1 and d*Δft-1 (table 2:AA2 and 2:AA4) represent interaction dummies: here, the variable takes the value 0 before the break and 1 multiplied by the lagged value of the spot/futures price after the break.

For all the considered MS, the models that incorporate the dummy (table 2:AA1 to 2:AA3) and the interaction dummy (table 2:AA2 and 2:AA4) confirm VECM results reported in the text (table 2:AA6a and 2:AA6b). The coefficients discussed in the results section are similar among models (with and without dummies). The considered model confirms the significance, and the signs of the model without the dummy, without improving the overall model selection criteria.

[3] Escribano, Á., & Arranz, M. A. (2000). Cointegration testing under structural breaks: A robust extended error correction model.

Table 2:AA1. Results of the VECM with dummy between Euronext futures contract and Member States spot prices.

		EU	AU	BE	FR	GE	GR	IT	PO	RS	SL	SP
Coint. Eq.	*s*	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	f	-1.017*** (0.038)	-1.263*** (0.054)	-0.994*** (0.034)	-1.053*** (0.029)	-0.987*** (0.037)	-1.104*** (0.080)	-0.99*** (0.057)	-0.849*** (0.031)	-1.423*** (0.085)	-1.315*** (0.074)	-0.881*** (0.035)
	c	0.086	1.456	-0.108	0.276	0.064	0.603	-0.087	-0.889	2.384	1.654	-0.718
Δs_t	*ect.*	-0.278*** (0.061)	-0.353*** (0.063)	-0.583*** (0.100)	-0.379*** (0.115)	-0.419*** (0.080)	-0.289*** (0.055)	-0.275*** (0.064)	-0.436*** (0.079)	-0.296*** (0.048)	-0.363*** (0.056	-0.361*** (0.073
	Δs_{t-1}	0.420*** (0.074)	0.186** (0.076)	0.489*** (0.105)	0.297*** (0.113)	0.285*** (0.087)	0.249*** (0.070)	0.572*** (0.104)	0.400*** (0.089)	0.255*** (0.065)		0.269*** (0.082)
	Δs_{t-2}			n.s.			n.s.	-0.181** (0.091)				
	Δf_{t-1}	n.s.	n.s.	-0.181* (0.108)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Δf_{t-2}						0.167** (0.081)	n.s.				
	d	n.s.	n.s.	0.021** (0.009)	n.s.	0.017** (0.008)	0.020** (0.010)	n.s.	-0.028*** (0.008)	n.s.	n.s.	-0.017*** (0.006)
	c	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	R-sq	0.452	0.293	0.323	0.126	0.272	0.374	0.38	0.284	0.379	0.313	0.352
	P>chi2	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.000	0.000	0.000	0.000
Δf_t	*ect.*	n.s.	n.s.	n.s.	0.284** (0.116)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Δs_{t-1}	n.s.	0.164** (0.083)	0.359*** (0.129)	0.247** (0.113)	n.s.	n.s.	0.378** (0.153)	0.283** (0.132)	n.s.	n.s.	n.s.
	Δs_{t-2}			-0.221*** (0.122)			n.s.	-0.228* (0.135)				
	Δf_{t-1}	n.s.	n.s.	n.s.	n.s.	n.s.	0.177* (0.096)	n.s.	n.s.	0.162* (0.098)	n.s.	n.s.
	Δf_{t-2}						n.s.	n.s.				
	d	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	c	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	R-sq	0.035	0.053	0.096	0.147	0.035	0.029	0.07	0.051	0.025	0.026	0.025
	P>chi2	0.322	0.111	0.019	0.000	0.321	0.689	0.11	0.121	0.521	0.512	0.533
	LM	0.010	0.320	0.680	0.409	0.013	0.627	0.74	0.042	0.476	0.093	0.038
	Q	0.016	0.932	0.950	0.309	0.015	0.987	0.74	0.039	0.328	0.616	0.015
	E	0.601	0.444	0.693	0.515	0.526	0.568	0.782	0.608	0.479	0.583	0.471

*Note: the optimal lag length was determined using the modified Akaike Information Criterion. asterisks *, ** and ***, denote level of significance at the 10%, 5%* and *1% level, respectively. Standard errors are reported within parenthesis. Tests' statistics: Lagrange multiplier (LM) and Portmanteau test (Q) and Eigenvalue stability condition (E)*

TABLE 2:AA2. Results of the VECM with dummy and with interaction dummy between Euronext futures contract and Member States spot price.

		EU	AU	BE	FR	GE	GR	IT	PO	RS	SL	SP
Coint. Eq.	*s*	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	f	-1.011*** (0.037)	-1.264*** (0.054)	-0.951*** (0.031)	-1.051*** (0.029)	-0.987*** (0.037)	-1.105*** (0.081)	-1.00*** (0.053)	-0.850*** (0.031)	-1.427*** (0.086)	-1.314*** (0.075)	-0.879*** (0.027)
	c	0.055	1.460	-0.309	0.268	-0.064	0.607	-0.002	-0.884	2.401	1.646	-0.727
Δs_t	*ect.*	-0.297*** (0.061)	-0.350*** (0.063)	-0.585*** (0.100)	-0.395*** (0.115)	-0.424*** (0.079)	-0.281*** (0.054)	-0.271*** (0.066)	-0.429*** (0.081	-0.288*** (0.048	-0.361*** 0.056	-0.357*** 0.073
	Δs_{t-1}	0.500*** (0.082)	0.162** (0.083)	0.596*** (0.157)	0.121*** (0.411)	0.298** (0.144)	0.346*** (0.081)	0.567*** (0.106)	0.407*** (0.098	0.266*** (0.000	n.s.	0.323*** 0.093
	Δs_{t-2}			n.s.			n.s.	-0.185** (0.092)				
	Δf_{t-1}	n.s.	n.s.	n.s.	-0.762*** (0.298)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Δf_{t-2}			n.s.			0.175** (0.080)	n.s.				
	d	-0.010* (0.006)	n.s.	0.021** (0.009)	n.s.	0.018** (0.008)	0.020** (0.009)	n.s.	-0.027*** (0.008)	-0.027*** (0.008)	n.s.	-0.017** (0.006)
	$d^*\Delta s_{t-1}$	-0.439** (0.193)	n.s.	n.s.	-0.967** (0.415)	n.s.	-0.335* (0.146)	n.s.	N.s.	n.s.	n.s.	n.s.
	$d^*\Delta f_{t-1}$	n.s.	n.s.	n.s.	0.736** (0.308)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	c	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	R-sq	0.471	0.296	0.333	0.159	0.316	0.404	0.383	0.284	0.387	0.318	0.365
	P>chi2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Δf_t	*ect.*	n.s.	n.s.	n.s.	0.266** (0.114)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Δs_{t-1}	0.263* (0.141)	0.160* (0.091)	0.546*** (0.194)	1.397*** (0.408)	n.s.	n.s.	0.377** (0.157)	0.255* (0.146)	n.s.	0.316** (0.156)	n.s.
	Δs_{t-2}			-0.224* (0.123)			n.s.	-0.239* (0.135)				
	Δf_{t-1}	n.s.	n.s.	n.s.	-0.854*** (0.295)	n.s.	0.230** (0.105)	n.s.	0.254* (0.146)	0.175* (0.101)	n.s.	n.s.
	Δf_{t-2}			n.s.			n.s.	n.s.				
	d	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	$d^*\Delta s_{t-1}$	n.s.	n.s.	n.s.	-1.214*** (0.412)	n.s.	n.s.	-0.508* (0.268)	n.s.	n.s.	-0.316* (0.172)	n.s.
	$d^*\Delta f_{t-1}$	n.s.	n.s.	n.s.	0.960*** (0.305)	n.s.	n.s.	n.s.	n.s.	n.s.	0.337* (0.201)	n.s.
	c	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	R-sq	0.056	0.056	0.108	0.198	0.034	0.052	0.072	0.057	0.033	0.052	0.030
	P>chi2	0.218	0.224	0.027	0.000	0.587	0.479	0.206	0.213	0.605	0.275	0.661
	LM	0.010	0.320	0.680	0.409	0.013	0.627	0.745	0.042	0.479	0.093	0.038
	Q	0.014	0.895	0.930	0.445	0.013	0.979	0.663	0.033	0.297	0.615	0.009
	E	0.605	0.386	0.754	0.866	0.585	0.580	0.617	0.638	0.524	0.729	0.542

*Note: the optimal lag length was determined using the modified Akaike Information Criterion. asterisks *, ** and ***, denote level of significance at the 10%, 5%* and *1% level, respectively. Standard errors are reported within parenthesis. Tests' statistics: Lagrange multiplier (LM) and Portmanteau test (Q) and Eigenvalue stability condition (E)*

TABLE 2:AA3. Results of the VECM with dummy between CBOT futures contract and Member States spot prices.

		EU	AU	BE	FR	GE	GR	IT	PO	RS	SL	SP
Coint. Eq.	*s*	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	f	-0.731*** (0.071)	-0.866*** (0.129)	-0.762*** (0.075	-0.806*** (0.084)	-0.786*** (0.102)	-0.764*** (0.121)	-0.764*** (0.101)	-0.677*** (0.057)	-1.028*** (0.137)	-0.980*** (0.153)	-0.685*** (0.058)
	c	-1.686	-0.962	-1.605	-1.370	-1.415	-1.536	-1.542	-2.066	-0.203	-0.530	-1.983
Δs_t	*ect.*	-0.125*** (0.031)	-0.117*** (0.039)	-0.130*** (0.047)	-0.131*** (0.047)	-0.079** (0.039)	-0.136*** (0.038)	-0.082** (0.034)	-0.174*** (0.047)	-0.136*** (0.036)	-0.129*** (0.040)	-0.113*** (0.038)
	Δs_{t-1}	0.591 *** (0.066)	0.261*** (0.079)	0.465*** (0.085)	0.247*** (0.084)	0.438*** (0.079)	0.286*** (0.076)	0.576*** (0.081)	0.379*** (0.079)	0.350*** (0.075)	0.130* (0.076)	0.449*** (0.076)
	Δs_{t-2}		n.s.	-0.261*** (0.088)		-0.243*** (0.082)	n.s.	-0.251*** (0.081)			n.s.	
	Δs_{t-3}			n.s.								
	Δf_{t-1}	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Δf_{t-2}		0.112* (0.064)	n.s.		n.s.	0.162*** (0.061)	n.s.			0.204*** (0.075)	
	Δf_{t-3}			n.s.								
	d	-0.037*** (0.011)	-0.040** (0.016)	-0.044*** (0.015)	-0.051*** (0.017)	-0.035*** (0.013)	-0.046*** (0.015)	-0.035** (0.012)	-0.047*** (0.014)	-0.060*** (0.018)	-0.058*** (0.019)	-0.032*** (0.011)
	c	0.017** (0.008)	n.s.	0.026** (0.012)	0.024* (0.013)	0.025** (0.011)	n.s.	0.025*** (0.010)	0.017** (0.009)	n.s.	n.s.	0.018** (0.008)
	R-sq	0.404	0.178	0.235	0.104	0.241	0.250	0.350	0.214	0.205	0.177	0.257
	P>chi2	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Δf_t	*ect.*	0.151** (0.064)	0.118** (0.051)	0.229*** (0.070)	0.188*** (0.061)	0.192*** (0.061)	0.113** (0.051)	0.161*** (0.061)	0.178** (0.086)	0.083** (0.040)	0.099** (0.044)	0.227*** (0.082)
	Δs_{t-1}	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Δs_{t-2}		n.s.	n.s.		n.s.	n.s.	-0.344** (0.146)			n.s.	
	Δs_{t-3}			ns								
	Δf_{t-1}	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Δf_{t-2}		n.s.	n.s.		n.s.	n.s.	n.s.			n.s.	
	Δf_{t-3}			ns								
	dummy	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	c	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	R-sq	0.058	0.069	0.086	0.086	0.084	0.058	0.081	0.053	0.059	0.056	0.063
	P>chi2	0.079	0.113	0.105	0.010	0.042	0.203	0.053	0.108	0.075	0.230	0.055
	LM	0.013	0.915	0.525	0.282	0.628	0.541	0.388	0.072	0.854	0.710	0.088
	Q	0.081	0.964	0.958	0.384	0.684	0.989	0.713	0.217	0.454	0.992	0.196
	E	0.708	0.782	0.630	0.667	0.809	0.762	0.826	0.547	0.652	0.796	0.606

*Note: the optimal lag length was determined using the modified Akaike Information Criterion. asterisks *, ** and *** denote level of significance at the 10%, 5%* and *1% level, respectively. Standard errors are reported within parenthesis. Tests' statistics: Lagrange multiplier (LM), Portmanteau test (Q) and Eigenvalue stability condition (E)*

TABLE 2:AA4. Results of the VECM with dummy and with interaction dummy between CBOT futures contract and Member States spot price.

		EU	AU	BE	FR	GE	GR	IT	PO	RS	SL	SP
Coint. Eq.	*s*	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	f	-0.745*** (0.072)	-0.902*** (0.134)	-0.767*** (0.076)	-0.796*** (0.080)	-0.790*** (0.105)	-0.726*** (0.124)	-0.778*** (0.103)	-0.683*** (0.058)	-1.033*** (0.136)	-0.992*** (0.157)	-0.688*** (0.058)
	c	-1.625	-0.774	-1.580	-1.431	-1.422	-1.770	-1.443	-2.053	-0.147	-0.472	-1.975
Δs_t	*ect.*	-0.119*** (0.031)	-0.103*** (0.038)	-0.122*** (0.047)	-0.137*** (0.046)	-0.074* (0.039)	-0.145*** (0.038)	-0.070** (0.033)	-0.167*** (0.047)	-0.140*** (0.037)	-0.119*** (0.039)	-0.110*** (0.038)
	Δs_{t-1}	0.643*** (0.189)	0.668*** (0.221)	0.567*** (0.189)	n.s.	0.590*** (0.190)	0.795** (0.330)	0.557*** (0.185)	Ns	0.508** (0.216)	0.321* (0.178)	0.506*** (0.176)
	Δs_{t-2}	n.s.	n.s.	-0.262*** (0.088)		-0.236*** (0.081)	n.s.	n.s.			n.s.	
	Δs_{t-3}			Ns								
	Δf_{t-1}	-0.161** (0.080)	-0.262** (0.127)	-0.267** (0.115)	-0.291** (0.131)	-0.193* (0.106)	n.s.	-0.192** (0.091	n.s.	n.s.	-0.379** (0.151)	n.s.
	Δf_{t-2}		0.166*** (0.064)	n.s.		0.105* (0.054)	0.175*** (0.060)	n.s.			0.243*** (0.075)	
	d	-0.039*** (0.011)	-0.034** (0.017)	-0.044*** (0.016)	-0.055*** (0.017)	-0.034** (0.014)	-0.035** (0.017)	-0.039*** (0.012)	-0.050*** (0.014)	-0.055*** (0.020)	-0.059*** (0.020)	-0.034*** (0.011)
	$d^*\Delta s_{t-1}$	n.s.	-0.509** (0.236)	n.s.	n.s.	n.s.		n.s.	n.s.	n.s.	n.s.	n.s.
	$d^*\Delta f_{t-1}$	0.204** (0.093)	0.405*** (0.145)	0.263** (0.132)	0.357** (0.149)	0.256** (0.122)	0.315** (0.155)	0.296** (0.105)	n.s.	n.s.	0.484*** (0.172)	0.168* (0.090)
	c	0.019** (0.009)	n.s.	0.027** (0.036)	0.025* (0.014)	0.023** (0.012)	n.s.	0.032*** (0.011)	0.018	n.s.	0.025** (0.016)	0.019** (0.008)
	R-sq	0.421	0.238	0.258	0.140	0.266	0.275	0.381	0.226	0.208	0.224	0.273
	P>chi2	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Δf_t	*ect.*	0.157** (0.066)	0.120** (0.051)	0.228*** (0.070)	0.188*** (0.061)	0.188*** (0.062)	0.088* (0.051)	0.167*** (0.062)	0.179** (0.087)	0.083** (0.041)	0.100** (0.044)	0.228*** (0.083)
	Δs_{t-1}	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Δs_{t-2}		n.s.	n.s.		n.s.	n.s.	-0.347** (0.146)			n.s.	
	Δf_{t-1}	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Δf_{t-2}		n.s.	n.s.		n.s.	n.s.	n.s.			n.s.	
	d	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.		n.s.	n.s.
	$d^*\Delta s_{t-1}$	n.s.	n.s.	n.s.	n.s.	n.s.	-1.020** (0.450)	n.s.	n.s.	n.s.	n.s.	n.s.
	$d^*\Delta f_{t-1}$	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	c	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	R-sq	0.062	0.074	0.088	0.092	0.088	0.085	0.092	0.059	0.062	0.059	0.064
	P>chi2	0.158	0.192	0.193	0.024	0.089	0.107	0.072	0.196	0.159	0.368	0.141
	LM	0.013	0.916	0.525	0.287	0.628	0.532	0.389	0.071	0.853	0.710	0.088
	Q	0.124	0.883	0.913	0.563	0.700	0.966	0.856	0.328	0.441	0.990	0.352
	E	0.721	0.662	0.750	0.666	0.671	1.094	0.787	0.490	0.681	0.829	0.631

*Note: the optimal lag length was determined using the modified Akaike Information Criterion. asterisks *, ** and *** denote level of significance at the 10%, 5%* and *1% level, respectively. Standard errors are reported within parenthesis. Tests' statistics: Lagrange multiplier (LM) and Portmanteau test (Q) and Eigenvalue stability condition (E)*

APPENDIX 2:B

To improve the cointegration tests results, this appendix presents the results of the Phillips-Perron stationarity tests on the residuals of the Engle-Granger first step cointegration procedure. Confirming the results of table 2:3, the nonparametric tests show that the CBOT and Euronext futures prices are cointegrated with the spot prices of the selected MS.

Table 2:AB1. Result of the Phillips-Perron stationarity tests.

		CBOT				Euronext			
		Test statistic	1% critical value	5% critical value	10% critical value	Test statistic	1% critical value	5% critical value	10% critical value
EU	Z(rho)	-24.408	-27.847	-20.968	-17.723	-62.806	-27.847	-20.968	-17.723
	Z(t)	-3.543	-4.018	-3.441	-3.141	-6.137	-4.018	-3.441	-3.141
Austria	Z(rho)	-24.451	-27.847	-20.968	-17.723	-60.203	-27.847	-20.968	-17.723
	Z(t)	-3.563	-4.018	-3.441	-3.141	-6.057	-4.018	-3.441	-3.141
Belgium	Z(rho)	-30.023	-27.847	-20.968	-17.723	-72.783	-27.847	-20.968	-17.723
	Z(t)	-3.964	-4.018	-3.441	-3.141	-6.75	-4.018	-3.441	-3.141
France	Z(rho)	-27.263	-27.847	-20.968	-17.723	-100.36	-27.847	-20.968	-17.723
	Z(t)	-3.792	-4.018	-3.441	-3.141	-8.46	-4.018	-3.441	-3.141
Germany	Z(rho)	-25.885	-27.847	-20.968	-17.723	-70.614	-27.847	-20.968	-17.723
	Z(t)	-3.691	-4.018	-3.441	-3.141	-6.7	-4.018	-3.441	-3.141
Greece	Z(rho)	-25.791	-27.847	-20.968	-17.723	-52.711	-27.847	-20.968	-17.723
	Z(t)	-3.676	-4.018	-3.441	-3.141	-5.486	-4.018	-3.441	-3.141
Italy	Z(rho)	-23.226	-27.847	-20.968	-17.723	-46.543	-27.847	-20.968	-17.723
	Z(t)	-3.448	-4.018	-3.441	-3.141	-5.102	-4.018	-3.441	-3.141
Portugal	Z(rho)	-29.151	-27.847	-20.968	-17.723	-66.872	-27.847	-20.968	-17.723
	Z(t)	-3.914	-4.018	-3.441	-3.141	-6.336	-4.018	-3.441	-3.141
Slovakia	Z(rho)	-24.778	-27.847	-20.968	-17.723	-52.28	-27.847	-20.968	-17.723
	Z(t)	-3.6	-4.018	-3.441	-3.141	-5.519	-4.018	-3.441	-3.141
Slovenia	Z(rho)	-26.799	-27.847	-20.968	-17.723	-54.974	-27.847	-20.968	-17.723
	Z(t)	-3.736	-4.018	-3.441	-3.141	-5.642	-4.018	-3.441	-3.141
Spain	Z(rho)	-26.97	-27.847	-20.968	-17.723	-61.498	-27.847	-20.968	-17.723
	Z(t)	-3.735	-4.018	-3.441	-3.141	-5.999	-4.018	-3.441	-3.141

3

Testing for asymmetric cointegration of Italian agricultural commodities prices: evidence from the futures-spot market relationship

Abstract

The volatility of food prices still raises concerns among agricultural market players, increasing interest in the futures markets, thus calling for a better understanding of the connection between the futures and the Italian spot prices. This study uses symmetric and asymmetric vector error correction models to investigate the relationship between futures and spot prices for the Italian agricultural markets of soybean, corn, and milling wheat. The results confirm the leading role of the futures contract prices for all the considered commodities. Moreover, the non-linear cointegration analysis results suggest price transmission's asymmetries for all the agricultural commodity prices. This research provides critical insight into the shape of the futures-spot price transmission.

Keywords

Price Transmission, Basis Behavior , Vector Error Correction Model, Threshold Vector Error Correction Model

Introduction

The relationship between futures and spot markets is the premise for the efficient use of futures contracts to hedge against price risk (Goodwin and Schnepf, 2000). Price risk affects all economic activities, including the agricultural sector that is increasingly vulnerable to the high variability in output prices (Santeramo *et al.*, 2018). Following this, it is expected that in these uncertain environments in which farmers operate, they are incentivized to adopt risk management strategies and tools (Coletta et al., 2018). Futures contracts may represent a viable alternative for farmers and operators to lock in delivery prices in advance, thus reducing price risk (Penone et al., 2021). The increasing interest in futures contracts calls for a better understanding of the Italian spot prices connection to the futures market.

The effectiveness of the hedging activities is sensitive to the spread between the futures and the spot prices, i.e., the basis. According to the no-arbitrage price theory, prices in two different markets should tend to converge (Lence et al., 2018). Past studies have documented the existence of a stationary basis between futures and spot prices, among others, within the Canadian and the Brazilian agri-commodity futures and spot markets (respectively: Brockman and Tse, 1995; Mattos and Garcia, 2004). Also, the relationship between spot and futures prices for European agri-commodities has been tested, confirming the presence of a cointegrating relationship and the leading role of cereals futures prices (Kuiper *et al.*, 2002; Adämmer and Bohl, 2018). Thus, the literature confirms the existence of a cointegration relationship between futures and spot prices using error correction models to test for cointegration. However, it is typically assumed a symmetric adjustment toward equilibrium.

The issue of price transmission asymmetries has attracted considerable research interest among agricultural economists (von Cramon-Taubadel, 1998; Enders and Siklos, 2001; Meyer and von Cramon-Taubadel, 2004; Santeramo and von Cramon-Taubadel, 2016). A positive (negative) price asymmetry occurs when a decrease (increase) in prices is not fully or immediately transmitted, but an increase (decrease) passes on more quickly or thoroughly. However, to the best of our knowledge, there is little evidence regarding asymmetric price transmission (APT) in the relationship between agricultural commodity futures-spot prices. The degree and shape with which shocks are transmitted between the futures and spot markets can have important implications for hedging activities, agricultural commodities pricing and, policy implications. The presence of APT has been confirmed for the US and Canadian grain markets, implying the most profitable opportunities for traders when the basis is narrowing (Chang et al., 2012). Similarly, Wu *et al.*, (2018), confirmed the presence of negative APT between the Chicago futures market and the Ontario spot market for soybean while the corn markets showed positive APT. Their finding suggests that operators of assorted commodities must resort to different trading strategies in response to shock.

The purpose of this paper is to examine the relationship between futures and spot prices and testing for the presence of an asymmetric price transmission for soybean, corn, and milling wheat (hereafter wheat) in Italy. This study contributes to the literature by examining the non-linear dynamic relationship between futures and Italian spot prices, using error correction methods. While the methodology has been applied, to a limited extent, to the futures-spot transmission studies, to the best of our knowledge, this is the first analysis regarding countries that do not have access to a domestic derivatives exchange. Indeed, like others within the European Union, Italian agricultural commodities' operators must operate in foreign futures exchanges. Therefore, this analysis will show insight into the use of futures markets within multiple settings in which a local derivatives exchange is absent.

Material And Methods

The soybean corn and milling wheat production account for more than 60% of all cereals and oilseed produced in Italy in 2019, representing a holistic picture of the Italian arable crop sector. The sample period of this study runs from January 2008 to December 2019. The Italian spot prices are weekly wholesale prices listed on the Bologna market every Thursday (Associazione Granaria Emilia Romagna, 2021). The futures markets investigated in this analysis are the Chicago Board of Trade (CBOT), the world reference market for agricultural trading, and Euronext, the main agri-commodity European futures market (Agriculture and Horticulture Development Board, 2021).

Figure 3:1. The futures prices (CBOT and Euronext).

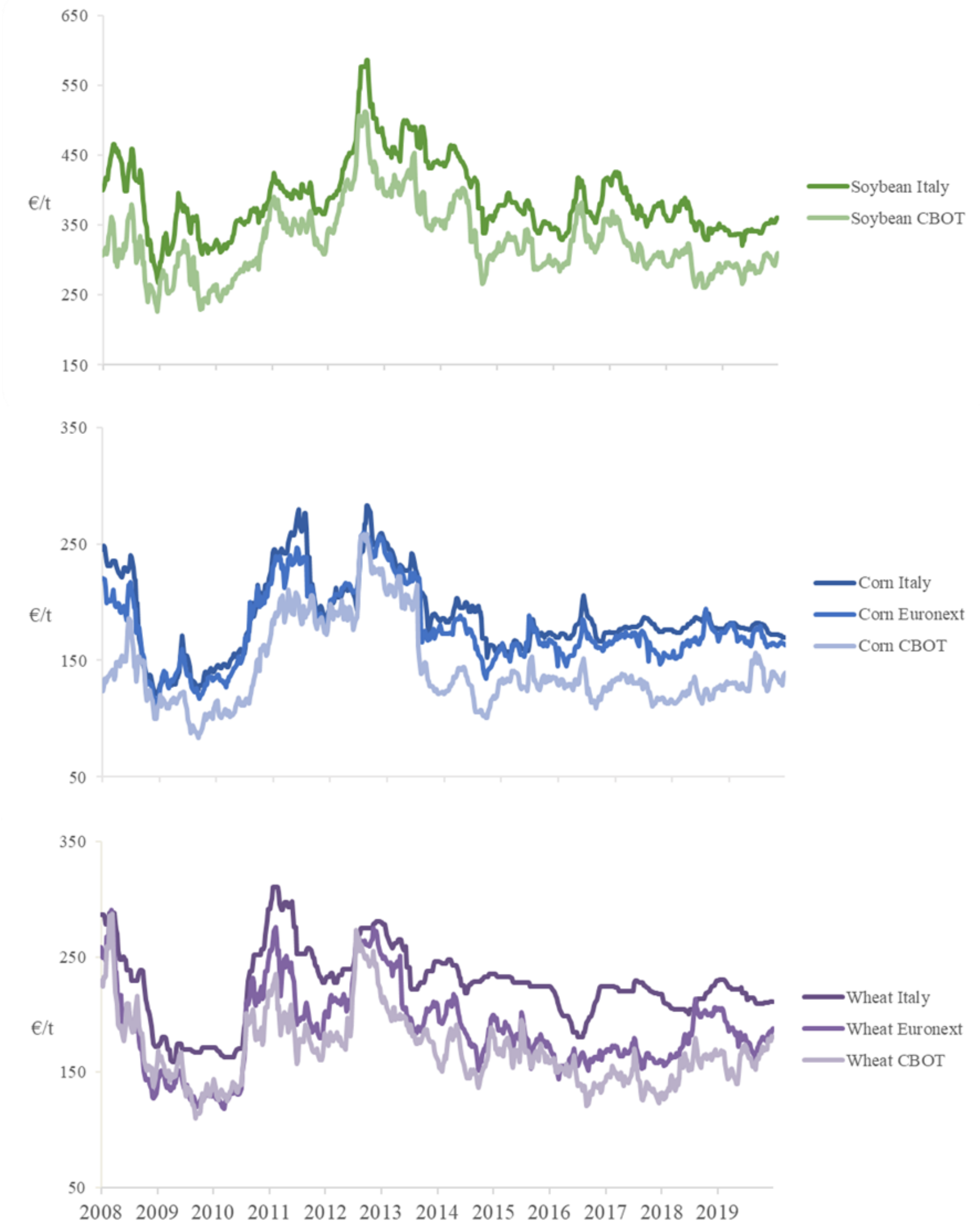

Figure 3:1 illustrates the joint movement of the Italian spot prices for soybean, corn, and milling wheat with the counterpart futures contract prices of CBOT and Euronext. Even if futures and spot prices move together, it is possible to observe how the basis is not precisely constant. Summary statistics are reported in table 3:1.

Table 3:1. Summary statistics of the futures and spot prices.

Commodities	Prices	N. of Obs.	Mean	SD	Min.	Max.
Soybean	Italian spot	626	387.49	53.12	267.50	586.50
	CBOT futures	626	325.82	51.50	226.64	512.73
Corn	Italian spot	626	187.75	34.04	121.50	282.50
	Euronext futures	626	177.06	32.10	111.65	259.75
	CBOT futures	626	143.10	35.48	83.68	258.58
Milling wheat	Italian spot	626	225.42	32.88	158.50	310.50
	Euronext futures	626	186.28	36.39	118.35	290.65
	CBOT futures	626	168.71	30.78	109.97	287.17

Note: prices are expressed in €/t (Agriculture and Horticulture Development Board, 2021; Associazione Granaria Emilia Romagna, 2021).

The equilibrium relationship between futures and spot prices is based on the following equation:

$$F_{tT} = S_t e^{(r_t+u_t+c_t)(t-T)} \qquad \text{(Eq. 3:1)}$$

Where F and S are the futures contract and spot price of a commodity, t is the current date, T is the futures contract expiration date, r is the interest rate due for holding the commodity, u is the marginal storage cost rate, and c is the marginal convenience yield (Fama and French, 1987). This implies:

$$b_t = S_t - F_t = -(r_t + u_t + c_t)(T - t) \qquad \text{(Eq. 3:2)}$$

Where b_t is the basis, *i.e.*, the difference between stop and futures prices. The Law of One Price (LOP) implies a decline in the international dispersion of prices which tend to converge as a result of arbitrage (von Cramon-Taubadel and Goodwin, 2021). Indeed, if $b_t < 0$, arbitrageurs will buy the spot commodity and sell futures contracts to profit from the difference. Alternatively, if $b_t > 0$, arbitrageurs would profit by selling the spot commodity and buying the futures contracts. The LOP abstract from trade and transportation costs which may have a significant impact on the market efficiency. If futures and spot prices are linearly cointegrated, i.e., the basis is stationary with zero mean, futures contracts can be used as an efficient price risk management instrument

(Penone et al., 2021). However, as stated in the literature, deviations from arbitrage equilibrium can influence price transmission throughout the markets (Goodwin et al., 2021).

Preliminary steps are needed to test for the presence of asymmetric price transmission. Firstly, the time series are tested to identify the order of integration through the Augmented Dickey-Fueller (Dickey-Fuller, 1979), and the non-parametric Phillips-Perron (1988) approaches. Then, the application of error correction models implies a stationary combination of the futures spot price sets. The futures spot price pairs for the same commodities are tested with the Engle-Granger (EG) two-step procedure (Engle and Granger, 1987). Moreover, given the linearity of the EG procedure, to include threshold types of effect and therefore testing for the presence of APT, we applied Enders and Siklos (2001) threshold autoregressive model (TAR).

After the testing for symmetric and asymmetric behaviour of the basis, both symmetric and asymmetric error correction models (ECM) are applied to the futures-spot price pairs. Firstly, a symmetric ECM, as in equation (3), was performed.

$$\Delta y_t = \beta_0 + \sum_{i=1}^{l} \beta_1 \Delta x_{t-i} + \sum_{i=1}^{l} \beta_2 \Delta y_{t-j} + \beta_3 ECT_{t-1} + \varepsilon_t \qquad \text{(Eq. 3:3)}$$

Where Δy_t and Δx_t are the lagged log differences of spot (futures) and futures (spot) prices from the time interval (i) 1 to l (the number of selected lags), β_0 is the intercept terms, β_1 denotes the coefficient of the lagged differenced futures (spot) representing the short-run transmission; and β_2 represent the autoregressive coefficient of the spot (futures) prices. Finally, the ECT, defined as $ECT_{t-1} = y_{t-1} - b_1 - b_2 x_{t-1}$, is the error correction term corresponding to the speed at which the cointegrated series converges (Santeramo and von Cramon-Taubadel, 2016).

As previously stated, prices may show APT, thus calling for the examination of threshold types of effects in the ECM model of the utmost importance. The threshold error correction model (TVECM) specification can be computed according to equations 3:4 and 3:4.1.

$$\Delta y_t = \gamma_0 + \sum_{i=1}^{l} \gamma_1 \Delta x_{t-i} + \sum_{i=1}^{l} \gamma_2 \Delta y_{t-i} + I_t \gamma_3 ECT_{t-1} + (1 - I_t)\gamma_4 ECT_{t-1} + \varepsilon_{st} \qquad \text{(Eq. 3:4)}$$

$$I_t = \begin{cases} 1 & if \;\; ECT_{t-1} \geq \tau \\ 0 & if \;\; ECT_{t-1} < \tau \end{cases} \qquad \text{(Eq. 3:5)}$$

Where Δy_t and Δx_t are the lagged log differences of spot (futures) and futures (spot) prices from the time interval (i) 1 to l (the number of selected lags), α_0 is the intercept terms, γ_1 denote the coefficient of the lagged differenced futures (spot) representing the short-run transmission, and γ_2 represent the autoregressive coefficient of the spot (futures) prices. *ECT* is the error correction term and γ_3 and γ_4 are the adjustment coefficients calculated according to the Heaviside indicator (I_t) setting, $\tau = 0$ (Wu *et al.*, 2018).

In summary, the empirical analysis of price transmission from futures to spot prices for Italian commodities involves the following steps. First, the price series under investigation are examined through a unit root test (Dickey-Fuller, 1979; Philipp-Perron, 1988). Second, the standard Engle-Granger procedure to test the cointegration is applied to the futures-spot and spot-futures price pairs (Engle-Granger, 1987). Third, a TAR model for the analysis of asymmetries is implemented (Enders and Siklos, 2001). Lastly, both VECM and TVECM are estimated (Wu *et al.*, 2018).

Results And Discussion

The tests results confirm stationarity for all prices' first differences (Table 3:2).

Table 3:2. Unit root test on spot and futures prices of designated agricultural commodities.

Commodities	Prices	Augmented Dickey-Fuller		Phillips-Perron	
		Levels	First differences	Levels	First differences
Soybean	Italian spot[3]	-3.360*	-10.660***	-3.203*	-21.712***
	CBOT futures[2]	-3.102	-14.417***	-3.197*	-22.329***
Corn	Italian spot[2]	-2.410	-13.186***	-2.143	-20.643***
	CBOT futures[2]	-2.370	-13.911***	-2.341	-21.034***
	Euronext futures[2]	-2.350	-13.797***	-2.329	-21.569***
Milling wheat	Italian spot[4]	-2.919	-8.169***	-2.146	-19.548***
	CBOT futures[2]	-3.530**	-13.956***	-3.326*	-20.880***
	Euronext futures[4]	-2.854	-10.518***	-2.582	-19.127***

Note. H_0: series has a unit root. Asterisks denote levels of significance (for 10%, ** for 5%, and *** for 1%). Based on series characteristics both tests allow for both the constant and linear trend. The optimal lag length was chosen according to the Akaike information criterion (AIC), numbers in square brackets indicates the selected lags. Augmented Dickey-Fuller and Phillips-Perron test critical values at 1%, 5% and 10% are -3.960, -3.410 and -3.120 respectively.*

The results of the EG cointegration methodology are presented in the first part of table 3:3. The results show a long-run cointegrating relationship, confirming literature on futures-spot price analysis (among others: Kuiper *et al.*, 2002; Beckmann and Czudaj, 2014).

Table 3:3. Cointegration of designated agricultural commodities.

		Prices	Coefficients		α_2-α_3=0	R^2	AIC	LM	Q
EG	Soybean	Italian Spot-CBOT	α_1	-0.075*** (0.015)	-	-	-	0.045	0.014
	Corn	Italian Spot -CBOT	α_1	-0.028*** (0.009)	-	-	-	0.028	0.440
		Italian Spot -Euronext	α_1	-0.126*** (0.021)	-	-	-	0.084	0.216
	Wheat	Italian Spot -CBOT	α_1	-0.044*** (0.012)	-	-	-	0.036	0.335
		Italian Spot -Euronext	α_1	-0.060*** (0.013)	-	-	-	0.054	0.234
TAR	Soybean	Italian Spot -CBOT	α_2	-0.056** (0.024)	0.505	0.045	-5.000	0.016	0.215
			α_3	-0.088*** (0.033)					
	Corn	Italian Spot -CBOT	α_2	-0.033** (0.014)	0.647	0.028	-4.344	0.705	0.444
			α_3	-0.021 (0.017)					
		Italian Spot -Euronext	α_2	-0.090*** (0.035)	0.237	0.099	-4.291	0.004	0.046
			α_3	-0.164*** (0.040)					
	Wheat	Italian Spot -CBOT	α_2	-0.036 (0.023)	0.832	0.036	-4.459	0.645	0.339
			α_3	-0.044** (0.020)					
		Italian Spot -Euronext	α_2	-0.055** (0.025)	0.832	0.058	-4.908	0.246	0.734
			α_3	-0.064** (0.025)					

Note. EG: Engle-Granger two step procedure; TAR: threshold autoregressive; Standard error in parenthesis. Asterisks denote levels of significance (for 10%, ** for 5%, and *** for 1%). Tests' statistics: Lagrange multiplier (LM) and Portmanteau test (Q). EG and TAR are the results coefficients from an ADF-type test on the residuals: Δz_t, of $S_t = a_0 + a_1 F_t + z_t$, where S_t are the spot prices at time t and F the futures prices at time t. The coefficients are calculated according:*

EG $\rightarrow \Delta z_t = \alpha_0 + \alpha_1 z_{t-1} + \sum_{i=1}^{n} \sigma_i \Delta z_{t-i} + \varepsilon_t$

TAR $\rightarrow \Delta z_t = \alpha_0 + \alpha_2 z_{t-1}^{+} + \alpha_3 z_{t-1}^{-} + \sum_{i=1}^{n} \sigma_i \Delta z_{t-i} + \varepsilon_t,$

The results for the threshold cointegration tests present some interesting relations (table 3:3). For all the considered futures markets and commodities, the TAR models suggest convergence given the negative α_2 and α_3 coefficients. The null hypothesis of symmetric adjustment (α_2-α_3=0) cannot be accepted for future-spot price pairs. These results align with the agricultural commodity literature regarding price transmission and asymmetric tests in futures markets (Wu *et al.,* 2018; Chang *et al.,* 2012). The estimated adjustment parameters for positive and negative basis changes (α_2= positive basis changes, α_3= negative basis changes) show, overall, a faster adjustment when the basis changes are below the threshold value and a slower adjustment when the basis changes are above the threshold value. For all the considered prices pairs, the model suggests the strongest adjustment occur during the narrowing of the futures-spot basis. Therefore, a shock that results in the narrowing of corn basis (decline in futures contract prices relative to spot price) will tend to revert faster back toward the equilibrium. Contrariwise, a shock that results in widening of corn basis (rise in futures price relative to spot price) will tend to revert faster back toward the equilibrium. Surprisingly, the CBOT-Italian spot prices for corn show $|\alpha_2| > |\alpha_3|$, thus suggesting positive APT between the two prices. A shock in the CBOT futures prices will tend to persist if futures prices increase relative to the spot prices. Similar conflicting results are shown in the literature for some commodities (Wu *et al.,* 2018; Chang *et al.,* 2012).

Table 3:4.a. VECM of designated agricultural commodities.

Δy	Δx	Soybean	Corn		Wheat	
		Spot-CBOT	Spot-CBOT	Spot-Euronext	Spot-CBOT	Spot-Euronext
Δs_t	ECT_{t-1}	-0.056*** (0.015)	-0.018** (0.007)	-0.112*** (0.016)	-0.017*** (0.006)	-0.044*** (0.009)
	Δs_{t-1}	n.s.	0.206*** (0.038)	0.170*** (0.037)	0.185*** (0.038)	0.100*** (0.039)
	Δs_{t-2}				0.172*** (0.037)	0.096** (0.038)
	Δs_{t-3}					0.106*** (0.037)
	Δf_{t-1}	0.156*** (0.033)	0.094*** (0.026)	0.152*** (0.035)	0.088*** (0.016)	0.118*** (0.021)
	Δf_{t-2}				0.028* (0.016)	n.s.
	Δf_{t-3}					0.051** (0.022)
	c	n.s.	n.s.	n.s.	n.s.	n.s.
	$AdjR^2$	0.095	0.075	0.166	0.185	0.250
	$P>chi^2$	0.000	0.000	0.000	0.000	0.000
	Q	0.0744	0.2874	0.2632	0.0486	0.8178
Δf_t	ECT_{t-1}	n.s.	0.020* (0.011)	0.033* (0.020)	0.032** (0.015)	0.049** (0.024)
	Δs_{t-1}	n.s.	n.s.	0.110** (0.045)	n.s.	n.s.
	Δs_{t-2}				n.s.	n.s.
	Δs_{t-3}					0.166* (0.095)
	Δf_{t-1}	0.152*** (0.049)	0.201*** (0.039)	0.171*** (0.042)	0.226*** (0.040)	0.364*** (0.054)
	Δf_{t-2}				n.s.	n.s.
	Δf_{t-3}					n.s.
	c	n.s.	n.s.	n.s.	n.s.	n.s.
	$AdjR^2$	0.020	0.045	0.042	0.050	0.070
	$P>chi^2$	0.000	0.000	0.000	0.000	0.000
	Q	0.409	0.164	0.443	0.035	0.015

*Note: the optimal lag length was determined using the modified Akaike Information Criterion. asterisks *, **, and ***, denote level of significance at 10%, 5%, 1%. respectively. Standard errors are reported within parenthesis. Tests' statistics: Portmanteau test (Q).*

Table 3:4.b. TVECM of designated agricultural commodities.

Δy	Δx	Soybean	Corn		Wheat	
		Spot-CBOT	Spot-CBOT	Spot-Euronext	Spot-CBOT	Spot-Euronext
Δs_t	ECT^{+}_{t-1}	-0.059** (0.024)	n.s.	-0.082*** (0.028)	n.s.	-0.029* (0.017)
	ECT^{-}_{t-1}	n.s.	n.s.	-0.150*** (0.032)	-0.030*** (0.011)	-0.059*** (0.017)
	Δs_{t-1}	n.s.	0.188*** (0.038)	n.s.	0.167*** (0.039)	n.s.
	Δs_{t-2}				0.172*** (0.037)	0.096** (0.038)
	Δs_{t-3}					0.106*** (0.037)
	Δf_{t-1}	0.201*** (0.033)	0.104*** (0.026)	0.259*** (0.033)	0.099*** (0.016)	0.148*** (0.020)
	Δf_{t-2}				0.028* (0.016)	n.s.
	Δf_{t-3}					0.051** (0.022)
	c	n.s.	n.s.	n.s.	n.s.	n.s.
	$AdjR^2$	0.093	0.073	0.167	0.187	0.250
	$P>chi^2$	0.000	0.000	0.000	0.000	0.000
	Q	0.071	0.287	0.208	0.030	0.823
Δf_t	ECT^{+}_{t-1}	n.s.	n.s.	n.s.	0.055* (0.032)	n.s.
	ECT^{-}_{t-1}	n.s.	n.s.	0.078** (0.038)	n.s.	0.081* (0.044)
	Δs_{t-1}	n.s.	n.s.	0.149*** (0.047)	n.s.	n.s.
	Δs_{t-2}	n.s.	n.s.		n.s.	n.s.
	Δs_{t-3}					0.164* (0.095)
	Δf_{t-1}	0.138*** (0.048)	0.190*** (0.039)	0.140*** (0.040)	0.204*** (0.039)	0.330*** (0.052)
	Δf_{t-2}				n.s.	n.s.
	Δf_{t-3}					n.s.
	c	n.s	n.s	n.s	n.s	n.s.
	$AdjR^2$	0.018	0.0438	0.043	0.049	0.069
	$P>chi^2$	0.002	0.000	0.000	0.000	0.000
	Q	0.415	0.160	0.406	0.036	0.015

*Note: the optimal lag length was determined using the modified Akaike Information Criterion. asterisks *, **, and ***, denote level of significance at 10%, 5%, 1%. respectively. Standard errors are reported within parenthesis. Tests' statistics: Portmanteau test (Q).*

The VECM and TVECM analysis results are reported in table 3:4.a and table 3:4.b. Overall, the results are consistent across methods (EG - TAR -VECM - TVECM), confirming the presence of significant a long-run cointegrating relationship and an asymmetric adjustment between futures and spot prices. Consistency of results support the application of error correction-based inference (von Cramon-Taubadel, 1998).

The symmetric vector error correction model (tab 4.a) shows for the spot price equation (Δs_t) a positive and significant short-run effect from both the Euronext and the CBOT futures prices (Δf_t). In contrast, the futures prices equation (Δf_t) shows that the spot prices only have a significant adjustment effect for Euronext corn contracts. This implies that the causality of the relationship runs from futures to spot prices, confirming the existing literature (Brockman and Tse, 1995). Therefore, the Euronext futures contract and Italian spot prices pair show signs of bidirectional causality. The lagged coefficient of the spot prices on the futures prices equation (Δf_t) is significant, implying a feedback system (Ali and Gupta, 2011). Moreover, comparing the CBOT and Euronext short-run price transmission coefficients (corn and wheat commodity) shows a higher percentage of short-run transmission from the European futures prices. These findings are consistent with a highly liquid European futures market for the two commodities, with Euronext playing a leading role in Italian spot prices (Wu *et al.*, 2018).

Within VECM and TVECM analysis framework, the analysis of the ECT allows for the investigation of the speed of the adjustment between the two prices. Moreover, the ECT coefficients allow for examining which price moves to restore the long-run cointegrating relationship. Within the VECM framework, the ECT for the soybean spot equation is negative and statistically significant, while the counterpart ECT in the future’s equation is not significantly different from zero. This confirms that the spot prices react to restore the long-run equilibrium in the soybean markets (von Cramon-Tabaudel, 1998). These results align with the literature highlighting the leading role of the CBOT soybean futures prices (Mattos and Garcia, 2004). Instead, the corn and wheat ECT coefficients for both the CBOT and the Euronext exchanges show that both futures and spot prices move to restore the long-run equilibrium.

The asymmetric TVECM model confirms the presence of a significant short-run effect (Δs_t in the futures price equation) from futures to spot prices for all the considered prices and commodity pairs. Throughout the interpretation of positive and negative ECT coefficients, the model confirmed the presence of APT between the CBOT and Italian prices for soybean and wheat and the Euronext and Italian prices for corn and wheat. These findings provide further support to the TAR model results. TVECM results show that the negative ECT has a higher coefficient for corn and wheat prices (Euronext-Italian spot for corn and wheat and CBOT-Italian spot for wheat). In contrast, in soybean CBOT-Italian prices pairs, the positive ECT coefficient is higher (Wu *et al.*, 2018). Therefore, based on the TAR and TVECM model, a narrowing of the Euronext and Italian corn and wheat spot basis will revert faster and more fully back toward the equilibrium than an increase. Conversely, the CBOT and Italian spot basis showed positive APT. Thus after a positive shock in the basis, prices tend to revert to equilibrium more quickly.

The preponderant theory explaining the presence of negative vertical APT refers to imperfect competition, adjustment costs, inventory management, political interventions, or asymmetric information (Meyer and von Cramon-Taubadel, 2004; Santeramo and von Cramon-Taubadel, 2016). However, the asymmetric link between futures and spot prices may require a different interpretation compared to vertical asymmetric price transmission. Assuming lower futures prices with respect to the local spot prices, the narrowing of the basis of the futures-spot price would benefit short positions seeking to protect the selling prices for the physical commodity. Our results show that for corn (Euronext-Italian spot) and wheat (Euronext-Italian spot and CBOT-Italian spot), the spot prices react more fully to a negative ECT movement than to a positive one. Therefore, given the leading role of futures markets (Kuiper *et al.*, 2002; Adämmer and Bohl, 2018), an increase in the futures prices, which will strengthen the local basis, would imply a faster transmission of the shock with respect to an increase. Contrariwise, given the positive APT shown for the soybean commodity's CBOT-Italian spot prices, strengthening the local basis would imply a slower transmission of the shock with respect to an increase, thus allowing farmers to benefit more from the movement. Therefore, spot commodities pricing agents and hedgers should consider that, after a shock, corn and wheat spot prices respond more to negative variation in the basis than to an increase.

Conclusion

This paper explores the price transmission dynamics between the futures spot prices for the Italian soybean, corn, and wheat markets. The analysis confirmed a significant long-run relationship and a significant short-run effect of the futures prices on the spot prices and provided strong evidence supporting the asymmetric behaviour for all the considered commodities and markets. Furthermore, this asymmetric behaviour has been tested and confirmed in the context of an ECM, which assessed the response in the spot and futures prices to a shock to the basis. As a result, negative APT was confirmed from corn (Euronext-Italian spot) and wheat (Euronext-Italian spot and CBOT-Italian spot) markets. On the other hand, soybean price transmission (CBOT-Italian spot) showed positive APT. The agricultural spot-futures price relationship analysis has important implications for producers and buyers. The presence of negative (positive) APT will call for different strategies and timing in opening and closing the contract for negative or positive movements. The asymmetric nature of price transmission of futures contracts prices to Italian spot prices will affect the cost-effectiveness of hedging for all operators. Indeed, negative (positive) APT implies faster (slower) adjustment after a negative ECT shock, thus implying a faster (slower) transmission of a strong basis, making it less (more) beneficial for farmers.

The present analysis reinforces the findings of recent literature on the presence of asymmetric price transmission in the agricultural derivatives exchange, signalling the increasing importance of the adoption of price risk management tools. In addition to existing evidence, we show that for Italian farmers who, similarly to others within the EU, do not have access to a national derivatives exchange, futures-spot prices are cointegrated but show asymmetric behaviour. These results are of prominent importance for farmers and other operators along the agricultural commodities supply chain by providing a better assessment of the futures markets as possible instruments for Italian farmers aiming to manage price risk.

We recognize the limitation of the present study, which lies in the local nature of the spot prices, making the results specific to the Italian agricultural sector. However, given that many other European countries do not have access to a domestic derivatives market, this research is of general explorative interest for all market sharing situations. Under this point of view, further research should aim to test the presence of APT within the broader context of the European Union spot prices, helping the understanding of EU futures-spot prices transmission.

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4

Hedging Effectiveness of Commodity Futures Contracts to Minimize Price Risk: Empirical Evidence from the Italian Field Crop Sector

Abstract

Over the last years, farmers have been increasingly exposed to income risk due to the volatility of the commodities prices. Among others, hedging in futures markets (i.e., financial markets) represents an available strategy for producers to cope with income risks at farm level. To better understand the advantages of such promising tools, this paper aims at analyzing the hedging effectiveness for soybean, corn and milling wheat producers in Italy. Following the literature, three different methodologies (i.e., naïve, OLS, GARCH) are applied for the estimation of the hedge portfolio, then compared to an unhedged portfolio for assessing the income risk reduction. Findings confirm the hedging effectiveness of futures contracts for all the considered commodities, showing also that this effect increases with longer hedge horizons, and also showing better performances for the European exchange market (i.e., Euronext), compared to the North American counterpart.

Keywords

Agricultural Commodities; Futures Contracts; Hedging Effectiveness; Hedging Ratio; Time Horizon

Introduction

Since the beginning of the twenty-first century, global and domestic food prices have shown periods of high instability, during which agricultural commodities more than doubled their prices (Santeramo et al. 2018; USDA 2021). This market instability has become an important issue in the international debate (e.g., for scholars and policymakers), given its increasing effect on farmers (EPRS 2016). Price uncertainty represents one of the main risks for farmers, due to the natural time lapse between production and marketing decisions (Moschini and Hennessy 2001). In recent decades the increased price volatility, also emphasized by the COVID-19 pandemic (Höhler and Lansink 2021), inflated the general level of uncertainty in both global and domestic spot markets, making income risk a common threat for farmers (Tangermann 2011; Baffes and Haniotis 2016). According to the economic theory, this increasing uncertainty should incentivize the latent demand for risk management tools among farmers (Coletta et al. 2018).

Against this background, the European Union (EU) historically supported farmers facing risks. In particular, the most recent reforms of the Common Agricultural Policy promoted the adoption of different risk management tools, i.e., insurance, mutual funds, and the Income Stabilization Tool (De Castro et al. 2012; Frascarelli et al. 2021; Trestini et al. 2017a, 2017b). In addition to these, financial derivatives (e.g., contracts traded in financial exchanges) represent alternative instruments for farmers seeking to protect their income (EPRS 2016). Hedging with futures contracts allows farmers, or their associations, to mitigate the risk of adverse price movements by seeking to achieve delivery prices in advance (Hull 2008). So, the use of futures contracts provides a way for farmers to reduce the volatility of selling prices (Zuppiroli and Revoredo-Giha 2016), thus minimizing price risk and stabilizing income. Nevertheless, the adoption of futures contracts by farmers is still limited in Europe (Michels et al. 2019).

Like in other EU Member states, farmers in Italy cannot benefit directly from a domestic derivatives exchange. So, they resort to foreign markets for hedging purposes, as the Chicago Board of Trade (CBOT) or Euronext. Due to the imperfect correlation characterizing financial derivatives (e.g., futures prices) and domestic markets (e.g., spot prices), the evaluation of the hedging effectiveness (HE) of such financial instruments is a relevant issue. So far, the literature on HE in Italy is limited, with some rare exceptions (see for instance Stefani and Tiberti 2016; Zuppiroli and Revoredo-Giha 2016). To the best of the authors' knowledge, the research measuring the hedging effectiveness for different commodities, also comparing different markets, and considering different time horizons is scant. To contribute to the literature, this paper represents an empirical investigation aiming at understanding whether futures contracts provide a good hedge in the field crop sector in Italy. More specifically, it focuses on Italian farmers producing standardized and storable commodities, namely soybean, corn and milling wheat which show higher effectiveness in the North American markets (Yang and Awokuse 2003). The paper also compares the effectiveness of different hedging strategies, taking into consideration both CBOT and Euronext exchange markets.

Hedging with Futures Contracts

Price risk for farmers refers to their uncertainty about the expected value of returns from selling products on the market (i.e., agricultural commodities). This is mainly due to the global phenomenon of price volatility (Santeramo et al. 2018; Candila and Farace 2018). Managing income risk with futures contracts implies that a producer takes a position on a financial exchange market (e.g., CBOT or Euronext); therefore, he will have a portfolio of a combined long spot position and a short hedge position[1]. Assuming a reduction in sales prices, farmers will experience a lower income reduction by holding the opposite position in the futures market. Indeed, if the value of the hedger's spot market position decreases, the value of the hedger's return from the futures market will increase, and vice versa (Hull 2008). This hedging activity would be effective if futures and spot prices moved perfectly together, so that an increase in one euro in the spot market would imply an increase in one euro in the futures market. However, as confirmed by the literature (Trestini and Penone 2018), futures and spot prices in distant markets are not perfectly correlated. Therefore, focusing on a specific market is essential to test the amount of income reduction that hedging with futures prices grants there.

To date, a considerable amount of research focusing on derivatives' hedging effectiveness exists, for both storable and non-storable commodities (for a detailed review, see Chen et al. 2003). Research on cereals and oilseeds has been mainly applied in the North American market, where the use of futures contracts for price risk management is common among farmers (Antón et al. 2012). For instance, HE was evaluated in Ontario, measured through the stability of the basis between futures and spot prices (Carter 1984); findings supported the effectiveness in the use of the CBOT derivatives exchange to hedge price risk for both barley and corn producers in Canada. The most widespread principles for testing the effectiveness of a hedge portfolio refer to the Modern Portfolio Theory (Markowitz 1952), where portfolios of different assets are combined and examined through their mean and variance. Indeed, expected value and variance define a hedge portfolio, being the factors that would help farmers to choose between them. However, by assuming that hedgers (i.e., farmers) are infinite risk averse, thus always preferring the certain choice (Giampietri et al. 2020), the minimization of the variance of the hedge portfolio is analogous to the maximization of the producer expected utility. Thus, the application of the minimum variance hedge ratio holds for farmers (Rao 2000; Lence 1995; Chen et al. 2003). Furthermore, considering the imperfect correlation between futures and spot prices, the exact share of futures contracts used to cover a spot position (i.e., the optimal hedging ratio—OHR) should be estimated to calculate the hedge portfolio that minimizes variance. To this purpose, Ederington (1979) applied OLS regression to calculate OHR. Although it has been largely applied in literature (Lien et al. 2002; Yang and Allen 2005), the OLS model may be outperformed by conditional volatility models, as demonstrated by Chang et al. (2010) within the energy markets, or by Brooks and Chong (2001) within the currency markets. Conditional volatility models can be successfully applied (e.g., Generalized Autoregressive Conditional Heteroskedasticity model—GARCH), as in previous applications to the US cereals' production (Dahlgran 2005; Wilson et al. 2006; Bekkerman 2011).

Performing hedging on futures market implies strategies costs, including commissions paid to brokers for administrative costs and for operation and regulation of the futures exchange (Hull 2008). Moreover, costs of hedging change with respect to the complexity of the hedging strategy. Thus, these costs are not taken into consideration into this analysis due to the impracticability of applying them to the analysis. The literature identifies benefits for the hedging activities, however the magnitude of the OHR and their effectiveness vary among markets and commodities. Empirical evidence also show that the hedging horizon can affect HE, with multiple studies showing that longer time horizons result in a higher reduction in the portfolio variance (Bekkerman 2011; Conlon et al. 2016).

Previous studies applied different risk measures to the HE portfolio analysis. For instance, McKenzie and Singh (2011) applied additional risk reduction measures to analyze the effectiveness of hedging practices to limit price volatility: they evaluated the worst expected losses (i.e., Value at Risk—VaR) of an unhedged and hedged portfolio for two US wheat markets, finding considerable differences in price risk reduction between them. These reported differences strongly suggest the necessity to evaluate HE in different markets, thus encouraging this research focused on the Italian field crop sector.

Materials and Methods

This paper aims at answering to the empirical question of whether futures contracts provide a good hedge for farmers in the field crop sector in Italy. Consider a hedger with a long (short) position in the cash markets: it follows that he will take a short (long) position in the futures market to offset the risk of the spot position. Given that spot and futures prices are not perfectly correlated in Italy (Trestini and Penone 2018), the OHR (γ) for a specific objective function must be calculated. According to the minimum variance (MV) hedging approach proposed by Johnson (1960) and Stein (1976) and developed by Ederington (1979), we assume that hedgers aim at minimizing the variance of the overall portfolio.

Dataset and Hedging Horizon

The analyzed period runs from January 2007 to December 2020. The dataset consists of weekly spot prices and futures contracts' prices for three major agricultural commodities, namely soybean, corn and milling wheat (hereafter wheat), which account for more than 60% of the Italian cereals and oilseed production. The Italian spot prices for soybean corn and wheat are weekly wholesale prices listed on the Bologna market[2], which show a high connection with international futures prices (Esposti and Listorti 2013). Opposite, futures contracts' prices are retrieved from two different international exchanges: the CBOT[3] and the Euronext[4]. However, price data for soybean are retrieved only from the CBOT market, because futures contracts for this crop are not traded by the Euronext.

As suggested by Conlon et al. (2016), the effectiveness of hedging practices is deeply affected by the choice of a specific hedging (time) horizon. Indeed, essential features of financial data, such as volatility and correlations, show specific characteristics depending on the time interval used to measure price changes. With regards to the time horizon for returns, along with the hedge ratio for week-to-week (hereafter one week) changes, this research analyses changes in 4, 12, and 32 weeks. These intervals imply approximately one, three, and eight months, respectively. The literature on HE considers various time periods: for instance, some authors (Conlon et al. 2016) examined time horizons of one, three, and six months, while others (Revoredo-Giha and Zuppiroli 2013) refer to the sowing-harvesting interval. This study considers gradually increasing periods of time which, according to the authors, are well suited to farmers' needs (i.e., long growing periods for producers in the field crop sector).

The daily returns of both the futures and the spot prices were calculated as the difference between the logarithms of two consecutive prices, that is $R_t = \ln\left(\frac{P_t}{P_{t-n}}\right) * 100$, where P_t is the price at time t and n, which represents the number of weeks that we considered in our study as time horizon (i.e., one week, four weeks, 12 weeks, and 32 weeks). Thus, the dataset for each commodity consists of returns calculated:

- within each week: $R_1 = \ln\left(\frac{P_t}{P_{t-1}}\right) * 100$;
- every four weeks: $R_4 = \ln\left(\frac{P_t}{P_{t-4}}\right) * 100$;
- every 12 weeks: $R_{12} = \ln\left(\frac{P_t}{P_{t-12}}\right) * 100$;
- every 32 weeks: $R_{32} = \ln\left(\frac{P_t}{P_{t-32}}\right) * 100$.

Problems related to data overlapping can emerge when calculating the hedge ratio for longer time horizons. Analysis of non-overlapping data would result in a highly inefficient OLS regression, with low number of observations and a reduction in the information which can be collected form the data. Non overlapping data usually are accompanied by problems of autocorrelation. By contrast, greater efficiency in the estimates will result in overlapping data since no information is left out from the estimation. Following Stefani and Tiberti (2016), we applied robust standard errors to OLS regression to overcome the overlapping data problems.

Determination of the Optimal Hedging Ratio

After obtaining the returns for both spot and futures prices, the returns of the overall portfolio (i.e., composed of the spot and futures positions) are calculated by applying the OHR. Several distinct empirical methods have been developed for OHR estimation, to evaluate whether the portfolio of combined spot and futures positions is effective in reducing income risk. To do this, this paper applies and compares three different methodologies.

The first one is a fully hedge portfolio (i.e., naïve methodology), where futures position is equal in magnitude but opposite in sign to spot position (Misund and Asche 2016; Butterworth and Holmes 2001). In the naïve approach, $\gamma = 1$, and the returns of the hedge portfolio (R_{naive}) is given by:

$$R_{naive,t} = R_{S,t} - 1R_{F,t} \quad \text{(Eq. 4:1)}$$

where $R_{S,t}$ are the returns of the spot position and $R_{F,t}$ are the returns of the futures position.

However, given that futures and spot prices usually do not move perfectly together, the hedger selects $\gamma \neq 1$ to improve the hedging effectiveness (Ederington 1979). Therefore, the second approach consists of applying OLS regression to construct the following ratio (γ_{OLS}): the amount of futures contract held against one unit of the underling commodity (See Appendix A for details). In line with this, Ederington (1979) obtained γ_{OLS} according to Equation (4:2):

$$\gamma_{OLS} = \frac{cov(R_{S,t}, R_{F,t})}{var\ (R_{F,t})} \quad \text{(Eq. 4:2)}$$

where $cov(R_{S,t}, R_{F,t})$ and $var\ (R_{F,t})$ are the covariances and variances of the futures and the spot returns. The returns of the hedge portfolio are derived by Equation (4:3):

$$R_{OLS,t} = R_{S,t} - \gamma_{OLS} R_{F,t} \quad \text{(Eq. 4:3)}$$

where R_{OLS} are the returns of the hedge portfolio calculated through OLS. However, as evidenced by Chen et al. (2003), the limitation of the OLS methodology lies in the assumption that the risk in spot and futures portfolio is constant over time.

Since the returns' distribution changes over time, the OLS methodology may not precisely estimate the risk-minimizing portfolio. Following this, this paper applies a model which allows the risk to change over time. Literature shows that generalized autoregressive conditional heteroskedasticity models (GARCH) are empirically appropriate and comparable to OLS estimates. However, the risk reduction achieved over constant hedges may vary across markets and commodities (Lien et al. 2002), making the application of both OLS and GARCH meaningful (Chang et al. 2013). For the identification of γ_{GARCH}, the Bollerslev's Constant Conditional Correlation (CCC—GARCH) model was applied (Bollerslev 1990) (See Appendix A for details). Hence, the resulting conditional variances and quasicovariances were used to calculate the OHR as follows:

$$\gamma_{GARCH}|\Omega_{t-1} = \frac{cov(R_{S,t}, R_{F,t}|\Omega_{t-1})}{var\ (R_{F,t}|\Omega_{t-1})} \qquad \text{(Eq. 4:4)}$$

where $cov(R_{S,t}, R_{F,t}|\Omega_{t-1})$ and $var\ (R_{F,t}|\Omega_{t-1})$ are the time-varying covariances and variances of the futures and the spot returns conditional in the information set prior to time t. Therefore, we derive the return of the hedge portfolio according to Equation (4:5)

$$R_{GARCH,t} = R_{S,t} - \gamma_{GARCH} R_{F,t} \qquad \text{(Eq. 4:5)}$$

where R_{GARCH} are the returns of the hedge portfolio calculated through GARCH.

Each of the calculated portfolio's returns (naïve, OLS, and GARCH) is then compared with the return of an unhedged portfolio, consisting only in a spot position, to evaluate the income risk reduction granted by these three strategies.

Hedging Effectiveness

To measure the income risk reduction, for each series of calculated returns (naïve, OLS, and GARCH), this research applies a variety of different HE measures (Figure 4:1). The primary measure represents the reduction in the variance of the hedge position, compared to the unhedged position, according to Equation (4:6):

$$HE_{naive,OLS,GARCH} = \frac{Var_{unhedged} - Var_{hedged}}{Var_{unhedged}} \qquad \text{(Eq. 4:6)}$$

Moreover, the study proposes some other HE measures, specifically the Semi-Standard Deviation (SSD), the Value at Risk and the Expected Shortfall (ES) (Figure 4:1). Farmers are specifically threatened by income reduction, thus negative movement of prices. These risk measures focus on farmer's downside risk exposure, describing the left-hand side of the probability density function of risks.

Firstly, to measure the dispersion of those observations that are lower than the expected value of the variables, SSD is computed according to Equation (7) (Zinnanti et al. 2019):

$$SSD = \sqrt{\frac{\sum_{t=k}^{N} |min(X_t - \bar{X}, 0)|^2}{N}} \qquad \text{(Eq. 4:7)}$$

where *X* are the observed values of the hedge and unhedged portfolios.

Further, this analysis calculated the VaR which quantifies the extent of possible financial losses within a portfolio, offering insights on the worst potential loss over a given time interval, for a given confidence level (Jorion 2006). VaR is defined contingent on two arbitrarily chosen parameters, i.e., the horizon period of the portfolio and the confidence level, thus it is calculated as follows:

$$VaR_{\alpha}(X) = E(X) - \bar{X}_{\alpha} \qquad \text{(Eq. 4:8)}$$

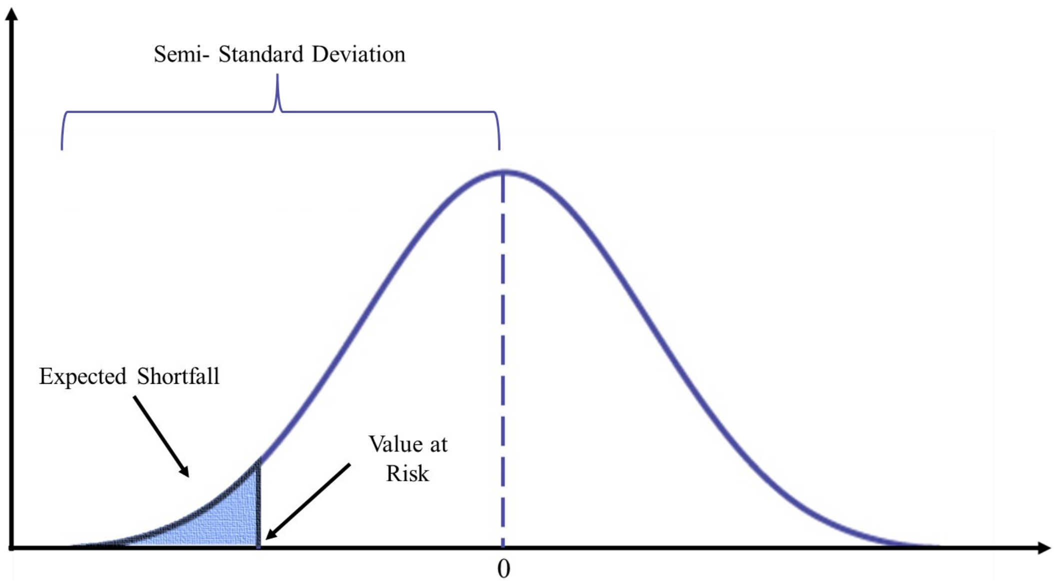
where the VaR for the confidence level α of the portfolio X is defined as the expected value of X minus the expected value of X at the confidence level α.

However, VaR only states the maximum loss if a tail event (i.e., exceeding confidence level α) does not occur, thus giving only an upper bound on the losses that occur with a given frequency (α). To improve the reading of our left tailed distribution events, we also calculated the expected shortfall (*ES*), that is defined as the expectation of all events less than VaR, as follows:

$$ES_{\alpha} = \mathrm{E}(\check{X}|\check{X} > VaR_{\alpha}) \quad \text{(Eq. 4:9)}$$

where *ES* for a certain confidence level α represents the expected value of all the intervals ($\check{X}$) that are lower than the VarR (Dowd 2007).

Figure 4:1. Probability density function of risks and measures of hedging effectiveness.



Results and Discussion

Table 4:1 provides the descriptive statistics and the preliminary stationarity analysis for farmers portfolio returns. The stationarity tests (i.e., Augmented Dickey-Fuller test and Phillips-Perron test) confirm that the null hypothesis of a unit autoregressive root can be rejected for all the considered commodities and time horizons, so that all the considered returns are found to be stationary.

Table 4:1. Returns descriptive statistics and stationarity tests.

		Time Horizon (n. of Weeks)	N. of Obs.	Mean	St. Dev.	Min	Max	ADF t-Stat	PP t-Stat
Italian spot	Soybean	1	750	0.11	2.06	−9.84	8.23	−12.66 ***	−22.27 ***
		4	747	0.45	5.02	−18.41	17.14	−7.32 ***	−9.09 ***
		12	739	1.28	9.86	−35.31	25.11	−5.95 ***	−22.27 ***
		32	719	2.72	16.51	−44.02	48.95	−3.65 ***	−29.50 ***
	Corn	1	750	0.06	2.40	−19.01	23.52	−15.92 ***	−21.25 ***
		4	747	0.24	5.87	−27.52	26.44	−10.29 ***	−9.01 ***
		12	739	0.59	11.57	−50.94	38.26	−5.63 ***	−4.80 ***
		32	719	1.00	19.65	−60.50	44.58	−3.19 *	−2.56
	Wheat	1	750	0.04	1.53	−8.61	12.40	−9.26 ***	−19.96 ***
		4	747	0.16	4.19	−16.54	21.01	−6.66 ***	−7.73 ***
		12	739	0.46	9.16	−32.40	39.02	−6.11 ***	−4.37 ***
		32	719	0.93	17.81	−40.86	60.09	−4.20 ***	−2.58
CBOT	Soybean	1	750	0.12	2.82	−14.68	8.71	−17.08 ***	−22.76 ***
		4	747	0.47	6.47	−22.97	21.00	−13.40 ***	−10.53 ***
		12	739	1.27	11.28	−33.33	28.92	−6.54 ***	−5.77 ***
		32	719	2.84	17.19	−39.96	49.51	−3.81 **	−3.37 *
	Corn	1	750	0.09	3.42	−21.72	12.90	−17.83 ***	−22.63 ***
		4	747	0.35	7.84	−28.31	31.48	−8.00 ***	−10.08 ***
		12	739	0.80	13.64	−40.40	38.37	−5.81 ***	−5.40 ***
		32	719	1.85	22.48	−58.40	62.67	−3.19 *	−2.91
	Wheat	1	750	0.06	3.61	−12.67	16.04	−17.59 ***	−22.68 ***
		4	747	0.27	8.19	−30.00	35.96	−8.32 ***	−10.28 ***
		12	739	0.72	13.30	−45.99	44.79	−7.06 ***	−6.13 ***
		32	719	1.48	20.73	−65.11	61.88	−4.46 ***	−4.10 ***
Euronext	Corn	1	750	0.06	2.58	−24.86	11.96	−17.52 ***	−21.99 ***
		4	747	0.22	6.02	−29.18	19.34	−11.78 ***	−9.90 ***
		12	739	0.57	11.15	−44.40	30.42	−5.57 ***	−5.15 ***
		32	719	0.88	18.57	−53.89	47.39	−3.40 **	−3.24 *
	Wheat	1	750	0.05	2.81	−13.98	17.50	−17.12 ***	−20.83 ***
		4	747	0.21	6.85	−26.71	33.40	−7.38 ***	−9.32 ***
		12	739	0.63	12.68	−43.56	56.67	−6.39 ***	−5.48 ***
		32	719	1.32	22.42	−68.81	72.90	−3.72 **	−3.27 *

*Note: the table reports different descriptive statistics for the analyzed series. ADF t-statistics stands for the Augmented Dickey-Fuller test for the presence of a unit root (Dickey and Fuller 1979). PP t-statistics stands for the Phillips-Perron test for the presence of a unit root (Phillips and Perron 1988). ***, ** and * indicate the level of significance at the 1%, 5% and 10% level, respectively.*

As a first step in the analysis of the HE of futures contracts for agricultural commodities, the amount of futures contracts that need to be shortened against the farmer's natural long position in the cash market (OHR) needs to be evaluated. Table 4:2 reports the estimated OHR (γ). The naïve hedge ratio ($\gamma_{naive} = 1$) means that one futures contract position is upheld for each spot position, thus it does not change over the time horizon. Conversely, OHR estimates from OLS (γ_{OLS}) and GARCH (γ_{GARCH}) show comparable results consistently changing with the hedge horizon. For all the considered commodities, the estimated OHR increases with longer time horizons, as reported by the literature (Chen et al. 2003; Juhl et al. 2012).

Among the selected commodities, the returns for soybean (i.e., Italian soybean spot prices and the CBOT futures prices) show the higher one-week OHR and a steady increase of the estimated parameter through the hedging horizon. All the considered estimates show a similar pattern, with the Italian spot-Euronext futures corn prices showing the highest OHR estimates at 32-weeks period. Indeed, for the aforementioned prices (soybean and corn), the longer the hedging horizon, the closer the OHR is to the naïve hedge ratio (i.e., HR=1).

Compared with the results on the US commodity market, the estimated OHR is lower for all the considered commodities (Chen et al. 2003; Bekkerman 2011). However, since US farmers have access to a domestic derivatives exchange (i.e., CBOT), the existence of a stronger connection between futures and spot prices and thus a higher OHR is not surprising (Conforti 2004). As regards the wheat market, the OHR estimates are comparable to what shown by previous studies in Italy (Revoredo-Giha and Zuppiroli 2013; Stefani and Tiberti 2016).

Table 4:3 reports the income volatility reduction (%) (i.e., the variance of the portfolio) granted by the hedging activity for the data sample. Confirming the literature on the European durum wheat and the US corn sector, the effectiveness of the hedging activity in reducing income risk for farmers increases when the considered hedging horizon is extended (Zuppiroli and Revoredo-Giha 2016; Conlon et al. 2016).

Table 4:2. Estimates of the Optimal Hedging Ratio for all the considered commodities.

		Time Horizon (n. of Weeks)	γ_{OLS}	γ_{GARCH}
Italian spot-CBOT	Soybean	1	0.449	0.461
		4	0.565	0.586
		12	0.710	0.730
		32	0.864	0.809
	Corn	1	0.140	0.130
		4	0.294	0.327
		12	0.438	0.454
		32	0.524	0.668
	Wheat	1	0.093	0.094
		4	0.238	0.225
		12	0.420	0.253[A]
		32	0.660	0.678
Italian spot-Euronext	Corn	1	0.304	0.263
		4	0.652	0.651
		12	0.866	0.809
		32	0.952	0.966
	Wheat	1	0.185	0.189
		4	0.370	0.361
		12	0.540	0.565
		32	0.689	0.706

Note: the table reports the optimal hedging ratio calculated according to Equation (4:2) (γ_{OLS}) and to Equation (4:4) (γ_{GARCH}) (the naïve optimal hedging ratio is not reported as γ is always equal to 1). [A] The optimal hedging ratio was calculated according to DVECH model by Bollerslev et al. (1988), due to the lack of convergence of the CCC-GARCH model for this set of futures and spot prices.

First, by comparing the naïve hedging strategy with the strategies that consider the correlations among the set of prices (OLS and GARCH), it is possible to notice some differences. Indeed, the results from the naïve hedging strategy for a short hedge horizon increase the income risk for farmers (see negative values in Table 4:3). For example, the one-week hedge for soybean indicates that the variance of the naïve return portfolio increases by 20% with respect to the unhedged portfolio. Regarding all the selected commodities, the naïve HE for smaller time horizons results in an increase of the portfolio volatility.

Considering the correlation among set of prices is relevant to improve the hedging effectiveness of the farmers portfolio. In line with previous studies (Chang et al. 2013, the OLS and GARCH methodologies share similar results in terms of HE (i.e., amount of income variance reduction). Mixed literature results brought us to the analysis of both OLS and GARCH methods. In the hedging effectiveness analysis, the research shows that OLS performs better than GARCH in some cases, and vice versa (Lien et al. 2002). The results of our analysis confirmed that there is no clear cut among the two models in term of performance of the hedging activities.

Compared to soybean, both corn and wheat futures contracts with the shorter time horizon (one-week hedge) ensure a smaller reduction in the farmer's portfolio volatility, for both Euronext and CBOT. As expected, HE (for both OLS and GARCH) increases with longer time horizons, for all the selected commodities.

Moreover, regarding all the considered hedge horizons, Italian farmers can better hedge their income risk by resorting to Euronext futures contracts, compared to CBOT. For instance, corn producers hedging with Euronext futures contracts (32-weeks hedge) can reduce their income risk (i.e., they reduce the returns variability) by 81% (OLS), compared to with CBOT futures contracts (35%). Similarly, for the wheat commodity a 32-weeks hedge with a CBOT futures contract can reduce income volatility by 59%, compared to Euronext (75%). These results confirm the evidence from Stefani and Tiberti (2016) on the better hedging performance of Euronext futures contracts, respect to CBOT, and highlight the advantages linked to long time horizons.

These results are encouraging for the developing of futures contracts in the European Union. Indeed, farmers facing income risks have been found to increase the use of contracts for managing price risks (Ricome and Reynaud 2021). Moreover, futures contracts' efficiency within the EU can be helpful for the spread of different financial derivatives instruments (Harčariková 2018).

Table 4:3. Hedging Effectiveness through variance reduction, for all the considered commodities.

		Time Horizon (n. of Weeks)	Variance		
			γ_{naive}	γ_{OLS}	γ_{GARCH}
Italian spot-CBOT	Soybean	1	−0.207	0.377	0.377
		4	0.217	0.531	0.531
		12	0.549	0.660	0.659
		32	0.788	0.808	0.805
	Corn	1	−1.464	0.038	0.038
		4	−0.761	0.145	0.143
		12	−0.178	0.264	0.264
		32	0.051	0.353	0.324
	Wheat	1	−4.492	0.049	0.049
		4	−1.998	0.218	0.217
		12	−0.334	0.372	0.314
		32	0.433	0.591	0.590
Italian spot−Euronext	Corn	1	−0.456	0.105	0.103
		4	0.310	0.440	0.440
		12	0.678	0.695	0.692
		32	0.805	0.808	0.808
	Wheat	1	−2.097	0.116	0.116
		4	−0.700	0.367	0.366
		12	0.155	0.561	0.559
		32	0.597	0.752	0.752

Note: the table reports the amount of the hedged portfolio variance reduction (hedging effectiveness) with respect to an unhedged portfolio. Increases in the hedge portfolio variance are depicted by negative numbers, while decreases by positive ones. Hedging effectiveness values are produced through the three different methodologies used for calculating the optimal hedging ratio, that are the naïve, OLS and GARCH.

In the literature on risk management, hedging effectiveness has been commonly measured through the variance reduction of the hedge portfolio, and compared to the unhedged portfolio (Chen et al. 2003). However, also different risk indexes can be used. Indeed, variance analysis is a simplified measure of risk analysis, because it only measures the distribution width: the wider the distribution, the higher the income risk for farmers, given the broad range of potential outcomes. However, according to some authors (see for instance Monjardino et al. 2013) the analysis of variance reduction can only partly represent the actual income risk faced by farmers. Following this, this paper applies also different risk measures, namely SSD, VaR, and ES, according to Equations (4:7)–(4:9). These indexes examine the left side of the distribution, thus evaluating the reduction of unfavorable outcomes granted by hedging practices. As shown in Table 4:4, the different risk measures overall confirm the results of the variance reduction analysis. The naïve optimal hedging ratio brings worst results, while the OLS and GARCH estimation brings similar results. Moreover, for the all the considered measures of risks, it is confirmed that HE increases with longer hedges. The effectiveness of hedging in reducing the volatility of the left side of the distribution (SSD) confirms that hedging reduces the risk of negative outcomes. For example, corn farmers that hedge their income risk with Euronext futures contracts show an SSD reduction up to 87%. Similarly, focusing on the left tail of the distribution, both VaR and ES confirm HE for all the considered strategies calculated through OLS and GARCH. Thus, hedging with futures contracts not only reduces the variability of the return portfolio, but it also reduces the risk of high losses (i.e., left side of the return distribution) for soybean, corn, and wheat producers (Luo et al. 2017).

Table 4:4. Estimates of the Hedging Effectiveness through risk indexes, for all the considered commodities.

		Time Horizon (n. of Weeks)	SSD			VaR			ES		
			γ_{naive}	γ_{OLS}	γ_{GARCH}	γ_{naive}	γ_{OLS}	γ_{GARCH}	γ_{naive}	γ_{OLS}	γ_{GARCH}
Italian spot-CBOT	Soybean	1	0.219	0.415	0.419	−0.043	0.247	0.242	0.013	0.209	0.210
		4	0.339	0.536	0.537	0.231	0.370	0.377	0.148	0.303	0.306
		12	0.472	0.547	0.545	0.147	0.321	0.296	0.254	0.324	0.322
		32	0.688	0.722	0.726	0.431	0.517	0.541	0.483	0.510	0.514
	Corn	1	−0.565	0.190	0.192	−0.970	0.046	0.047	−0.499	0.027	0.026
		4	−0.404	0.077	0.071	−0.292	0.127	0.139	−0.219	0.077	0.079
		12	0.374	0.345	0.354	−0.057	0.192	0.171	0.148	0.149	0.151
		32	0.209	0.302	0.321	−0.116	0.044	0.004	0.089	0.185	0.204
	Wheat	1	−2.001	0.403	0.404	−2.072	0.013	0.013	−1.385	0.034	0.034
		4	−1.820	0.334	0.327	−0.952	0.073	0.067	−0.832	0.108	0.105
		12	−0.550	0.364	0.306	−0.315	0.217	0.175	−0.256	0.196	0.149
		32	0.274	0.529	0.528	0.072	0.267	0.261	0.167	0.332	0.329
Italian spot-Euronext	Corn	1	−0.039	0.213	0.216	−0.255	0.096	0.089	−0.132	0.068	0.062
		4	0.334	0.372	0.372	0.188	0.287	0.287	0.179	0.243	0.243
		12	0.803	0.782	0.765	0.444	0.432	0.412	0.525	0.505	0.488
		32	0.878	0.871	0.874	0.567	0.555	0.554	0.644	0.632	0.636
	Wheat	1	−0.335	0.527	0.528	−1.258	0.088	0.081	−0.686	0.095	0.096
		4	−0.010	0.622	0.620	−0.426	0.159	0.160	−0.323	0.204	0.203
		12	0.334	0.620	0.619	−0.105	0.263	0.241	0.007	0.272	0.270
		32	0.490	0.590	0.590	0.238	0.391	0.381	0.283	0.409	0.409

Note: the table reports the hedging effectiveness measured according to Equation (4:6), with different indexes as the Semi-Standard Deviation (SSD), the Value at Risk (VaR) and the Expected Shortfall (ES).

Conclusions

Nowadays, farmers' income is increasingly at risk, and this is mainly due to the volatility of the commodities' selling prices and to the reduction of EU direct support to farmers. This increased uncertainty has been exacerbated by COVID-19 pandemic, which has strongly influenced agricultural prices, being also expected to affect agricultural markets and farmer incomes over the next decade (Elleby et al. 2020; OECD 2020; Ezeaku et al. 2021).

Generally, price fluctuations have a detrimental impact on farmers' incomes and thus to their viability in the long term. In the prospect of low prices, futures contracts represent instruments to tackle the price and income volatility for farmers, particularly providing the possibility to lock-in delivery prices in advance. Hedging strategies especially apply to farmers which do not participate in contact farming with production quality schemes, for which output prices may diverge from market prices.

The opening of a futures contract throughout a brokerage service to hedge harvesting prices will subsequently imply the closing of the contracts around contract expiration. Conversely to the outcome on the cash market, the derivatives exchange will have gain/loss in farmer money (Hull 2008). The effectiveness of these hedging practices for farmers depends on the connection that futures and spot markets exhibit.

Given the lack of a domestic derivatives exchange for Italian farmers, the current study provides interesting insights for European farmers, as it shows the effectiveness of hedging with futures contracts to reduce income risk. In particular, the analysis focused on soybean, corn and milling wheat prices, providing evidence on futures contracts' hedging effectiveness for the mitigation of farmers' income risk. The considered Italian spot prices are hedged against two futures markets, i.e., CBOT and Euronext. Moreover, three different methodologies are used to calculate the optimal number of futures contract that an Italian farmer must open to hedge his spot position: i.e., the naïve methods, in which the farmer is assumed to fully hedge his position, and the OLS and GARCH methodologies, which consider the relationship between spot and futures prices. Moreover, given the importance of the length of the hedge for the reduction of income volatility, four different hedging horizons (i.e., one week, four weeks, 12 weeks, and 32 weeks) are considered. Finally, the portfolio of a farmer which does not hedge its spot position is compared to a farmer's portfolio composed by both spot and futures positions.

Findings confirm that hedging strategies can be useful for farmers involved in the field crop sector in Italy for the reduction of output price volatility. Our results show positive evidence for the OHR estimates, calculated throughout the OLS and GARCH methodologies, in ensuring HE for all the considered commodities. Contrariwise, the naïve hedging strategy for the calculation of the OHR subsequentially brings to an increase in the farmers portfolio volatility at low hedge horizons. This aligns with the part of the literature on hedging effectiveness according to which the best performance is obtained by models that take into consideration prices correlation (Conlon et al. 2016). Confirming literature, results on the effectiveness of hedging for different commodities show, transversely to all examined commodities, that the OHR increases with longer hedge horizons (Zuppiroli and Revoredo-Giha 2016). Among the analyzed commodities, results for corn and wheat producers confirm that the Euronext futures contracts grant a higher reduction of income volatility for farmers, resulting in the best hedging strategy, compared to CBOT. However, this latter shows a comparable HE for soybean, providing interesting insights for Italian farmers which cannot benefit from a European soybean futures contract. Finally, our results show how hedging strategies consistently reduce the negative outcome for farmers. Indeed, for all the considered commodities, the indexes chosen for the description of the left-hand side of the distribution and the worst-case scenarios (Dowd 2007) confirmed that hedging strategies reduce the probability of a negative income, compared to the unedged portfolio.

Regarding hedging practices, a common issue relates to the impact of transaction costs in the overall hedging profitability for farmers. However, given that data on these costs remain unavailable, the following analysis cannot take this aspect into account, representing a limit of the current study. Nevertheless, transaction costs are usually assumed to be fixed within a small-time frame, thus they may not impact on the hedging efficiency. For future research, the inclusion of the costs of hedging would improve the analysis of futures contracts' HE in the agricultural sector.

To conclude, given that most European farmers continue to suffer a high-income volatility, further analysis could analyze HE at European level, to highlight potential analogies and differences among countries.

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APPENDIX 4:A

For the identification of γ_{OLS}, the OLS equation is constructed as follows:

$$r_{s,t} = \alpha + \beta r_{f,t} + \varepsilon_t \qquad \text{(Eq. 4:A1)}$$

In Equation (4:A1) $r_{s,t}$ are the return of the spot position at time t, $r_{f,t}$ are the return on the futures contract at period t, ε_t is the error term at time t, α is the constant included in the model, and β is defined as follows:

$$\beta = \frac{Cov(r_{s,t}, r_{f,t})}{Var(,r_{f,t})} \qquad \text{(Eq. 4:A2)}$$

In Equation (4:A2) $Cov(r_{s,t},r_{f,t})$ is defined as the covariance between the spot returns and the futures returns and $Var(r_{f,t})$ is the variance of the futures returns. Thus, $\beta = \gamma_{OLS}$.

For the identification of γ_{GARCH}, it has been applied the Constant Conditional Correlation Generalized Autoregressive Conditional Heteroskedastic model of Bollerslev (1990), which can be written as:

$$y_t = Cx_t + \varepsilon_t \qquad \text{(Eq. 4:A3)}$$

$$\varepsilon_t = H_t^{1/2} v_t \qquad \text{(Eq. 4:A4)}$$

$$\varepsilon_t = H_t^{1/2} v_t \qquad \text{(Eq. 4:A5)}$$

where y_t is a vector of dependent variables and x_t is a vector of independent variables. $H_t^{1/2}$ is the Cholesky factor of the time-varying conditional covariance matrix H_t and v_t is a vector of normal, independent, and identically distributed innovations. D_t is a diagonal matrix of conditional variances as in:

$$D_t = \begin{pmatrix} \sigma_{1,t}^2 & 0 & \cdots & 0 \\ 0 & \sigma_{2,t}^2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \sigma_{m,t}^2 \end{pmatrix} \qquad \text{(Eq. 4:A6)}$$

in which each $\sigma_{i,t}^2$ evolves according to a univariate GARCH model of the form:

$$\sigma_{i,t}^2 = \zeta_1 + \sum_{i=1}^{p_i} \alpha_j \varepsilon_{i,t-j}^2 + \sum_{j=1}^{q_i} \beta_j \sigma_{i,t-j}^2 \qquad \text{(Eq. 4:A7)}$$

Finally, R_t is a matrix of time-invariant unconditional correlations of the standardized residuals $D_t^{-1/2}\varepsilon_t$

$$R_t = \begin{pmatrix} 1 & \rho_{12,t} & \cdots & \rho_{1m,t} \\ \rho_{12,t} & 1 & \cdots & \rho_{2m,t} \\ \vdots & \vdots & \ddots & \vdots \\ \rho_{1m,t} & \rho_{2m,t} & \cdots & 1 \end{pmatrix} \qquad \text{(Eq. 4:A8)}$$

5

Analysing farmers' intention to adopt marketing contracts as an innovative strategy to tackle income risk at the farm level

Abstract

As a result of the ongoing market orientation of the Common Agricultural Policy (CAP) and the increasing market volatility, farmers producing commodities are increasingly exposed to price risk. Among the numerous marketing and risk management tools, marketing contracts have been shown to be an effective means for farmers to reduce risks related to market and production shocks. Being common in both developed and developing countries, the spread of marketing contracts appears heterogeneous and generally scarce in Europe and Italy. To facilitate the adoption, it is important to understand farmers' intention to be involved in agricultural contracts. To this purpose, this paper examines farmers' decision to be involved in marketing contracts as an innovative strategy to tackle income risk at the farm level. In particular, the analysis focuses on producers of arable crops in Italy. An adapted Technology Organisation Environmental model merged with a Technology Acceptance Model has been estimated based on an online survey with 84 Italian farmers. Findings confirm the importance of marketing contracts' perceived compatibility with the farm's production characteristics. Moreover, the intention to participate in marketing contracts is higher when both the farm owner is in favour, and the buyers encourage the adoption of these tools.

Keywords

Adapted Technology Acceptance & Technology Organisation Environment Model, Hedging, Agricultural Commodities, Italian farmers, Price risk management

Introduction

In the last twenty years, agricultural commodity prices have shown periods of high instability, as evident from the 2006/2008 price increase (Baffes and Haniotis, 2010) and the following 2011 spikes (Tadesse et al., 2014). Similar increases are registered today in European and International markets (USDA, 2021). Further, the ongoing COVID-19 crisis is expected to affect economies over the next decades (Coibion et al., 2020), inflating price volatility and strongly influencing agricultural prices worldwide (Elleby et al., 2020). So, nowadays, European farmers are threatened by great uncertainty over their income. Until the end of the last century, the European Union used to effectively protect farmers' income against world commodity prices fluctuations through direct price support financed by the Common Agricultural Policy (CAP). Then, as a consequence of the progressive switch from direct support policies to direct payment schemes within the CAP, interest in risk management instruments has emerged, albeit slowly, among European farmers (Giampietri et al., 2020).

Farmers can protect their income in different ways, e.g. by adopting farm level self-copying strategies (i.e., crop diversification, farm's financial management and informative marketing of the products) or specific instruments such as insurances, mutual funds, and the income stabilisation tool, and finally hedging instruments as agricultural contracts (i.e., forward contracts, futures contracts). Among European producers, the adoption of risk management strategies is fairly widespread (De Castro et al. 2012; Frascarelli et al. 2021; Trestini et al. 2017a, 2017b), except for financial instruments, such as agricultural contracts, of which the adoption is still very limited (Michels et al., 2019; Solazzo et al., 2020).

Generally speaking, agricultural contracts (or contract farming) represent an agreement between the farmer and the buyer (i.e., storage centre, farmers' cooperatives or consortia) to sell the product before the commodity is ready to be marketed, thus providing a chance to mitigate income risk for the farmer (Kirsten and Sartorius, 2002). In practice, contract farming assumes many different nuances, but generally, it has been confirmed a useful practice for farmers' welfare (Bellemare, 2012) and income stabilisation (Wilson and Dahl, 2009; Penone et al., 2021). Nevertheless, the adoption rate remains low in Europe and Italy, spurring the investigation on the drivers of farmers' adoption of such innovative tools at the farm level is of significant interest.

Agricultural contracts adoption studies have recently been developing in Europe due to the proven efficacy and the low adoption rate. Most of the literature links the adoption of agricultural contracts to farmers and farm characteristics (demographics, size and risk profile) (Roussy et al., 2018; Ricome and Reynaude, 2021), showing how to use agricultural contracts increases when farmers' price risk exposure increases and when farmers' price expectations are lower. Interestingly, Michels et al. (2019) implemented an adoption decision framework, namely the technology acceptance model (TAM), for the analysis of the factor influencing farmers' adoption of futures contracts (a specific type of agricultural contract).

Adoption decisions framework is widely applied in the agricultural sector for the analysis of innovation adoption by farmers, for the study of agricultural information technology adoption by farmer cooperatives (Wang et al., 2014), and for the exploration of the factors affecting the intention to adopt web marketing (Giampietri and Trestini 2020). Thus, given the novelty that agricultural contracts represent for European farmers (Michels et al., 2019; Solazzo et al., 2020), the application of an innovation adoption framework is a relevant scientific question.

Given the above, as a novel contribution, this study focuses on investigating the behavioural drivers of farmers' intention to participate in contract farming practices in Italy under the lens of an innovation adoption theoretical framework, namely an adapted TOE-TAM model. For the estimation, we used a partial least squares structural equation model (PLS-SEM), consistently with the literature.

Background

Literature on contract farming

Broadly speaking, agricultural contracts, or contract farming, is a practice that essentially involves an agreement between a producer and a buyer. However, many different forms of contract farming exist. Worley and McCluskey (2000) identified three types of contract farming: marketing contracts, production management contracts, and production contracts with provided input. These contracts diversify according to the degree of controls imposed on the farmer. Thus, marketing contracts (MC) can be defined as a verbal or written agreement between a producer and a buyer that defines a price for a specified quality and quantity of a commodity before harvest or before the commodity is ready to be marketed (Harwood et al., 1999). The farmers remain in charge of all productive decisions and input supply. Marketing contracts are more common in the arable sector and are linked to the concept of price risk management (Ricome and Reynaude, 2021). Contrarily, production management contracts and production contracts with given input also involve an agreement for the sales of the commodity and involve the provision of technical support by the contractor (for the first) and all the inputs for the production (for the second). In this type of contract, farmers are not entrepreneurs but get paid for service (Solazzo et al. 2020). Additionally, other forms of contract farming have been depicted by literature, especially for perishable crops that need a high degree of processing (coffee, oil palm, tea, oranges) (Vamuloh et al., 2019). In these cases, contract farming is seen as a vertical coordination method with companies holding the land in which farmers operate or joint ventures between farmers and local governments. Another standardised agricultural contract is the futures contract, a hedging strategy that does not require the presence of a local buyer but by which farmers can effectively reduce price risk (Penone et al., 2020). Hedging with futures contracts requires opening a financial position on a derivatives exchange, and there is little to no evidence of futures contract use in Europe and Italy (Michels et al., 2019). Thus, given that literature reveals a dislike for constraints from farmers (Solazzo et al., 2020) and given that the analysis of an unknown instrument (futures contracts) would require different methodologies, this article examined the form of contract farming that imposes less restriction to the farmer, i.e., marketing contracts.

Agricultural contracts are not widely used in Europe (Michels et al., 2019) and in Italy (Solazzo et al., 2020); thus, identifying the factor influencing the adoption of these instruments represents an interesting question for researchers. On a broad spectrum, marketing contracts adoption has been linked to three main categories of factors: the farmer demographic characteristics, the farm structure and the farmers' risk profile (Vamuloh et al., 2019). Demographic characteristics (age, education and experience) report the most heterogeneous results regarding adoption (Goodwin and Schroeder, 1994; Reynaud and Ricome, 2010). Instead, the farm's size in hectares and its capital structure (high level of debt to asset ratio) are constantly positively correlated with the adoption of marketing contracts (Pennings et al., 2008; Sartwelle et al., 2000; Shapiro and Brorsen, 1988). As for the farmers' risk profile, studies confirmed the relevance within North

American farmers (Goodwin and Schroeder, 1994; Sartwelle et al., 2000; Pennings et al., 2008; Franken et al. 2012; Franken et al., 2014; Coffey and Schroeder, 2019). As for European farmers, studies on what influences the adoption of agricultural contracts as risk management tools are limited. Pennings and Leuthold (2000) and Pennings and Garcia (2004) examined the impact of farmers' behavioural attitudes toward adopting futures contracts within the Dutch hog industry. Risk aversion and perceived risk exposure are positively related to futures contracts usage. Moreover, a positive influence on futures contract adoption is also found for the interaction between risk aversion and perceived risk, implying a higher adoption of futures contracts if the farmer perceives more risk (Pennings and Garcia 2004). This is also confirmed by Ricome and Reynaud (2021), according to whom French cereal farmers' probability of using marketing contracts increases when price risk exposure increases and when farmers' price expectations are lower. As for Italian farmers, studies are scant. Solazzo et al. (2020) investigated the factors affecting farmers' behaviour in adopting production management contracts within the Italian durum wheat supply chain, highlighting the low frequency of contract adoption among farmers. Italian farmers' preference for spot market sales for their production prompts the analyse of the behavioural factor affecting the decision to adopt CF within innovation adoption frameworks.

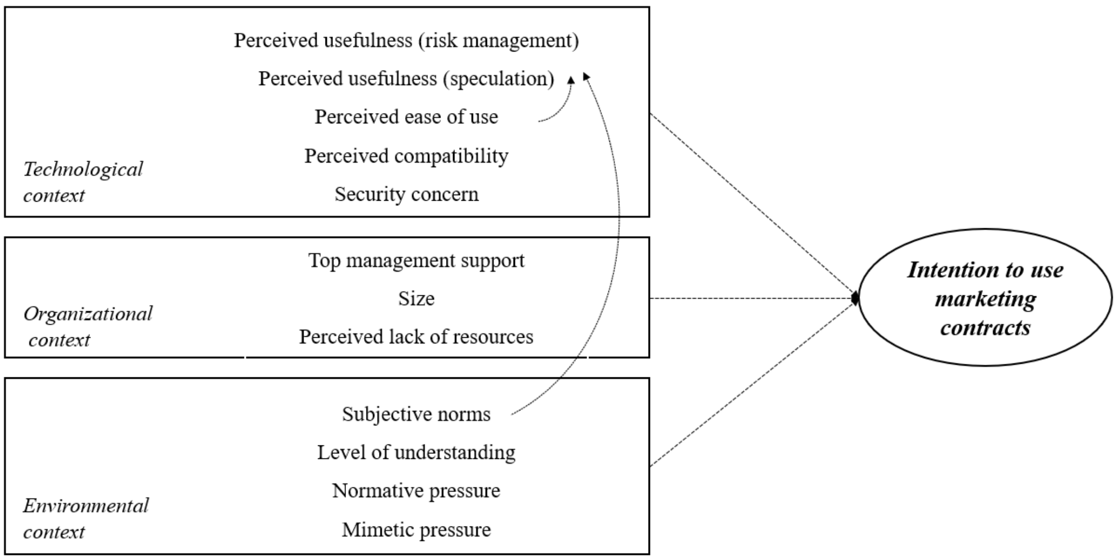
Theoretical background

Decision on adopting an innovation (e.g., new technologies or new strategies) at the firm level is a necessary part of the farming activity (Kumar and Joshi, 2014). Various theoretical frameworks have been developed for the understanding of innovation adoption behaviour in an organization. Among them, there are the theory of reasoned action (TRA), the theory of planned behaviour (TPB), the innovation diffusion theory, the decision maker-technology-organization-environment, the technology acceptance model (TAM) and the technology-organization-environment (TOE). The technology-organisation-environment (TOE) framework developed by Tornatzky and Fleisher (1990) hypothesises that three factors' categories affect the intention to adopt. First, the technological context (TC) represents the internal and external factors that can influence the adoption. Second, the organisational context (OC) includes the firm's characteristics, such as the leader's opinion or the readiness to adopt the innovation. Lastly the environmental context (EC) concerning the role of policy, competitors, trading partners and customers. The major barrier of TOE application to farmers is that some of the constructs in the adoption predictors are assumed to apply more to large organizations (Awa et al., 2014). However, the adaptation of the construct to the specific sector (Michel et al., 2019) allows for meaningful and interesting results. Another relevant framework is the technology-acceptance model (TAM) (Davis, 1989). According to TAM, the decision regarding the adoption of an innovation is determined by the perceived usefulness (PU), and the perceived ease of use (PEOU) linked to the innovation. Both TOE and TAM frameworks have been extensively applied in small and medium enterprises (SMEs) research. Regarding the agricultural sector, so far, TOE has been applied to explain farmer cooperatives' adoption of agricultural information technology (Wang et al., 2014) and farmers' adoption of web marketing (Giampietri and Trestini, 2020). Similarly, the TAM model has been recently applied to understand farmers' intention to use commodity futures contracts for German farmers (Michel et al., 2019). Interestingly, mixed models were recently applied to study the adoption of enterprise resource planning systems to increase the efficiency of agricultural activities in Brazil (Junior et al., 2019). TAM model alone provides less meaningful information on the farmers' opinions about adopting specific innovation by narrowing its constructs to only perceived usefulness and perceived ease of use. Hence, as performed by other researchers (Davis, 1993; Venkatesh and Davis, 2000), the need to expand the factors or integrate with other innovations acceptance models to improve TAM's explanatory and predictive utilities, brought to the development of the adapted TAM-TOE model. Both models allow for understanding the drivers of farmers in decisions regarding innovation adoption, allowing for an interesting specific analysis of each farmer's behaviour. The application of mixed TAM-TOE and other theories regarding the decision to adopt an innovation, which is carried out in SMEs literature (Gangwar et al., 2013; Awa et al., 2017; Bryan and Zuva, 2021), supported the choice to implement the TOE framework with TAM components within an adapted TOE-TAM framework for the analysis of farmers' intention regarding marketing contracts adoption in this study.

Research model and hypothesis

The adapted TOE-TAMs analyses how the technological, organisational, and environmental contexts affects farmers' intention on adopting marketing contracts. The latent variables and the wording of the indicators are based on the literature and subsequently adapted to the research context to investigate the factors influencing contracts adoption among farmers in our sample (Figure 5:1 and Table 5:1).

Figure 5:1. Indicators structural map.



Note: qualitative map of the adapted TAM-TOE model

First, the intention to use (IU) agricultural contracts derive from three different indicators. As regards the technological context, constructs were adapted from the literature (see Michels et al., 2019; Junior et al., 2019; Giampietri and Trestini, 2020). First, to analyse the extent to which the farmer perceives that the innovation is able to enhance the performances of the farm, the perceived usefulness (PU) of marketing contracts has been investigated through three different indicators. In particular, following Michels et al. (2019), the study measured PU through three indicators ($pu1_{1\text{-}3}$ – latent variable PU1) regarding the farmer perception of contacts as a useful tool to reduce price risk (hedging purpose), and three indicators ($pu2_{1\text{-}3}$ – latent variable PU2) regarding the farmer perception of contracts as a useful tool to enhance price (speculative purpose). Both PU1 and PU2 latent variables are expected to influence IU positively. The literature also stresses the importance of the perceived ease of use (PEOU) as a positive influence on an individual intention to adopt a specific innovation (Davis, 1989). Thus, all else being equal, it is expected that the easier the farmers perceive the use, the more likely they are to adopt this risk management practice. Similarly, given that the literature reports that the lack of compatibility (CP) of the innovation with the farm infrastructure and management could generate limits on the adoption of that innovation, it is assumed that the more marketing contracts are perceived as compatible with the farms' characteristics, the more it would influence their adoption at farm level (Junior et al., 2019). Moreover, previous research suggests a lack of trust in marketing contracts, thus making the analysis of farmers' security concerns (SC) very relevant. Adapting SC indicator from the literature on e-commerce and web marketing adoption (see Schaupp and Carter, 2008; Giampietri and Trestini, 2020), the perceived risk related to the non-fulfilment of the contracts from the other parties entering it has been analysed.

For the organisational context, two different items were adapted from the literature (Giampietri and Trestini, 2020). As researchers highlighted, support from the top management (TMS) is fundamental for adopting an innovation due to the willingness of the manager (herein the farmer) to understand the benefits and implement the innovation (Gangwar et al., 2014). Thus, two different items were developed for the understanding of the perception of the business management attitude toward marketing contracts. Additionally, a perceived lack of resources (PLR) could lower the adoption rate. Indeed, following Giampietri and Trestini (2020), this study investigates whether contracts' adoption is perceived as additional work for farmers, thus being a non-sustainable choice in the short run. Lastly, as a relevant part of the TOE model, the farm size was considered. Indeed, according to different authors, the larger the firm, the higher the probability of contracts' adoption as a marketing strategy (Ricome and Reynaud, 2021).

The environmental context was analysed throughout different constructs: normative pressure (NP), mimetic pressure (MP), subjective norm (SN), and level of understanding (LU). Normative pressures primarily arise from professional and trade associations or customers and suppliers of the farm, which, through recommendations and suggestions, can influence the adoption of marketing contracts by the farm (Yoon and George, 2013). Thus, the construct was built to analyse if the buyers positively or negatively influenced contracts adoption. Mimetic pressures proved to be a significant driver on innovation adoption through the perceived positive effect granted by the use of the innovation by others in the individual environment (Yoon and George, 2013). Similarly, subjective norms (SN) reflect the subjective perception of how people that an individual perceives as important, think that the individual should behave with regards to adopting the innovation. Albeit the original TOE and TAM frameworks do not consider SN, we decided to include this in the model following Michels et al. (2019). Indeed, in their study investigating the intention to adopt futures contracts among farmers in Germany, they consider an extended TAM including SN. In line with this, Awa et al. (2017) revisited the TOE framework, including a fourth context, namely the individual context, which considers SN as a determinant of technology adoption. Thus, to differentiate subjective norm and mimetic pressure, the SN construct was built, stressing the behavioural connection between the farmer and his farming colleagues. As for SN, we decided to consider another factor that the literature does not always consider within the TOE framework: the level of understanding (LU). Indeed, since a marketing contract can be perceived as a complicated risk management tool (Solazzo et al., 2020), LU is expected to positively affect the adoption of contracts (Pennings and Leuthold, 2000).

The adapted TOE-TAM framework implies that SN and PEOU constructs have an impact both on IU and on PU of marketing contracts, following Michels et al. (2019).

Table 5:1. Latent variables, related indicators, and statements for each indicator.

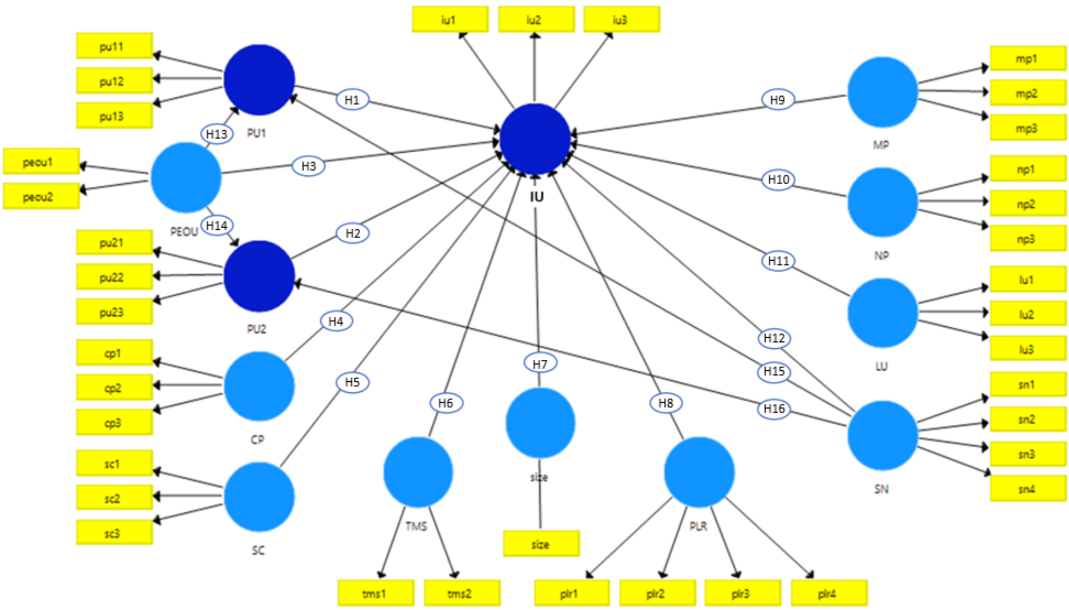
Context	Construct	Code	Indicator
	IU	iu_1	I intend to market my next crop production through MC
		iu_1	My farm intends to participate in MC to sell the production
		iu_1	I think I will use MC to sell my next production
TC	PU1	$pu1_1$	MC makes it possible to mitigate price risk at the farm level
		$pu1_2$	I think that the use of MC can help me to protect my finances
		$pu1_3$	The adoption of MC reduces the fluctuations in my turnover
	PU2	$pu2_1$	Overall, I think that MC is a useful tool to improve my financial situation
		$pu2_2$	The adoption of MC can guarantee higher selling prices to me
		$pu2_3$	I think MC can increase my income
	PEOU	$peou_1$	For me, MC is simple to use
		$peou_2$	In my opinion, MC are easy to use
	CP	cp_1	The use of MC is compatible with the production characteristics (quality and quantity) of my farm
		cp_2	The use of MC is compatible with the management of my farm
		cp_3	The use of MC is compatible with the size of my farm (i.e., minimum production)
	SC	sc_1	In the case of MC, I am concerned that buyers may not comply with the contract in the event of price drops
		sc_2	I don't trust marketing my products through MC
		sc_3	In the case of MC, it is possible that the buyer does not respect the contract
OC	TMS	tms_1	The farm owner is in favour of MC
		tms_2	The farm owner believes that using MC is advantageous
	PLR	plr_1	The use of MC in my farm requires additional investments
		plr_2	The use of MC in my farm requires additional work
		plr_3	The use of MC in my farm requires new specialised workers (e.g., consultants)
		plr_4	The use of MC in my farm requires additional specific training
EC	NP	np_1	My buyer (e.g., agricultural consortium, feed mill, mill, dryer, etc.) strongly recommend MC adoption to me
		np_2	My buyer (e.g., agricultural consortium, feed mill, mill, dryer, etc.) encourages the use of MC
		np_3	My buyer (e.g., agricultural consortium, feed mill, mill, dryer, etc.) suggests the use of MC
	MP	mp_1	More and more farmers are using MC
		mp_2	Many farmers already use MC
		mp_3	The use of MC is spreading more and more among farmers
	SN	sn_1	I would use MC if my farming colleagues advised me on it
		sn_2	My farming colleagues would agree if I used MC
		sn_3	My farming colleagues would approve my choice to use MC
		sn_4	My farming colleagues believe that the use of MC is beneficial for me
	LU	lu_1	I fully understand how MC work
		lu_2	My level of knowledge of MC is adequate
		lu_3	I know well how MC work

Notes: MC = marketing contract; IU = intention to use CF; PU1 = perceive usefulness for price risk reduction; PU2 = perceive usefulness for price enhancement; PEOU = perceive ease of use; CP = compatibility; SC = security concerns; TMS = top management support; PLR = perceive lack of resources; NP = normative pressure; MP = mimetic pressure; LU = level of understanding; SN = subjective norms.

To sum up, we hypothesised as follows (figure 5:1):

- H1: perceived usefulness for price risk reduction (PU1) influences IU;
- H2: perceived usefulness for price enhancement (PU2) influences IU;
- H3: perceived ease of use (PEOU) influences IU;
- H4: compatibility (CP) influences IU;
- H5: security concern (SC) influences IU;
- H6: farm's top management support (TMS) influences IU;
- H7: the size of the farm influences IU;
- H8: perceived lack of resources (PLR) influences IU;
- H9: mimetic pressure (MP) influences IU;
- H10: normative pressure (NP) influences IU;
- H11: level of understanding (LU) influences IU;
- H12: subjective norms (SN) influences IU;
- H13: perceived ease of use (PEOU) influences PU1;
- H14: perceived ease of use (PEOU) influences PU2;
- H15: subjective norms (SN) influences PU1;
- H16: subjective norms (SN) influences PU2.

Figure 5:2. Structural model and path analysis of the hypotheses.



Notes: IU = intention to use CF; PU1= perceive usefulness for price risk reduction; PU2 = perceive usefulness for price enhancement; PEOU = perceive ease of use; CP = compatibility; SC = security concerns; TMS = top management support; PLR = perceive lack of resources; NP = normative pressure; MP = mimetic pressure; LU = level of understanding; SN = subjective norms.
Source: authors' own illustration.

Material and methods

The estimation of models on innovation adoption usually applies structural equation modelling (SEM). SEM allow the simultaneous estimation of cause-effect relationships between multiple independent and dependent constructs. Recently, SEM has been applied in agricultural contexts to the analysis of commodity futures contracts use both in its covariance-based form (Franken et al., 2017) and in its variances-based form (Michels et al., 2019). Specifically, partial least squares structural equation modelling (PLS-SEM) is a variance-based technique to analyse the simultaneous relationship between different variables (for a detailed methodology description, see Michels et al., 2019). Exploratory studies, like the adapted TAM-TOE model presented here, have been shown to perform better with PLS-SEM (Aktar and Pangil, 2017). This is due to the flexibility of PLS-SEM in analysing data that are not normally distributed (Hair et al., 2018) and in its ability to perform even with a limited sample (Willaby et al., 2015; Richter et al., 2016).

Many latent variables are considered within the model, as measured by multiple observed indicators derived from the questionnaire's answers. Latent variables can be exogenous (the independent variables) and/or endogenous (the dependent variables). Our model consists of two endogenous constructs, namely the intention to use marketing contracts (IU), explained by different latent variables included in the adapted TOE-TAM model, and the perceived usefulness of marketing contracts (PU1 and PU2), which act both as endogenous (explained by PEOU and SN) and exogenous. The link between different latent variables constitutes the inner model, while the relationship between each latent variable and its indicators represents the outer model (Hair et al., 2018; Sarstedt et al., 2014).

To measure the latent variable within the adapted TOE-TAM model, after a pre-test on a small sample (N=10), an online survey addressed to Italian farmers was conducted via social media and online advertisement during summer-autumn 2021. Even if the internet is the least accessible in European rural areas, e spread of internet usage among farmers (CIT), online questionnaires are a valid instrument that effectively reaches many farmers within Italy. Therefore, the final data sample consists of 84 completed questionnaires. The results were analysed through PLS-SEM using Smart-PLS software (Ringle et al., 2015).

The survey was structured as follows: first, the farmers were provided with a description of agricultural marketing contracts (MC). Then the adapted TOE-TAM contexts were investigated through 5-point Likert-type scales ranging from 1 (totally disagree) to 5 (totally agree) (Table 5:1). Finally, farmers were asked to provide farm and farmer related information.

Results and discussion

As reported in Table 5:2, the sample is composed mainly of men (93%), with an average age of 44 years, and up to 38% has a higher education (i.e., university degree). As for the characteristics of the farms, 57% of the sample specialises in the arable crop sector and has an average size of 76 hectares. Moreover, 63% of the farms sell/deliver their product to a farms' association as cooperatives or consortia. As for the active risk management already applied by the farm, it is possible to notice how the majority (93%) use some strategies as irrigation, insurances and modernisation (49%, 44%, 39%, respectively), whereas only 20% of the farms in our sample applies financial saving or diversification with related activities (such as direct sales or agritourism).

Table 5:2. Descriptive statistics of the sample.

Variable	Description	%	Mean	SD	Min.	Max.
Age	Farmers' age		44	13	23	72
Education	1 if the farmer has a university degree 0 otherwise	0.38		-	0	1
Gender	1 if farmer is male 0 otherwise	0.93		-	0	1
Farm size	hectares of arable land		76	127	1.7	900
Full-time farmer	1 if the farmer is a full--time farmer 0 otherwise	0.77		-	0	1
Arable crop	1 if the farm is specialised (arable crop sector) 0 otherwise (mixed farm)	0.57		-	0	1
Assoc.	1 if the farmer is associated (consortia) 0 otherwise	0.63		-	0	1
CF used	1 if the farmer has ever used CF 0 otherwise	0.63		-	0	1

Note: n = 80. [a] ISTAT

Table 5:3 reports the evaluation for the PLS-SEM outer model. Firstly, the indicator reliability is approved for all the considered indicators, given that the loadings are equal to or higher than 0.7 (see column 3). Thus, the indicator in our model well predicts the overall variance of each construct (Hair et al., 2018). Next, the model collinearity is evaluated through the variance inflation factor (VIF) values. According to the results reported in column 4, all values are uniformly below the threshold value of 5 (Hair et al., 2018). Similarly, all the constructs report values equal to or higher than 0.7 for Cronbach's α, composite reliability and Dijkstra-Henseler's ρ_a (see columns 5, 6 and 7), confirming the internal consistency of the model. Finally, as regards the variance captured by each item with respect to the variance explained by measurement error for each construct, the average variance extracted (AVE) reported in column 8 shows results that are consistently above the 0.5 threshold (Hair et al., 2018).

Table 5:3. Outer model evaluation criteria.

Context	Construct	Indicator code	Factor Loading	Cronbach's α	Composite reliability	Dijkstra-Hensler's ρ_A	AVE
	IU	iu_1	0.931	0.929	0.955	0.932	0.875
		iu_1	0.923				
		iu_1	0.952				
TC	PU1	$pu1_1$	0.895	0.827	0.897	0.858	0.744
		$pu1_2$	0.921				
		$pu1_3$	0.763				
	PU2	$pu2_1$	0.927	0.921	0.950	0.922	0.863
		$pu2_2$	0.912				
		$pu2_3$	0.949				
	PEOU	$peou_1$	0.911	0.744	0.886	0.760	0.795
		$peou_2$	0.872				
	CP	cp_1	0.825	0.812	0.888	0.832	0.727
		cp_2	0.903				
		cp_3	0.827				
	SC	sc_1	0.710	0.759	0.819	1.279	0.606
		sc_2	0.930				
		sc_3	0.670				
OC	TMS	tms_1	0.934	0.872	0.940	0.881	0.886
		tms_2	0.949				
	PLR	plr_1	0.699	0.811	0.875	0.870	0.639
		plr_2	0.821				
		plr_3	0.758				
		plr_4	0.905				
EC	NP	np_1	0.865	0.900	0.938	0.902	0.834
		np_2	0.931				
		np_3	0.942				
	MP	mp_1	0.902	0.842	0.902	0.885	0.756
		mp_2	0.801				
		mp_3	0.901				
	SN	sn_1	0.690	0.848	0.900	0.850	0.694
		sn_2	0.853				
		sn_3	0.877				
		sn_4	0.895				
	LU	lu_1	0.887	0.858	0.911	0.901	0.774
		lu_2	0.909				
		lu_3	0.842				

Notes: IU = intention to use MC; PU1 = perceive usefulness for price risk reduction; PU2 = perceive usefulness for price enhancement; PEOU = perceive ease of use; CP = compatibility; SC = security concerns; TMS = top management support; PLR = perceive lack of resources; NP = normative pressure; MP = mimetic pressure; LU = level of understanding; SN = subjective norms.

Cut-off level for standardised indicator loadingsW0.7; Cronbach's αW0.7; Composite reliability ρcW0.7; Dijkstra-Henseler's ρaW0.7; AVEW0.5.

Table 5:4 shows the results for the Heterotrait-Monotrait (HTMT) criterion, which measures how each indicator correspond to only one construct and should give correlation values smaller than 0.9 (Henseler et al., 2015; Hair et al., 2018). Finally, considering the good results of the evaluation of the external model, it was possible to proceed with the estimation of the internal model through the evaluation of the PLS path coefficients.

Table 5:4. Outer model evaluation criteria (HTMT ratios for the discriminant validity).

	IU	PU1	PU2	PEOU	CP	SC	TMS	PLR	NP	MP	SN	LU	size
IU													
PU1	0.647												
PU2	0.698	0.930											
PEOU	0.662	0.750	0.678										
CP	0.809	0.513	0.560	0.806									
SC	0.343	0.396	0.276	0.445	0.470								
TMS	0.912	0.674	0.722	0.647	0.779	0.362							
PLR	0.213	0.318	0.163	0.487	0.496	0.743	0.274						
NP	0.479	0.154	0.257	0.388	0.363	0.136	0.345	0.057					
MP	0.343	0.310	0.365	0.318	0.309	0.231	0.312	0.089	0.365				
SN	0.406	0.577	0.672	0.529	0.406	0.185	0.541	0.139	0.425	0.643			
LU	0.314	0.359	0.231	0.589	0.569	0.304	0.265	0.205	0.173	0.115	0.121		
size	0.044	0.115	0.068	0.301	0.089	0.206	0.040	0.143	0.141	0.091	0.118	0.145	

Notes: IU = intention to use MCCF; PU1 = perceive usefulness for price risk reduction; PU2 = perceive usefulness for price enhancement; PEOU = perceive ease of use; CP = compatibility; SC = security concerns; TMS = top management support; PLR = perceive lack of resources; NP = normative pressure; MP = mimetic pressure; LU = level of understanding; SN = subjective norms. Heterotrait-monotrait Ratio of Correlations (HTMT) for discriminant validity. The cut-off level for the HTMT criterion is 0.9.

Regarding the evaluation of the inner model results, Table 5:5 presents the results of the R^2 for the endogenous constructs (Hair et al., 2018). The adapted TOE-TAM model explains most of the variance of farmers' intention on CF adoption. Indeed, 78% of the IU construct is explained. Moreover, given that the model comprehends multiple endogenous constructs, it also shows that 43% and 47% of the variance of PU1 and PU2 is explained by the model, respectively. Thus, the adapted TOE-TAM framework explains both the perceived usefulness for risk management practices and for speculation activities of CF. These results are a slight improvement over Michels et al. (2019), in which the explained variance of similar indicators (PU1 and PU2) is lower.

Table 5:5. Inner model evaluation.

	R^2	Q^2
IU	0.78	0.63
PU1	0.43	0.30
PU2	0.47	0.40

Notes: IU = intention to use CF; PU1 = perceive usefulness for price risk reduction; PU2 = perceive usefulness for price enhancement. The table report the results for the explained variance (R^2) and the predictive relevance (Q^2). Cut-off level for R^2>0.1; Q^2>0.

Table 5:6 lists the coefficients estimated through the PLS-SEM algorithm and their t-values and significance (Chin, 1998). Following Hair et al. (2018), 5,000 subsamples are run for the bootstrapping procedure, which is a non-parametric approach to check for the significance statistics for the path coefficients(Hair et al., 2018).

Table 5:6. The goodness of fit.

	Criteria
SRMR	0.08
d_{ULS}	5.00
d_G	2.91

Note: SRMR= standardized root mean squared residual; unweighted least squares discrepancy d_{ULS}; geodesic discrepancy d_G.

Finally, table 5:6 lists some goodness of fit criteria for the overall model. The overall goodness-of-fit of the adapted TAM-TOE model allows determining that the proposed model is well-fitted (Henseler et al, 2014). The model does not present measurement and structural misspecification (Dijkstra and Henseler, 2014).

The results, reported in table 5:7, show that CF adoption is influenced by different constructs belonging to the three dimensions of the TOE framework. Within the technological context, the compatibility of CF with the farm characteristics is found to be positively correlated with the intention to adopt (β_{CP}=0.300). In line with Junior et al. (2019), in which the construct is found to have a strong positive influence on the adoption of enterprise resource planning systems, compatibility is confirmed as an essential determinant of the innovation adoption (Tornatzky and Fleisher, 1990). Given that farmers are found to dislike constraints which usually are linked with CF (Solazzo et al., 2020), the more a contract is perceived as compatible with the farm's production characteristics (quantity and quality), management, and size, the greater the intention on the adoption of CF. Remarkably, the perceived usefulness for both risk management practices and speculation and the perceived ease of use linked to CF are not significantly correlated with the intention to adopt CF in our sample. The lack of a significant effect of perceived usefulness for risk management is in line with the results in Michels et al. (2019) on farmers' adoption of futures contracts. Contrariwise, Michels et al. (2020) results show a positive influence of perceived usefulness for futures contracts' speculation purposes. The different results here could be linked to the difference in forward pricing (CF) and futures contracts (Hull, 2008). Indeed, while the first one allows fixing the price with the buyer, the second could also be perceived as a tool to enhance prices instead of reducing price risk (Michels et al., 2020).

As regards the organisational context, the results show a significant effect of the top management support to CF adoption (β_{TMS}=0.488). This shows that the more the farm owner is favourable to this tool, thus the more he understands the benefits from CF adoption, and the higher is the intention to adopt marketing contracts. Conversely, to what reported by the literature, the firm's size does not influence Italian farmers' contracts adoption. Indeed, larger firms are believed to participate in marketing contracts more actively both because of the higher level of resources and potential trading volume (Penning et al., 2004).

In relation to the environmental context, our findings show the important role of farmers' buyers in suggesting the use of marketing contracts (βTMS=0.160). This result is in line with the agricultural innovation adoption literature (Yoon and George, 2013; Giampietri and Trestini, 2020). Interestingly, given the reported lack of trust in production management contracts (Solazzo et al., 2020), these results positively encourage farmers' buyers (cooperative, consortia and storage centre) to suggest marketing contracts to farmers, which can guarantee a more stable marketing strategy for the buyers (defined quantity and quality commodity purchase). Also, both MP and SN do not influence the intention to adopt marketing contracts. Thus, overall, the environmental context and the resulting network effect are important only in the case of buyers, focusing the attention of policymakers on these important actors to promote and spread agricultural contracts as innovative risk management tools.

Finally, the adapted part of the TAM model brings remarkable results. The perceived ease of use and subjective norms positively affect the perceived usefulness of marketing contracts for price risk reduction (PU1) and speculative purposes (PU2). Therefore, the positive coefficient implies that a higher PEOU and higher SN bring to higher PU1 and PU2. As shown in literature, the more a contract is perceived as complex, the more farmers are reluctant in adopting it (Ennew et al., 1992). Moreover, the farmers' colleagues can alter the perception of the farmers on the innovation (Michels et al., 2019).

To conclude, the adapted TOE-TAM model allows for the acceptance of H_4, H_6, H_{10}, H_{13}, H_{14}, H_{15} and H_{16}.

Table 5:7. Results of the inner model.

Model	Context	H_0	Hypothesis	Path coefficients	t-statistic (Bootstrap results)
TOE	TC	PU1 → IU	H_1	0.109	0.769
		PU2 → IU	H_2	0.043	0.261
		PEOU → IU	H_3	-0.040	0.393
		CP → IU	H_4	0.300	2.876***
		SC → IU	H_5	-0.030	0.383
	OC	TMS → IU	H_6	0.488	4.676***
		Size → IU	H_7	0.035	0.839
		PLR → IU	H_8	0.073	0.915
	EC	MP → IU	H_9	-0.035	0.508
		NP → IU	H_{10}	0.160	2.106***
		LU → IU	H_{11}	-0.023	0.303
		SN → IU	H_{12}	0.081	0.916
TAM		PEOU → PU1	H_{13}	0.482	4.596***
		PEOU → PU2	H_{14}	0.381	3.918***
		SN → PU1	H_{15}	0.280	3.023***
		SN → PU2	H_{16}	0.434	4.926***

Notes: IU = intention to use MC; PU1 = perceive usefulness for price risk reduction; PU2 = perceive usefulness for price enhancement; PEOU = perceive ease of use; CP = compatibility; SC = security concerns; TMS = top management support; PLR = perceive lack of resources; NP = normative pressure; MP = mimetic pressure; LU = level of understanding; SN = subjective norms. Bootstrapping procedures = 5,000 subsamples; p<0.10, p<0.05**, p<0.001***.*

Conclusions

European and Italian farmers producing commodities are increasingly exposed to price risk, threatening their income and their long-run resilience. Marketing contracts present some advantages in managing price risk at the farm level, providing the possibility for the farmer to sell the product at a fixed price before the product is marketed. Even with the efficacy in mitigating farmers income risks, the spread of agricultural contracts appears heterogeneous and generally scarce in Italy. Thus, it is important to understand farmers' intention to adopt this innovation at the farm level to facilitate its adoption.

To this purpose, this paper analyses if an adapted TOE-TAM framework would help explain the heterogeneity associated with farmers adoption of marketing contracts. The results show that the adapted TOE-TAM framework is suitable and well predict farmers' intention to adopt marketing contracts as an innovative price risk management tool at the farm level. Farmers' intention to adopt marketing contracts is influenced by different factors belonging to the three dimensions of the TOE framework. The results confirmed the importance of the perceived compatibility of marketing contracts with the farm's production characteristics, management and size. Moreover, the stronger the farm top management support the adoption of marketing contracts, the higher the adoption. Finally, for increasing the adoption of marketing contracts, the influence of buyers (e.g., farmers' cooperatives and consortia, storage facilities) resulted very relevant. Interestingly, farmers' perceived usefulness did not influence adoption, despite being affected by their subjective norm and perceived ease of use of marketing contracts.

Overall results implicate that a deeper level of information on marketing contracts and their effectiveness, combined with greater support in the adoption of these tools (from cooperatives or consultants), can favour the adoption of marketing contracts.

Although this paper is the first application of TOE and TAM frameworks to marketing contracts adoption, it provides interesting insights into the Italian agricultural scenario. However, this study is not without limitations: one major lies in the rather limited sample that does not represent the overall Italian arable sector. Nevertheless, the small sample size is common in studies focusing on farmers due to the difficulty to reach them. Furthermore, the online survey inherently implies that only farmers with a certain level of computer skills would be able to complete the survey. However, it can be argued that it is precisely the farmers who remain up-to-date on information technology that are the ones who may be most interested in adopting production contracts as a business innovation.

To conclude, further research related to the behavioural aspects of CF adoption among farmers should comprehend a larger sample and, possibly, comprehend other EU countries.

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CONCLUSIONS

Farmers' income has been increasingly affected by commodity prices' volatility. Environmental and political factors condition the environment in which farmers operate. Indeed, price risk has been exacerbated by the increasing negative effects of climate change and the overall uncertainty of the COVID-19 pandemic. To this, the political EU scenario adds some additional unrest given the ongoing transition toward more market-oriented support policies. Therefore, the increasing exposure to price risks threatens to invalidate farmers' long-run resilience by affecting their income.

Against this background, it is evident that farmers are increasingly called to manage risks. However, among the several strategies at their disposal, the use of financial derivatives remains scant both in Europe and, even more so, in Italy. To understand why farmers limitedly adopt futures and forward contracts, this thesis aims to first study the feasibility and effectiveness of these tools for European and Italian farmers and then understand the factors affecting farmers' adoption of marketing contracts.

A first analysis of the feasibility of hedging strategies with futures contracts was performed from a European perspective. Indeed, the common agricultural policy that rules over European agriculture standardises the environment and the legislation for European farmers. Thus, given that European farmers operate within similar regulations, the exploratory analysis on EU Member States prices would give an insightful overview. The corn market was chosen as a representative commodity, given the importance of its production at the EU level and the high tradability of the commodity. Member States were selected based on the availability of ten consecutive years of corn prices. As a result, the following ten MS were considered: Austria, Belgium, France, Germany, Greece, Italy, Portugal, Slovakia, Slovenia, and Spain. Two important derivatives exchanges were chosen for the analysis, namely the CBOT and the Euronext.

To confirm the presence of a stable-long run cointegrating relationship, different steps were carried out. After some preliminary analysis that assessed the involved time series' statistical properties, the futures-spot prices series were tested for the relationship's causality direction and cointegration by also allowing for structural breaks. Finally, a Vector Error Correction Model (VECM) was performed to analyse both long-run and short-run dynamics of the relationship of the futures-spot price.

The results of the Engle-Granger cointegration tests confirmed the presence of a long-run cointegration relationship between futures and spot prices. The cointegration was also confirmed in the presence of structural breaks by the Gregory-Hansen cointegration tests. The Toda-Yamamoto approach to Granger causality detected causality between futures and spot prices. Overall, the Euronext futures contract prices showed at least uni-directional causality (from futures to spot) and, in some instances, also bi-directional causality (Austria, Belgium, France and Portugal). Instead, the CBOT futures contract prices resulted in uni-directional causality, from futures to spot (Austria, Belgium, Germany, Greece, Slovenia) or from spot to futures (France and Italy). Finally, the VECM confirming all previous analyses showed both a significant long-run and short-run effect between the futures and the spot prices. For all the considered EU Member States and Euronext futures contract prices pairs, spot prices are found to react to adjust the long-run equilibrium relationship, confirming the leading role of futures markets. Finally, Euronext futures contract prices, compared with the CBOT prices, show a higher connection with the European spot prices.

These findings have important implications for farmers within the MS selected for the analysis. First, the presence of a stable, long-run cointegrating relationship implies efficient futures exchanges in which corn producers and processors could effectively operate. Given the well-known effect of policies on domestic prices, i.e., decoupling of domestic from global prices, the reduction in support granted by the Common Agricultural Policy also allowed domestic prices for European MS to increase the cointegration with derivatives prices, thus allowing for more efficient use of futures contracts as price risk management instrument. Finally, it is worth adding that, even if risk transfer is the main goal for farmers operating in derivatives exchange, it is not the only one. Indeed, efficient futures markets also provide for price discovery practices, thus allowing for informative practices from farmers and operators in the corn markets.

After the preliminary analysis at the EU level, the spot prices for three major Italian commodities, namely soybean corn and milling wheat, were analysed. Indeed, Italy is one of the prominent agricultural producers at the EU level, making the analysis of Italian prices attractive given the high number of holding affected by agricultural price volatility. Error correction approaches were thus subsequentially applied to Italian spot prices for these agricultural commodities. As mentioned, within an efficient market with a stationary basis and the assumption of constant interest rate, marginal storage cost, and marginal convenience yield, farmers and other operators along the supply chain can efficiently use futures contracts as a price risk management instrument.

Thus, after preliminary tests, Italian spot prices and the CBOT and Euronext futures contract prices were tested for stationarity and cointegration. Moreover, given the availability of high-frequency data (weekly), the basis was tested for asymmetric behaviour through a threshold autoregressive model (TAR). Then a threshold vector error correction model was performed for testing the presence of asymmetric price transmission (APT).

Preliminary analyses confirmed the stationarity of the series in the first difference form and the presence of a stable long-run cointegrating relationship. Moreover, the TAR model provided strong evidence supporting the asymmetric basis behaviour for all the considered commodities (soybean corn and milling wheat) and exchanges (CBOT Euronext). However, the specific analysis through the TVECM showed some differences among commodities. Indeed, negative APT was confirmed for corn (Euronext-Italian spot) and wheat (Euronext-Italian spot and CBOT-Italian spot) markets. On the other hand, soybean price transmission (CBOT-Italian spot) showed positive APT.

The agricultural spot-futures price relationship analysis has important implications for Italian producers and processors. Confirming the previous part of this thesis, corn spot prices depicted a stable long-run relationship with the CBOT and Euronext futures prices. Similarly, milling wheat prices and soybean prices also resulted cointegrated with the

Euronext and the CBOT, respectively. As mentioned, these results support the possibility of using futures contracts as price risk management instruments. Moreover, confirming the efficient market hypothesis, the futures market can also be used by Italian commodities producers and processors for price discovery purposes. The confirmed negative (positive) APT implies a faster (slower) adjustment after positive or negative price movements. Specifically, the asymmetric nature of price transmission of futures contracts prices to Italian spot prices will affect the cost-effectiveness of hedging for all operators. Indeed, negative (positive) APT implies a faster (slower) adjustment after a negative ECT shock, thus implying a faster (slower) transmission of a strong basis, making it less (more) beneficial for farmers.

Results at both the European and Italian levels, characterising and specifying the relationship between futures and spot prices, confirmed cointegrated futures and spot markets. However, price analysis does not aim at answering more than descriptive and forecasting questions thus assisting decision makers on the feasibility of hedging strategies. Given the limitation that exists in price analysis it follows that the effectiveness of futures contracts as risk management tools should be tested to measure the profitability of these strategies for Italian farmers.

Therefore, based on these preliminary findings, this research proceeded with the analysis of the effectiveness of hedging strategies for Italian farmers. The aim was to investigate the CBOT and Euronext futures prices' ability to reduce farm income volatility for soybean, corn and milling wheat producers. To this purpose, a portfolio of combined futures and spot returns was compared with the return of a portfolio composed of only a spot position.

Within the Modern Portfolio Theory, the optimal hedging ratio (OHR) has been computed for the minimisation of the returns' variance, with three different methodologies. First, a naïve hedge ratio, in which the futures position is equal in magnitude to the spot position. Then, considering prices correlation, the OLS and the generalised autoregressive conditional heteroskedasticity (GARCH) models were computed to estimate the amount of futures position to be upheld against one spot position. Moreover, different time horizons were considered, given the importance of choosing a specific hedging (time) horizon. The return for the hedge portfolio was calculated for the week-to-week changes and four, twelve, and thirty-two weeks changes. The resulting three portfolios (naïve, OLS and GARCH) for each commodity (soybean, corn and milling wheat) and for the different time horizons (one week, four weeks, 12 weeks, 32 weeks) were compared by analysing some risk measures (variance, semi-standard deviation, value at risk, and expected shortfall).

Overall, findings confirm that hedging strategies with futures contracts can be an effective strategy for farmers in the field crop sector in Italy. Indeed, the hedge portfolios reported a reduction in all the considered risk measures. More specifically, results show that the OLS and GARCH estimated portfolios ensured the highest efficiency. Contrariwise, the naïve hedging strategy for the calculation of the OHR originated an increase in the farmers' portfolio volatility at low hedge horizons (one and four-week hedge). Moreover, the effectiveness of hedging, transversely to all examined commodities, showed that the OLS and GARCH OHR increased with longer hedge horizons. Among the analysed commodities, results for corn and wheat producers confirmed that the Euronext futures contracts grant a higher reduction of income volatility for farmers, resulting in the best hedging strategy compared to CBOT. However, CBOT showed comparable hedging effectiveness for soybean for all the considered risk measures.

These findings provide promising results for the mitigation of the adverse effect of price volatility. Indeed, Italian farmers in the arable crop sector can effectively reduce price risk operating in the CBOT and in the Euronext. Moreover, results point to the high efficacy of the Euronext futures market. This allows for the recommendation of increased use and development of this exchange, in line with the Agricultural Markets Task Force of the European Commission, which considers commodity futures contracts an important price risk management instrument for European farmers.

A final step of this research analysed the characteristics that influence farmers adoption of hedging strategies as innovative instruments to cope with income risk at the farm level. Given the scarce adoption of hedging instruments in Europe, this thesis's concluding remark is whether an adapted technology-organisation-environment (TOE) – technology acceptance (TAM) model can contribute to the understanding of farmers' intention to use price risk management instruments (marketing contracts).

Throughout an online survey, farms' technology-related internal and external factors were investigated. These comprehend the technological context (perceived usefulness, perceived ease of use, compatibility and security concern); the organisational context (the top management support, size, and the perceived lack of resources); finally, the environmental context (the normative pressure, the mimetic pressure, and the subjective norms) concerning the role of policy, competitors, trading partners and customers. Moreover, the effects of the perceived ease of use and the subjective norm to the perceived usefulness for risk management and for price enhancing purposes were analysed. Through a partial least square-structural equation modelling (PLS-SEM), analysed with Smart-PLS software, simultaneous cause-effect relationships between independent and dependent constructs (or latent variables) were assessed in an iterative sequence of ordinary least squares regressions.

Results show that contract farming adoption is influenced by different factors belonging to the three dimensions of the TOE framework. Within the technological context, the perceived compatibility of marketing contracts with the farm characteristic positively influences the intention of adoption. Reportedly, farmers dislike constraints usually linked with production contracts. Thus, it draws that the higher a contract is perceived compatible with the farm's production characteristics (quantity and quality), management, and size, the greater the intention on the adoption. Moreover, within the organisational context, the top management support construct gives a strong significant effect on the intention to adopt marketing contracts. Indeed, given the importance of understanding the benefits granted by using innovation from the top management of a business, it is an important result for the spread of marketing contracts. In relation to the environmental context, findings show how the more the farmers' buyers suggest the use of marketing contracts, the higher the farmer's intention to adopt the innovation. Interestingly, given the reported lack of trust in agricultural contracts, this result positively encourages farmers' buyers (cooperative, consortia and storage centre) to suggest contracts to farmers, granting a more stable marketing strategy for the buyers (defined quantity and quality commodity purchase). Finally, the adapted part of the TAM model brings remarkable results. The perceived ease of use and the subjective norm positively affect marketing contracts' perceived usefulness (both for risk management and for speculation). Given that the more a contract is perceived as complex, the more hesitation on adoption is expected, the lack of a significant effect of the perceived usefulness of marketing contracts on adoption decision may refer to the complexity of these instruments, even if farmers report a high level of understanding.

Given the lack of perceived usefulness for what literature reports as effective instruments, our results allow for some interesting discussion with farmers and farmers' buyers on the possibility of implementing farmers knowledge and marketing training on agricultural contracts to implement the spread of this tool. Indeed, the strong link between adoption and the support of the farms' management and the farmers' buyers can drive efforts toward increasing the understanding of such tools by farmers. Therefore, it is worth highlighting that the adoption rate of hedging strategies would increase by developing farmers knowledge. The effectiveness of hedging strategies in reducing Italian farmers risk exposure, thus being beneficial for farmers, would grant a more extensive spread if the farms' management properly understood them.

Following the main findings, policymakers, buyers, and advisory services should encourage the use of hedging, due to its effectiveness in mitigating price risk for farmers. Indeed, these instruments have proven to grant a high-risk reduction effect for the major agricultural commodities. Nevertheless, the use of agricultural contracts presents some barriers. First, marketing contracts' adoption depends on farmers' trust towards the buyer of the commodities, given the lack of a transparent system in futures commodities prices. Second, the price of the contracts is negotiated by both the individual farmer and the buyer of the commodity, and it is not easy for the farmer to trace the price of a specific commodity in the futures. On the other hand, futures contract prices, despite being transparently available, presents some specific shortcomings: for instance, the futures prices are available in foreign website, so the language can represent a barrier as well as internet usage for the Italian farmers. Moreover, in the North American futures exchange prices are quoted in different units, implying an additional impediment. Finally, the use of futures contracts is connected with the use of a brokerage service, adding laboriousness that is a further impediment to farmer adoption.

However, even considering these adoption barriers, the use of agricultural contracts for price risk management resulted as an efficient method to stabilise farmers' income. Given the foreseen reduction in the direct support granted by the CAP in the next programming and the following reduction in farmers' margins, applying these tools would grant a protection for European and Italian farmers in the arable crop sector. Thus, the results of this thesis point to some important recommendations regarding the spreading of hedging practices among farmers.