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TESTING WILLIAMSON'S THEORY ON TRANSACTION-SPECIFIC GOVERNANCE STRUCTURES: EVIDENCE FROM ELECTRICITY MARKETS

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Long term contracts increase the hazard of ex post maladaptation, creating demand for processes that enable adaptation over the course of long-term exchange. Enabling adaptation, however, may diminish the effectiveness of the long-term contracts, designed as *prima facie* hold-up remedies. Following Joskow (1987), we attempt to empirically capture the positive relationship between physical asset specificity and the duration of long-term contracts between California electricity generators. In addition, following Masten and Crocker (1985), we try to measure the effect of legal provisions on contract duration and interpret them as efficient instruments for providing flexibility in long-term relationships. The more important the investment in relationship-specific assets, the longer the contractual duration. However, parties mitigate long-term contract inflexibility, based on ex ante bargained terms and conditions, with provisions that allow for contingent adaptation. Our empirical results provide support for the hypothesised relationships under different model specifications and alternative estimation techniques.

JEL classification codes: C2, K23, L140
Key words: electricity long-term contracts, idiosyncratic relations, asset specificity, efficient adaptation

I. Introduction

Transaction cost economics (TCE) acknowledges the role of contract terms in aligning marginal incentives ex ante and in preventing wasteful efforts to ex post

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redistribution of existing surplus. In order to achieve this twofold objective, contract terms have several dimensions (price provisions, incompleteness level, duration) that allow the transaction(s) at stake to adapt to the regulated contingencies and circumstances.

On the theoretical side, transaction cost economics is crucial because "understanding how and why economic agents use contracts to coordinate their activities is crucial to understanding the organization and efficiency of economic exchange" (Masten and Saussier 2002, p. 273). On the empirical side, TCE has produced testable hypotheses and explained actual contracting practices. Masten and Saussier (2002) survey the most important empirical contributions on the econometrics of TCE, and highlight two main streams of empirical research. On the one hand, the analysis explores the decision to contract as a standard discrete choice problem, where transactors will choose to contract if the expected gains (net of transaction costs) from doing so are greater than those of organizing the transaction in some other way. On the other hand, researchers focus on the contractual duration problem, where transactors' problem is selecting how many periods their contract should cover, and the TC determinants affecting contract duration.[1]

In this latter stream of TCE empirical research, a group of seminal papers and results have to be highlighted. Joskow's pioneering paper (1987) performs an econometric analysis of the duration of 277 contracts between coal mines and coal-fired electricity generators. Joskow's analysis exploited: (1) regional differences in the characteristics of coal and transportation alternatives across the United States; (2) differences in the proximity of mines and power plants; and (3) variations in contract quantity to create proxies for the degrees of physical-asset specificity, site specificity, and dedicated assets. Joskow found the duration of coal contracts to be approximately eleven years greater in western states, where coal is more heterogeneous, mines are larger, distances greater, and transportation alternatives fewer, than in the eastern United States, where coal tends to be more homogeneous, mines are smaller and more numerous, distances are shorter, and transportation

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[1] As pointed out by Masten and Saussier (2002), although not specifically designed to test agency hypotheses, the results of several of these studies bear indirectly on the validity of predictions derived from agency concerns. Thus inasmuch as high-technology projects tend to be riskier than simpler procurements, Lyons' (1994) finding that engineering sub-contractors adopt formal contracts less frequently for projects characterized as high-tech conflicts with what would be expected if risk transfer was a primary motive for contracting. Crocker and Masten's (1988) and Saussier's (1998, 1999) findings that contracts tend to be of shorter duration in periods of higher uncertainty appear also to be inconsistent with the use of contracting as a mechanism to allocate risk.

alternatives abundant, and with Midwestern coal contracts intermediate both in duration and characteristics. Longer still, by approximately twelve years, were contracts for coal supplied to power generators located at the mouth of a mine. Finally, contract duration increased by an additional thirteen years for each additional million tons of coal contracted for.

Crocker and Masten's (1988) study of 245 natural gas contracts sought to assess variations in the costs (as well as the benefits) of contracting on the duration of contractual agreements. They found evidence of a positive relation between contract duration and appropriation hazards; contracts tended to be of shorter duration for wells in gas fields (1) served by larger numbers of producers and pipelines (reducing appropriation hazards) and (2) in which only a single producer operated, eliminating the risk of pipelines exploiting the common-pool drainage problem to extract price concessions. Crocker and Masten (1988) also found, however, (1) that natural gas contracts written during the period of greater uncertainty following the 1973 Arab oil embargo tended to be shorter than contracts written before the embargo, and (2) that misaligned incentive provisions (a by product of price regulation) reduced contract duration by an average of fourteen years.

Recent papers by Saussier (1998, 1999, 2000), analyzing contracts for coal transportation in France, examined both the costs and benefits of contract duration. Saussier found that the duration of these contracts was positively related to the value of investments in relationship specific assets (as measured by the value of start-up investments and guaranteed contract quantities) and negatively related to the level of demand uncertainty over time. In addition, Saussier attempted to solve a well-known problem in operationalization of TCE. By using two-stage least squares (2SLS) estimation methods and a set of exogenous instruments, the author attempted to endogenize the level of specific investments, addressing a potential limitation of the earlier literature. He found his results to be largely robust to this refinement.

Bercovitz (1999) applied transaction-cost reasoning to analyze the duration of franchise contracts. Consistent with the evidence from other contract duration studies, Bercovitz found that the duration of franchise agreements are significantly longer the larger franchisees' initial investments, which, she argues, are likely to be correlated with the franchisees' specific investment. In addition, Bercovitz argues that the threat of non-renewal under shorter-term contracts allows franchisors greater ability to discipline opportunistic franchisees. Consistent with this, she found that franchise agreements tend to be of shorter duration in systems having the greatest potential for franchisee free-riding (as measured by the value of the system's brand name and the locational density of franchise outlets).

The present paper follows the empirical TCE research on the contractual duration problem. The paper studies an important, to our knowledge under-studied, problem in IO: how to maintain flexibility in long-term exchange relations while, at the same time, mitigating hold-ups. This problem involves trade-offs: long term contracts can increase the risk of ex post maladaptation, thus, creating demand for processes that enable adaptation over the course of long-term exchange. Enabling adaptation, however, may diminish the effectiveness of the long-term contracts, designed as *prima facie* (potential) hold-up remedies.

The research motivation starts from the proposition according to which, "the more uncertain the contractual environment and the harder it is to accommodate changing circumstances within the contract, the more likely it will be that parties will sacrifice the precision and ease of implementation of definite contract terms for more cumbersome but flexible «relational» contract terms that define performance obligations less precisely or establish procedures for negotiating adjustments in the terms of trade within the contract" (Saussier 2002).

On the one hand, long term contracting provides benefits, like the reduction in the cost of repeated bargaining and bigger willingness of transactors to take actions, whose value depends on the other party's performance. On the other hand, there are drawbacks on long term contracting, stemming from the costs of anticipating, devising optimal responses to, and specifying future contingencies (formation costs); and from the losses associated with efforts to enforce, evade, or force a renegotiation of the contract's terms and the "maladaptation" costs of failing to adjust to changing circumstances (execution costs).

The benefits of long term contracting increase with the asset specificity required to undertake the transaction (need to secure the transaction), and decrease with the complexity and the uncertainty of the transaction (need for a flexible contract). There exist, therefore, a basic trade-off, that the paper aims to explore in restructured electricity markets.

In particular, we want to test the following two hypotheses:

(1) The more important are relationship-specific investments, the longer the period of time that the parties agree upon in order to implement their exchanges in electricity wholesale markets. Therefore, the variation in the contractual length should be directly related to the variation in the importance of relationship-specific investments.

(2) However, the longer the contracts' duration, the more flexible provisions have to be designed, in order to avoid ex post maladaptation or hold-ups. Therefore, the variation in the contractual length should be inversely related to the need to secure flexibility.

More formally: $Duration = f(Asset\ Specificity;\ Uncertainty;\ Complexity)$.
(+) (−) (−)

The benefits of long-term contracts increase with asset specificity needed to realize the transaction (need to secure the transaction) and decrease with the complexity and the uncertainty of the transaction (need for a flexible contract).

In order to test hypothesis (1), we follow the analysis of Joskow in assuming that the more important are relation-specific investments, the longer the period of time over which the parties will establish the terms of trade ex ante by contract. Electricity restructuring, in fact, aimed at introducing competitive dynamics in generation and distribution segments.[2] Regulators worldwide had initially organised electricity transactions in the generation wholesale segment as market (auction) transactions. This auction based governance structure, however, was not sustainable and most of the power exchanges were combined with or substituted by long-term contracts.[3]

According to transaction costs theory, profit maximising firms select their governance structure such as to minimise transaction costs. In particular, when exchange involves significant investments in relationship-specific capital, an exchange relationship relying on repeated bargaining is not attractive. "Once the investments are sunk in anticipation of performance, 'hold-up' or 'opportunism' incentives are created ex post which, if mechanisms cannot be designed to mitigate the parties' ability to act on these incentives, could make a socially cost-minimising transaction privately unattractive at the contract execution stage." (Joskow 1987, p. 169). For this reason, long-term contracts that specify the terms and conditions for future transactions ex ante represent a remedy for ex post performance problems. Electricity contracts in restructured wholesale markets are mostly long-term contracts because the activity of generating electricity requires important asset specific investment and a new generator will defer investing in a new plant, until sufficiently long-term contracts are arranged and cover a sufficient portion of the required investment.[4]

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[2] For a general survey on electricity markets restructuring, see Armstrong et al. (1994).

[3] See, for the UK case, from the Pool to the NETA (New Electricity Trading Agreements). For a reference, see Mc Carthy (2000). For a definition of long-term contracts in electricity markets, see further note.

[4] For a deep analysis of the relationship between asset-specificity and building a new electricity plant, see Armstrong et al. (1994). One of the referees suggests that a continuous variable like capacity (MW), instead of building a new unit, would serve as a better proxy for "dedicated assets" in the restructured electricity markets, because the assets we are considering are more redeployable than a dogmatic appeal to asset-specificity would suggest.

In order to test hypothesis (2), we follow the analysis of Masten and Crocker (1985) in interpreting legal provisions -like "take-or-pay" provisions- as efficient adaptation to long relationships, therefore negatively affecting the duration of long-term contracts, since long term relationships motivated by asset specific investments need flexibility and adaptation to the change of contingencies.

In addition, the research follows Saussier (2000) in the attempt to adopt two-stage least squares (2SLS) estimation techniques for operationalizing relation-specific investments and contractual provisions.

The paper differs form the cited works because the analysis applies to long-term contracts in restructured electricity markets and because the empirical analysis not only includes economic contract terms (like the exchanged quantity), but also legal provisions that might affect the contractual duration, that represent how the parties regulate and adapt to transaction specific investments. The paper contributes to the existing literature from two perspectives: 1) to our knowledge, it is the first attempt to apply econometrics to the analysis of electricity contracts; 2) it attempts to test the trade-off between the need to secure the transaction and adopt a long-term contract, and the need to design a flexible contract that enables adaptation over the course of a long-term exchange, therefore combining the two seminal approaches by Joskow (1987) and Crocker and Masten (1988).

The work is organised as follows. Section II describes the dataset formation and provides for some descriptive statistics; Section III discusses the problem of endogeneity when testing TCE and suggests solutions; Section IV presents the model specification and the 2SLS estimation results; and Section V contains the model specification and the maximum likelihood estimation results. Finally, Section VI concludes.

II. Data

The analysis of twenty-seven long-term natural gas and renewable electricity contracts for electricity, signed by the California Department of Water Resources (DWR) on behalf of California's three investor-owned utilities during the California electricity crisis, forms the basis for the creation of the dataset.[5]

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[5] We define long-term contracts as those three years in length or longer. Unfortunately, the limited number of contracts is mainly due to the fact that it is very complicated to have access to such documents and because of the nature of the transaction (long term electricity contracts for building up generating plants).

These agreements are signed between the three investor-owned generation utilities, most of which is either hydroelectric or nuclear generation (Buyers), and other electricity generators, most of which is natural gas or renewables generation (Sellers). The market structure, within which the DWR electricity contracts were negotiated, was a deregulated, partially competitive market, where most electricity transactions were carried on an anonymous power exchange, where the participants bid "quantity-price schedules" for every half an hour of the following day. The resulting electricity wholesale prices (for each half hour of the following day) are equilibrium prices derived from an auction bidding procedure. The electricity prices in DWR contracts are wholesale prices, negotiated in long term bilateral markets. The contracts have four main dimensions:

(1) the selling prices for power and energy;
(2) the amount of power and energy sold;
(3) a set of incentives to improve performance and disincentives to ensure that performance does not fall below a basic standard;[6]
(4) a set of rules regulating the (ex ante and ex post) transaction costs[7] stemming from uncertainty, complexity and (physical and dedicated) asset specificity[8] that characterize electricity markets transactions. In particular, such provisions, in turn, regulate ex post maladaptation to changing circumstances (not forecasted in the agreement); set some degree of flexibility to adapt to the long-term bargaining; create the proper insurance for the parties to recover relation-specific investments they had to bear for the sake of the contract.

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[6] On this matter, see Onofri (2003).

[7] Williamson (1975) defines transaction costs as those costs associated with the problem of contracting; the author focuses on contracts rather than on contracting. In Williamson's scenario there exist two types of transaction costs: 1) Ex ante costs: "costs of drafting, negotiating, and safeguarding an agreement" and 2) Ex post costs: "maladaption costs"; costs of renegotiating contracts in response to misalignments; set-up and operating costs of governance structures for dispute resolution; and costs of effective secure commitment. Given the existence of transaction costs, the firm has several options, which span from opting for market transactions (short-term contracts) to choosing for long-term contracts and vertical integration.

[8] Williamson identifies four types of asset-specificity: 1) site-specificity: once sited the assets are very immobile. 2) physical asset specificity: when parties make investments in machinery or equipment that are specific to a certain transaction and these have lower values in alternative uses. 3) dedicated assets: general investment by a supplier or buyer that would otherwise not be made but for the prospect of transacting a specific (large) amount an item with a particular partner. If the contract is prematurely terminated, the supplier (who invested) would be with excess capacity/ the buyer would be with unexpected excess demand. And, 4) human asset specificity: workers acquired skills, know-how and information that is more valuable inside a particular transaction than outside it.

Table 1. Variables' description and statistics

Selected variables	Description	Mean	Min.	Max.	Std. Dev.
Duration	Contract duration in years	8.92	3	20	4.26
Annual Quantity	Annual contract quantity (GWh)	2,404	22.4	9,332	2,807
Total Quantity	Contract total quantity (GWh)	21,648	112	93,325	27,239
Costs	Contract total power production costs (in Million $)	1,493	7	6,238	1,699
Fixed Payment	Contract payment type: fixed price per MWh set in the contract.	D = 1: 40.8%			
Take-or-Pay	Provision requiring the seller to provide all the electricity scheduled in the contract. Non-dispatchable contract	D = 1: 59.2%			
Availability Penalties	Contractual availability penalties	D = 1: 48.1%			
New Units	Provision that signals whether the contract provides for the construction of new power units	D = 1: 62.9%			
Prevent Regulation	Provision regulating the risk that future laws or regulation, or regulatory review of a contract, will alter the benefits or burdens of an electricity contract to either party	D = 1: 48.1%			
Naturalgas	Electricity generating resource	D = 1: 66.6%			
Wind	Electricity generating resource	D = 1: 7.4%			
Biomass	Electricity generating resource	D = 1: 11.1%			
Geothermal Energy	Electricity generating resource	D = 1: 14.9%			
Base	Base products can supply power all day every day	D = 1: 48.1%			
Peak	Peak products can supply power from 6 am to 10 pm, Monday through Saturday.	D = 1: 25.9%			
Both Base-Peak	Combined product	D = 1: 12%			
Intermittent	Intermittent wind power plants generate electricity only when wind is available	D = 1: 14%			
Duration >10	Number of Contracts lasting more than 10 years	D = 1: 74%			
Fuel Supply Risk	Provision regulating the risk that fuel supply to a power plant will be unreliable	D = 1: 33.3%			
Construction Incentives	Provision that create incentives for the seller for reaching operation by dead-line	D = 1: 62.9%			
Construction Penalties	Provision that obliges the seller to pay for not reaching operation by dead-line	D = 1: 37.1%			

Table 1. (continued) Variables' description and statistics

Selected variables	Description	Mean	Min.	Max.	Std. Dev.
Availability Incentives	Incentives for production availability	D = 1: 51.9%			
Environmental Regulation	Provision about environmental risk, stemming from both existing environmental regulations and possible future regulations	D = 1: 25.9%			
Tolling Payment	Contract Payment Type: the buyer pays for the cost of the resource used to produce electricity, pays the generator a fee to reserve the use of the facility and pays operating charges when the facility generates power	D = 1: 59.2%			

Note: All of the information contained in the table was taken from our review of the contracts, except the estimates of the ten-year energy purchases, price range, and ten-year power costs, which are derived from other sources (e.g., U.S. Energy Information Administration 2002). D stands for a dummy variable that takes value 1 when the characteristic is present, and 0 otherwise.

Table 1 summarizes some of the principal terms of the twenty-seven long-term contracts.

From the analysis of each contract, we have selected the main legal and economic provisions and created the variables we needed to perform our econometric study. In general, the contracts contain information about the price at which energy is sold (setting a minimum and a maximum price range); costs of energy production; quantity of energy produced; production capacity; contract duration; dispatchability[9]; type of fuel used to produce energy (natural gas or renewables, like wind, geothermal energy, or biomass); type of electricity produced (whether base, peak, both base and peak or intermittent[10]); type of pricing mechanism (tolling or fixed price[11]);

[9] Non-dispatchable contracts (containing "take-or-pay" provisions) require the buyer to pay for, and the seller to provide, all the electricity scheduled in the contract. Dispatchable contracts allow the buyer to choose the amount of electricity to be generated, within particular limits set in the contract.

[10] Baseload products (7x24) can supply power all day every day (approximately 8,760 hours per year). Peak products (6x16) generally can supply power from 6 am to 10 pm, Monday through Saturday (approximately 5,000 hours per year). Intermittent wind power plants generate electricity only when wind is available.

[11] When *tolling*, the buyer pays for the cost of the resource used to produce electricity, pays the generator a fee to reserve the use of the facility and pays operating charges when the facility generates power. When there is a *fixed price*, there is a price per MWh set in the contract.

provisions about how to manage risk (fuel price risk; fuel supply risk; performance risk; demand risk; environmental risk and other type of risk[12]). Table 1 also contains some variables summary statistics. Table 2 is a correlation matrix of some elected variables that we further use in the regression analysis.

Table 2. Variables' correlation matrix

n = 27	*Duration*	*Total Quantity*	*Annual Quantity*	*Log-Quantity*	*Take-or-Pay*	*Tolling Payment*	*New Units*	*Availability Penalties*
Total Quantity	0.15	-						
Annual Quantity	0.01	0.96	-					
Log-Quantity	0.03	0.84	0.85	-				
Take-or-Pay	-0.35	0.22	0.21	-0.09	-			
Tolling Payment	0.17	0.01	0.03	0.19	-0.84	-		
New Units	0.37	-0.15	-0.25	-0.16	-0.37	0.37	-	
Availability Penalties	0.08	-0.41	-0.47	0.35	-0.55	0.55	0.62	-
Environmental Regulation	0.37	-0.15	-0.21	0.02	-0.71	0.71	0.38	0.61

[12] The *fuel price risk* is the risk that the price of the fuel used to generate electricity will exhibit variability (positive or negative) resulting in an uncertain cost to generate electricity. The *fuel supply risk* is the risk that the fuel supply to a power plant will be unreliable, resulting in the inability to generate electricity in a predictable and dependable manner. The *performance risk* is the risk that either party to an electricity contract will not fulfill its part of the agreement in an optional manner. The *demand risk* is the risk that the electricity that has been contracted for will not be needed as anticipated. The *financial risk* is the risk to which parties to an electricity contract are exposed, stemming from both existing environmental regulations and possible future regulations. The parties to an electricity contract face numerous *other sources of risk* (i.e. the risk that the transmission system will be unreliable: or the risk that a party to the contract will default on the contract, by entering into bankruptcy).

III. Empirical strategy: the endogeneity problem of contractual provisions

We want to simultaneously test two main hypotheses, that given one party dedicated assets to specific relationship, the contracting parties will commit to a longer term contract. At the same time, long-term contracts have to allow for (efficient) flexibility, in order to avoid ex post maladaptation or hold-ups.

The hypotheses reflect the general theory that contract terms both align ex ante marginal incentives and prevent wasteful efforts towards ex post redistribution of existing surplus. In the case at study, electricity contract provisions have both to secure sufficient reliability (for instance, by setting a longer duration to the contract) in order to allow the contracting parties (in particular the Seller) the recovery of ex ante durable transaction-specific investments. In fact, given that one party dedicates assets to a specific relationship, the contracting parties will commit to a longer term contract. At the same time, long-term contracts have to allow for (efficient) flexibility, in order to avoid ex post maladaptation and hold-ups.

We select the contract duration as the regression analysis dependent variable, on the grounds that the more important are relation-specific investments (i.e., building a new electricity production plant), the longer will be the period of time over which the parties will exchange the terms of trade ex ante by contract. However, when the contracts contain provisions that allow for ex post contingent adaptation, we expect such variables to negatively affect contract duration.

In order to empirically capture and operationalize the relationships between long term contracts and contractual provisions that enable efficient adaptation, we have to make some distinctions about the "nature" of contractual provisions. We assume that some contract provisions (like production capacity or the electricity production inputs) are determined before parties determine contract duration.[13] That is, such contract provisions are "predetermined variables" and, therefore, can be treated and interpreted as exogenous variables in the estimation of contract duration.

At the same time, modelling and testing the above hypothesis implies finding variables reflecting the decision to make specific investments. As pointed out in Saussier (2000, p. 201), "…many empirical attempts to refute transaction cost

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[13] The construction of a new generation electricity plant differs according to the type of generated product (base, peak or both) and to the type of generating resource (gas, wind and so on). All this generates different production costs and production capacities. The decision about whether building a new plant; type of electricity plant and production technology is definitely prior to the decision of the contract duration and the parties performance regulation.

economics ignore the possible endogeneity of asset specificity when testing the heuristic transaction cost model or avoid the endogeneity problem by estimating a reduced-form using proxies to reflect asset specificity levels at stake in transactions. These approaches…can be surpassed by taking into account the endogeneity of several explanatory variables, in what is known as the limited-information approach. To our knowledge, no econometric test has yet tried to endogenize asset specificity at stake in transactions. Williamson's advice (1993, p. 27) is worth quoting: 'To be sure, there is much to be done, hence there is no basis for complacency…most (empirical studies) are regressions in which asset specificity (and sometimes uncertainty and frequency) appear as independent variables'. This point requires urgent attention in the development of empirical tests of the theory".

Following Masten (1995, p. 60) we agree that "The specificity of assets and the level of investment in those assets that determine the size of appropriable quasi-rents are themselves decision variables. The location of facilities, the adoption of specialized designs or equipment, and the scale of investments should all, by rights, be treated as endogenous variables." This is why, following both Masten and Saussier (2002)[14], we endogenize the independent variable *New Units*, the dummy variable that represents whether the contract provides for the construction of new power units and captures the idea of dedicated assets and physical assets specificity as described in Williamson framework, by using the following argument. Building a new plant is an important, durable relation-specific investment because if the buyer breaches the contract and does not purchase electricity, the seller cannot easily reconvert the electricity plant for other purposes. Building a new plant takes from one year and a half to 3 years, depending on the adopted production technology. Electricity generation is capital intensive and investment costs are sunk. In addition,

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[14] "To endogenize CAPA (coal transportation capacity) and SITEDEF (site investment measured in monetary terms), we propose several elements that should influence the willingness of the parties to invest in specific assets: 1) Each river concerned in the contract (Loire, Seine or Rhône) has its distinct characteristics (depth, distance between port and power plants, sluice size) that influence technical choices and investment levels. We expect greater asset specificity in contracts for coal transportation on the Loire, because the river's sluices are larger than those on the Seine or the Rhône, and the distance between the port and power plants is shorter. These are two good reasons for EDF and its suppliers to make more specific investments rather than take other routes to cut transportation costs…2) With the changes in coal consumption by the French power-generation industry and the decline in the use of coal to produce electricity, the incentive to develop asset specificity (in order to reduce production costs) may disappear...3) With regards to the electrical output of the power plant concerned in the contract, each contract applies to a different plant, each with a different output. There are eleven coal-fired power plants in France, whose output ranges from 250MW to 1800MW…."(Saussier 2000, p. 201-202).

supply security requires that total capacity exceeds expected demand with a margin to allow for uncertainty. In general a very complex structure features the electricity markets, and this complexity affects the design of electricity transactions.[15] The generation function generally includes planning, designing, constructing, procuring fuel for, and operating the facilities necessary to produce electricity for delivery to consumers. Producing electricity means to supply a very particular good: electricity cannot be stored[16], except at prohibitively high costs, and it must be moved on a closely co-ordinated, integrated system, displaying large economies of scale.

Our sample of electricity contracts also contains a set of provisions that enable for efficient adaptation of the agreements to changing circumstances that might occur during the long-term contract life-cycle and might affect the execution stage, by causing maladaptation or hold-ups.[17]

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[15] The electricity industry, in fact, presents peculiar features, including: temporal and stochastic variability of demands and supply, non-storability of power, multiple technologies with varying sensitivities to capital and fuel costs, environmental and siting restrictions, dependence on a secure and reliable transmission system.

[16] Electricity, in fact, can't be stored, because supply and demand conditions change virtually instantaneously on an interconnected system, making it impossible, for decentralized markets, to manage physical transactions efficiently. At the same time, electricity demand fluctuates by time of day and year, as the weather varies, and randomly. Supply is also subjected to predictable outages. However, equilibrium between supply and demand must be maintained continuously and throughout the system. This combination of circumstances poses considerable problems for the organization of supply.

[17] A typical problem that might occur in electricity transactions, stemming from the technical characteristics of the electricity industry, is the problem of market power that can affect the contract execution stage, by causing ex post maladaptation and hold-ups. The electricity industry is characterized by extremely costly storage; significant capacity constraints in its production and transmission over the network; and highly variable and inelastic demand. An electricity spot market is unlike virtually any other market in that demand and supply must be equalized throughout the electricity grid, at every moment in time, continuously maintaining network "electrical equilibrium". These features, coupled with the virtual impossibility of storing electricity, implies that inventories cannot be used, as in most other markets, to mitigate the problem of the lack of available capacity and the resulting increase in prices in periods of high demand. The existence of binding capacity constraints on its production implies that, in periods of high demand, there will typically be one or several firms whose capacity is needed to balance the system, even when its competitors are operating at full capacity. This allows such a firm(s) to ask for extremely high prices with no risk of losing production. Furthermore, transmission constraints imply that separate markets may be created; depending on supply and demand conditions, as well as on the state of the transmission system, the ability to supply power from one geographic area to another may be severely limited. This gives rise to pockets of local market power were certain firms, insulated from the potential competition in adjacent areas, stand at a monopoly position. The low elasticity of demand further exacerbates the problems of market power.

To overcome this problem, the electricity contracts provide for efficient adaptation, including particular provisions like dispatchability provisions; availability incentives or different payment schemes. These provisions are interpreted as efficient instruments for providing flexibility in long-term relationships and regulate two opposite requirements. On the one hand, the parties, locked into a bilateral relationship, attempt both to secure their long-term agreement; on the other hand, the parties try to provide for some flexibility in the contract. In fact, long term horizons might require some flexible arrangements in order to adapt to changing circumstances that may occur in a very long-term time span. Our analysis, therefore, considers this group of provisions as endogenous variables, (positively or negatively) affecting the contractual duration

IV. 2SLS estimation results

Given the issues discussed in the previous paragraph, our econometrics of contracts continues by selecting a simple linear specification and estimating it by 2SLS method.

$$(Log\_)Duration_i = \alpha_i + \beta_1 Y_i + \gamma_2 Z_i + \varepsilon_i \qquad (1)$$

We attempt to estimate both the dependent variable *Duration* (contractual duration) and its logarithm, *Log_Duration*. In the latter case, as pointed by a referee, the empirical model can be interpreted as a duration model featuring log-normal hazards.

In (1), Y_i indicates the endogenous variables, including terms of contract, and Z_i indicates instruments. In particular, we estimate a simultaneous equation model where the selected instruments (plant capacity; electricity product; production costs; fuel type and other technical indications) represent variables determined before contracting.

The selected endogenous variables (*Fixed Payment*; *New Units* and *Take-or-Pay*) represent provisions that are jointly determined within the contract and that are jointly determined with the contract duration, in order to allow for contingent adaptation.

The 2SLS estimates (as reported in Table 3, columns 1 and 2) show that the adoption of *Take-or-Pay* provisions and *Fixed Payment* provisions in long-term contracts can be interpreted in the light of fluctuations in demand or costs, that may make it unprofitable or even inefficient, to carry out the original objectives of a

Table 3. Estimates for contract duration

Independent variables	*Duration* (1)	*Log_Duration* (2)	*Duration>10* (3)	*Duration>10* (4)
Log-Quantity	-	-	0.50**	1.05**
Fixed Payment	-2.62**	-0.45	-0.84	-2.07
Take-or-Pay	-3.82	-0.06	-0.05*	-0.28
Availability Penalties	-	-	-0.17	-0.43
New Units	3.99***	0.51***	1.60*	3.14*
Prevent Regulation	-	-	0.44*	0.22
Constant	9.44***	1.73*	-6.25**	-12.46**
Estimation method	2SLS estimate	2SLS estimate	Probit	Logit
Pseudo R^2	-	-	0.36	0.39
Loglikelihood	-	-	-8.780	-8.405

Notes: *, **, and *** denote 10%, 5% and 1% significance.

contract. By altering incentives to accept or reject delivery, *Take-or-Pay* provisions and fixed payment schemes can induce buyers to release investments to their alternative uses only when it is efficient to do so. At the same time, however, the contract will set shorter terms of duration (about 4 year less when the contract includes a *Take-or-Pay* provision; and about 3 years less when it contains fixed payments provisions). On the other hand, the choice to build an electricity generation new plant represents both a physical and dedicated asset specific relation that implies longer contractual terms (about 4 years) in order to avoid hold-ups. The trade-off between the need to secure idiosyncratic transactions and the need to secure adaptation in long-term contracts seems to be verified by the obtained results.

V. Alternative estimation specifications and methods

We attempt to adopt different empirical specifications and estimation methods in order to test the trade-offs between enabling adaptation and diminishing the effectiveness of the long-term contracts, designed as *prima facie* hold-up remedies.

We continue the analysis by considering only the population of electricity contracts with the longest duration (ten years and more). In this way, we can refine the analysis by using a sample of longer-term contracts and check whether and how asset-specificity affects the duration of the electricity contracts. In this case, the OLS estimation method would not be efficient because the sampling process might imply that the variance of the error term is not constant but dependent upon the explanatory variables. To solve for this problem, we can specify the likelihood function of the sample and then estimate the obtained logit and probit models by maximum likelihood.

$$\begin{aligned} Duration > 10_i = \ & \beta_0 + \beta_1 \, Log\_Quantity_i + \beta_2 \, New\ Units_i + \beta_3 \, Take\text{-}or\text{-}Pay_i \\ & + \beta_4 \, Fixed\ Payments_i + \beta_5 \, Availability\ Penalties_i \\ & + \beta_6 \, Prevent\ Regulation + \varepsilon_i \end{aligned} \quad (2)$$

The hypothesized relationship between asset specificity and contract duration implies that both β_1 and β_2 should present positive estimated coefficients. The hypothesized relationship between asset specificity, contract duration and contract flexibility implies that both β_3 and β_4 should present negative estimated coefficients. Building a new power plant and trading a large amount of power positively affect the probability that the contract lasts ten years or more. The adoption in the contract of *Take-or-Pay* provisions and fixed payment schemes negatively affects the probability of a long contractual duration.

The variables *Availability Penalties* and *Prevent Regulation* signal the need of flexibility that electricity transactions require, even if they occur through long-term agreements. In fact, supply security requires that the production total capacity exceeds expected demand with an availability margin to allow for uncertainty. Some contracts, therefore, prescribe for a set of penalties and incentives in order to "coordinate" the generator output with the market needs and the system equilibrium (*Availability Penalties*). *Prevent Regulation* is the dummy variable that operationalise the provision regulating the risk that future laws or regulation, or regulatory review of a contract, will alter the benefits (or burdens) of an electricity contract to either party. Both provisions regulate a need for flexibility in the long-term contracts. Flexibility is required to adapt to uncertain circumstances that might occur and affect the electricity transactions. We expect, therefore, negative estimated coefficients for both β_5 and β_6.

Again, the empirical model attempts to capture the trade-off between the need to secure the investment specific transaction and the need for flexibility in the long-term bargain.

The maximum likelihood estimation results reported in column 3 of Table 3 for the probit model, and in column 4 for the logit model, confirm the hypothesised relationship between asset specificity, need for flexibility and contractual duration. The signs of the estimated coefficients are as predicted.

VI. Conclusions

The paper has studied an important, to our knowledge under-studied, problem in IO: how to maintain flexibility in long-term exchange relations while at the same time mitigating hold-ups. This problem involves trade-offs: long term contracts are needed to secure asset specific investment, but negatively affect flexible adaptation to unexpected circumstances and/or uncertainty.

In particular, following Joskow, we have attempted to empirically capture the positive relationship between physical assets specificity and the duration of long-term contracts, stipulated between California electricity generators. In addition, following Masten and Crocker (1985), we have tried to capture the effect of selected legal provisions and interpret them as efficient instruments for providing flexibility in long-term relationships. The main result is that as the investment in relationship-specific assets becomes more important, the longer becomes the contractual duration. However, the parties will mitigate the long-term contracts inflexibility, based on ex ante bargained terms and conditions, with provisions that allow for contingent adaptation. Our empirical evidence highlights the trade-off between the parties' need to secure idiosyncratic transactions and the parties' need to get flexibility in long term relationships. The empirical results provide support for the hypothesised relationships and stem from different model specifications and alternative estimation techniques.

The obvious policy conclusion is that private parties are perfectly able to adapt to the specificity of the transactions in an efficient transaction costs minimising manner. In our opinion, this is the real challenge of electricity markets restructuring: let the parties adapt to the legal and institutional deregulated setting.

Further research should focus on improving the use of econometric instruments to test TCE. One approach might be the performance of non-parametric analysis that allows to capture relationship among the variables and to analyze data without assuming an underlying distribution. Another approach should focus on the attempt to operationalize the direct relationship between asset specificity and contract duration by using a continuous variable like capacity (MW), instead of *New Units*. Finally, the research agenda should focus on the need to solve and encompass the (asset specificity) endogeneity problem.

References

Armstrong, Mark C., Simon Cowan, and John Vickers (1994), *Regulatory reform: Economic analysis and British experience*, Cambridge, MA, MIT Press.

Bercovitz, Janet E. (1999), The organizational choice decision in business-format franchising: An empirical test, unpublished manuscript, Duke University.

California Department of Water Resources (2002), *California Energy Resources Scheduling Division Energy Costs*, www.water.ca.gov/newsreleases/2002/energy/4-2monthlycostsummarymar.

Crocker, Keith J. and Masten, Scott E. (1988), Mitigating contractual hazards: unilateral options and contract length, *Rand Journal of Economics* **19**: 327-343.

Joskow, Paul (1987), Contract duration and relationship specific investments: Empirical evidence from coal markets, American *Economic Review* **77**: 168-85.

Lyons, Bruce (1994), Contracts and specific investment: An empirical test of transaction cost theory, *Journal of Economics and Management Strategy* **3**: 257-278.

Masten, Scott E. (1995), Empirical research in transaction cost economics: Challenges, progress, directions, in J. Groenewegen, ed., *transaction cost economics and beyond*, Amsterdam, Kluwer.

Masten, Scott E., and Keith J. Crocker (1985), Efficient adaptation in long-term contracts: Take-or-pay provisions for natural gas, *American Economic Review* **75**: 1083-93.

Masten, Scott, E., and Stephane Saussier (2002), Econometrics of contracts: An assessment of developments in the empirical literature of contracting, in E. Brousseau and J.M. Glachant, eds., *The economics of contracts: Theories and applications*, Cambridge, Cambridge University Press.

Mc Carthy, Callum (2000), The British experience: From Pool to the New Trading Arrangements, in *Proceedings of the electricity market conference*, 4 July 2000, Rome.

Onofri, Laura (2003), Contracts, investment incentives and efficiency in the restructured electricity market, *European Journal of Law and Economics* **16**: 23-38.

Saussier, Stephane (1998), Théorie des coûts de transaction et durée des contrats: une analyse empirique, *Economie et Prévision* **135**: 137-147.

Saussier, Stephane (1999), Transaction cost economics and contract duration, *Louvain Economic Review* **65**: 3–21.

Saussier, Stephane (2000), Transaction costs and contractual completeness, *Journal of Economic Behavior and Organization*, **42**: 189-206.

Saussier, Stephane (2002), *Econometrics of contracts*, ESNIE Annual Conference, unpublished power point presentation.

U.S. Energy Information Administration (2002), *Average price of natural gas sold to electric utility consumers*, http://www.eia.doe.gov/emeu/states/_states_ng.html (accessed 10 April 2002).

Williamson, Oliver (1975), *Market and hierarchies: Analysis and antitrust implications,* New York, NY, Free Press.

Williamson, Oliver (1993), The economic analysis of institutions and organisations - in general and with respect to country studies, working paper, OECD.