Do Firms Sell Forward Contracts for Strategic Reasons? An Application to the Dutch Wholesale Market for Natural Gas*

Remco van Eijkel† José Luis Moraga-González‡

January 7, 2010

Abstract

We develop an empirical strategy to test whether firms use forward contracts for strategic motives or just for risk-hedging motives. We present a model of the interaction of risk-averse firms that compete in a forward market before they set quantities in a spot market. The empirical test exploits the effects of entry of new players on the total-to-forward-sales ratio. The theoretical model predicts that when contracts are used only for risk-hedging reasons, the total-to-forward-sales ratio goes up as new players enter the market; by contrast, if the strategic incentive is also present, the total-to-forward-sales ratio may increase or decrease as firm entry occurs, depending on the degree of observability in the market. Using data from the Dutch wholesale market for natural gas where we observe entry, forward and total sales, we find that forward contracts are used for strategic reasons rather than for risk-hedging motives.

*__PRELIMINARY AND IMCOMPLETE. DO NOT CITE WITHOUT THE AUTHORS' PERMISSION.__

†Department of Economics and Econometrics, University of Groningen. Email: r.van.eijkel@rug.nl

‡Department of Economics and Econometrics, University of Groningen; and IESE Business School, University of Navarra. E-mail: j.l.moraga-gonzalez@rug.nl.

1 Introduction

Electricity and gas industries used to be vertically integrated monopolies, state-owned or not, operating under regulatory constraints. Each country used to have a national monopolistic importer, which typically owned the transmission network. This monopoly either sold directly to consumers or to downstream (distribution) monopolies, which in turn sold to consumers. One-to-one negotiations was the standard of trade throughout the value chain and the different parties were typically subject to long-lasting contractual relationships.

The pursue of a fully integrated internal market led European authorities to enact various energy policy measures aimed at a gradual liberalisation of energy markets. A key feature was the unbundling of the integrated companies. The vertical separation of production and transportation enabled the creation of spot commodity markets, the so-called 'Pools' in power markets and the 'Gas Hubs' in the natural gas industry. Economists and policy makers emphasized the desirability of liquid spot markets instead of the traditional long-term contracts as the main trading mechanism in retail markets (see e.g. the recently published *DG Competition Report on Energy Sector Inquiry* (EC,2007)). The idea is that a well-functioning spot market allocates scarce resources more efficiently than bilateral negotiations; moreover, the information content of prices in well functioning spot markets constitutes a better guide for entry and investment in the industry.

In spite of the efforts undertaken to create liquid, well-functioning spot markets, still their importance is limited. For example, in the gas sector most of the trade is forward trade, taking place either via bilateral negotiations, via brokers or at centralized marketplaces and so little gas passes through the spot market. In power markets, it is often the case that almost all trades must pass through the Pools, however the great majority of the volumes are hedged via forward contracts. The question that arises is why firms find forward trading an attractive alternative to supplying their output in the spot market.

A first motive for trading forward is *risk hedging*. Forward contracts typically specify fixed delivery prices so risk-averse market participants can mitigate their exposure to price shocks in the spot market by acquiring a portfolio of futures. A central result in the literature relates to a competitive firm facing price uncertainty (see e.g. Holthausen, 1979). This type of firm turns out to choose its output as if it were operating under certainty. When a firm faces a downward sloping demand curve in the forward market and/or the spot market, then output is no longer independent of demand shocks and firms' optimally hedge against price fluctuations (see e.g. Katz, 1984; and Eldor and Zilcha, 1990). The existence of this risk-hedging motive for forward trading in real-world markets has been examined by e.g. Bessembinder and Lemmon (2006) and Longstaff and Wang (2004).

In their influential paper, Allaz and Vila (1993) proposed a second, *strategic*, motive for trading in a forward market. Forward contracts confer competitive advantages to firms with market power and, even when there is no uncertainty at all about future market conditions, firms have incentives to engage in forward trading. In a Cournot duopoly, they show that by selling forward, a firm puts a lower value on a high spot market price and therefore commits to a more aggressive behavior in the spot market. As a result, its competitors adhere to a less aggressive spot market strategy and this benefits the firm. However, because every seller has the incentive to use the forward market to compete more intensively, the resulting equilibrium output is higher and the price lower than in the absence of a futures market. Allaz and Vila show that the market outcome approaches the competitive limit as the number or forward trading periods approaches infinity. The model of Allaz and Vila has been adapted to suit the particular organization of power markets by Powell (1993), Newbery (1998) and Green (1999), among others.

The strategic motive behind firms' use of forward contracts presented in Allaz and Vila (1993) obtains under an array of assumptions and has therefore been subject to a significant amount of debate in the economics literature. One problem has to do with the mode of competition. Newbery (1998) and Green (1999) show that when firms compete in supply schedules in the spot market and in quantities in the contract market, then the contract cover firms choose is zero. Another important problem is related to the assumption that sellers are able to perfectly observe each other's forward (net) positions. Kao and Hughes (1997) study a commodity market where firms do not observe the forward positions of their rivals. They find that in such a situation the pro-competitive effect of forward markets also fails to exist. A third problem has to do with the number of periods the contract market opens. Ferreira (2003) studies a market where firms are able to sell in a futures market at infinitely many moments prior to the spot market and concludes, differently from Allaz and Vila, that the availability of futures markets may have an anti-competitive effect in oligopolistic markets. Finally, Mahenc and Salanié (2006) show that if firms compete in prices instead of quantities in a market with product differentiation, the presence of a forward market leads to a less competitive outcome.

The extent to which strategic reasons play a role in explaining observed forward contracting in real-world markets is, therefore, ultimately an empirical question. To the best of our knowledge, only the paper of Green (1999) takes up this issue. Studying the 1991-1996 post-deregulation electricity wholesale market in England and Wales. Using yearly data from the Monopolies and Mergers Commission, he shows how the two dominant generators sold contracts for almost all of their sales in that period.

The present paper is an attempt to fill this void in the context of the natural gas markets. For this purpose, we develop an empirical strategy to test whether firms use forward contracts for strategic motives or just for risk hedging motives only. We present a model of the interaction of risk-averse firms that compete in a forward market before they set quantities in a spot market.[1] The empirical test exploits the effects that entry of new players has on the equilibrium total-to-forward-sales ratio, or *(forward sales + spot sales)/ forward sales*. When contracts are used only for risk-hedging reasons, the total-to-forward-sales ratio goes up as new players enter the market; by contrast, if the strategic incentive is also present, then the total-to-forward-sales ratio may increase or decrease as firm entry occurs, depending on the degree of observability in the market. Using data from the Dutch wholesale market for natural gas where we observe entry, forward and total sales, we find that forward contracts are used for strategic reasons rather than for risk-hedging motives.

In our model there are three forces at work that shape the incentives of a firm to trade forward. The first two, the risk-hedging effect and the strategic effect, are pro-contracts and have been discussed above. The third is a *price* effect that arises because offering forward contracts lowers overall prices (spot and forward). This price effect actually puts a downward pressure on firm's (expected) profits and therefore makes forward contracting less attractive. Indeed, a risk-neutral monopolist would never engage in forward contracting (see Tirole, 2006).

[1] A great deal of the effort of Powell (1993), Newbery (1998) and Green (1999) is on developing models that suit closely the power markets in the UK. Notably, these papers extend the model of Allaz and Vila (1993) to an environment similar to the Pool, where firms first offer contracts for differences and then compete in the spot market in supply schedules. The natural gas market is different. Wholesalers have take or pay contracts so their marginal costs are constant, though different across players. We model the contract and the spot market as Cournot markets.

We consider an oligopoly with n risk-averse firms selling a homogeneous good and allow for marginal cost differences across firms. Apart from selling their output in a spot market, firms can also sell (or buy) the good in a forward market. Clearly, committing to a particular forward position has a strategic benefit only if it is observed by rival firms. In this light, we assume that with certain probability firms' actions in the forward market will become known by the competitors. Our model thus accommodates the Allaz and Vila case (forward trading is observed with probability one) and the setting of Kao and Hughes (forward positions become publicly known with zero probability), as well as intermediate cases of the two extremes. As we will see, the probability of observability considerably affects the incentives to trade forward and therefore affects the total-to-forward-sales ratio.

When the forward positions of the players are observable infrequently, the strategic effect is hardly present and the contract cover of a firm trades off the the risk-hedging effect against the price effect. In that situation we show that the incentive to hedge against demand shocks becomes less strong if more suppliers enter the market, which has a strengthening effect on the total-to-forward-sales ratio. The reason for this is that at the contracting stage, the rivals' strategies are random so the residual demand of a particular firm is less susceptible to fluctuating demand the higher the number of competitors. In addition, the price effect also puts an upward pressure on the ratio of interest if more firms enter the market. This is because the price effect does not (marginally) depend on the number of competitors, while the spot market sales are negatively affected by an increase in the number of active firms. Therefore, it is clear that when forward contracts are not observable forward sales as a fraction of total output increase in the number of suppliers.

If the forward price and/or the forward positions of the rival firms are regularly observable, next to the risk-hedging effect and the price effect, the strategic effect plays a role. This strategic effect turns out to be stronger as more players are around. This is because the (marginal) gains from affecting the rivals' spot market behavior rise with the number of competitors. While the risk-hedging and the price effect weakens as the number of competitors increases, we show that the strategic effect may have a dominating influence. Whether, ultimately, market entry has an upward or downward effect on the total-to-forward-sales ratio in case of observable forward positions depends on to what extent forward positions become observable.

We test for the existence of both the risk-hedging effect and the strategic effect of forward contracting in the Dutch wholesale market for natural gas. It is especially at this level where efforts have been made to create liquid gas markets and to aid this process, trading "hubs" and exchanges have been created.[2] The existence of hubs makes it possible for gas exchanges to arise. Our data set consists of a fairly large fraction of all trades conducted at the Dutch gas hub TTF, as well as the number of shippers active at TTF for the period from April 2003 until December 2006.[3] Using these data, we find that forward contracts are used for risk-hedging motives as well as for strategic reasons.

The rest of the paper is organized as follows. The next section discusses in somewhat more detail the institutions of the Dutch wholesale gas market. Section 3 presents a two-period model of competition. In the first period, the forward market opens and firms sell quantities. In the second period, the spot market opens, firms trade and all delivery of forward and spot quantities contracted takes places. The model presents the main empirical prediction of the model that we take to the data in Section 4. The paper closes with a discussion of the main results and some concluding remarks.

2 The Dutch wholesale market for natural gas

Traditionally, gas supply in the Dutch wholesale market was controlled by NV Nederlandse Gasunie, the integrated network company.[4] Gasunie did not only own the transmission network, but also had control over the national distribution pipelines and had access to gas supplies that originated from the Dutch gas fields or could be imported via long-term contracts signed with foreign producers.[5] In turn, it sold this gas to industrial costumers and distribution companies against a price that was linked to the oil price.

In order to limit the monopoly rents flowing to the Gasunie, not only the oil price link was

[2]Hubs can be virtual (like the Dutch Title Transfer Facility, TTF) or physical (like the Zeebrugge hub). Virtual marketplaces typically offer market parties the possibility to buy and sell gas that is already injected into (or for which transportation capacity has been booked in) the national gas transmission grid.

[3]In the past, the lack of data on contracts due to confidentiality reasons has precluded the proliferation of empirical work on forward contracts. Luckily, our data set is quite rich since it not only contains monthly spot and forward sales, but also includes the per month number of firms that are active at TTF.

[4]Gasunie was a joint venture between De Staatsmijnen (DSM), Shell, Esso and the Dutch State.

[5]The bulk of Dutch gas production takes place in the Groningen gas field. After the discovery of this field in 1959, the Nederlandse Aardolie Maatschappij (NAM), a joint venture between Shell and Esso, obtained a concession to explore this gas field. The NAM was however obliged to sell all the gas extracted from the Groningen field (and other small fields in the Netherlands) to Gasunie.

imposed, but there also existed a cap on the profits Gasunie was allowed to make. Due to these policy measures and a lack of competitive pressures, the incentives to reduce cost and to invest in infrastructure were rather weak. In the early 1990s, voices raised to follow the Anglo-Saxon liberalisation process that started in the 1980s, so as to restrict the inefficiencies that were present in the market. The market deregulation in the Netherlands started back in the late 1990s with the Price Transparency Directive, but gained full momentum with the First Gas Directive, annunciated by the European Commission. This ruling abolished import monopolies, forced the opening of markets and imposed the accounting unbundling of vertically integrated network companies.

The Second Gas Directive furthered the liberalisation by requiring full market opening, regulated third party network access, regulated or negotiated access to storage and legal unbundling of integrated network companies. As a consequence, Gasunie has been split up in two independent companies: Gas Transportation Services (GTS) controls the national transmission network and Gasterra is engaged in gas wholesaling. The Second Directive also requires the creation of national energy regulators. Their main roles include the approval of transmission and distribution tariffs, ensuring new entrants have access to the transmission networks and making sure the unbundling process is complete. The underlying objective of these measures is to ensure that all customers are able to freely choose among a significant number of gas suppliers.

Since retailers acquire gas from wholesalers, and in turn sell it to final consumers or industrial costumers, the development of a liquid wholesale market is crucial for retailers to have easy access to sources of supply. Especially new entrants at the retail level, who often do not have direct access to the gas supply of producers or wholesalers, have to rely on sources of supply that are not based on bilateral negotiations. In order to attain a well-functioning gas market, the Dutch Title Transfer Facility (TTF) has been created. The TTF is a virtual trading hub that offers market parties/shippers the possibility to buy and sell gas that is already injected into (or for which transportation capacity has been booked in) the national gas transmission grid. That is, gas for which entry capacity in the GTS system has already been booked can relatively easy change hands before it is extracted from the national system at a specific exit point.

The existence of the TTF makes it possible for gas exchanges to arise. Two companies have been appointed by the Ministry of Economic Affairs as gas exchanges for the Dutch gas market, namely ENDEX N.V. and APX Gas NL B.V. At ENDEX firms sell and buy forward contracts, with the minimum length of a contract being equal to one month and the maximum length being one (calendar) year. At APX, market parties can trade gas one day ahead and within the day of delivery. These exchanges a real-time markets where wholesalers, retailers and speculators participate. Among the services delivered by these two exchanges are the netting of traders' forward positions, nominating the shippers' net positions to GTS and reducing the counterparty risk by clearing the contracts traded. Speculators do not deliver gas to final consumers so they have to offset their positions before actual delivery takes place. While in the past almost all TTF-trade occurred via one-to-one negotiations or was facilitated by brokers, recently exchange-based trade has gained significance.[6]

Despite the efforts undertaken to create a liquid wholesale market, most of the gas traded in the Netherlands does not pass the TTF. According to the the Dutch antitrust authority NMa, one of the main reasons for the underdevelopment of the TTF is that Gasterra, the incumbent wholesaler, still enjoys inherited privileges (NMa, 2007). For instance, it is the sole wholesaler who has access to the low-calorific gas that flows from the Groningen gas field and is meant for household usage. Furthermore, Gasterra also largely controls upstream high-calorific gas supplies from foreign producers, since the bilateral agreements reached in the pre-liberalization period are still in force today. In addition, as is also recognized by the European Commission (EC, 2007), existing contracts between producers and importing incumbents are often extended into the future. To be able to engage in profitable price discrimination, Gasterra mostly bypasses the TTF ans sells gas via one-to-one negotiations.

Other explanations for the lack of liquidity at the TTF are that there is insufficient conversion capacity of high-calorific gas to low-calorific gas and that, due to limited pipeline capacity, foreign producers and wholesalers do not have easy access to the Dutch gas market. We however notice that very recently, the share of TTF-traded gas in total gas traded in the Netherlands exhibits a clear upward trend. In September 2008, about 23 percent of total Dutch gas trade passed through the TTF, with most of this gas being traded on a forward basis. In the next section, we develop a model in which different motives to engage in forward contracting coexist. The equilibrium outcomes provides us with an empirical strategy to test

[6] Gas sold at the centralized exchanges as a fraction of total TTF-trade grew from 0.5 percent in November 2006 to 7 percent in September 2008.

whether the strategic incentive of selling forward is present in the Dutch gas market.

3 A model of forward and spot contracting

Consider an oligopolistic market with n asymmetric risk-averse firms selling a homogeneous good at a firm-specific constant marginal cost c_i. Firms can sell output in the spot market; in addition, firms can also sell (or buy) the good in a forward market. Let s_i and x_i be, respectively, firm i's total spot and forward market sales; the total output firm i supplies on the market will be denoted $q_i(= s_i + x_i)$.

The fundamental distinction between the spot and the forward markets relates to demand uncertainty. We assume that market demand is random and given by the linear-normal specification

$$P = a + \epsilon - Q,\ \epsilon \sim N(0, \sigma^2), \tag{1}$$

where $Q = \sum_{i=1}^{n} q_i$ denotes the total output delivered and ϵ is a zero-mean random shock normally distributed with standard deviation σ. We assume that the realization of ϵ is observed when the spot market opens. Therefore, firm i chooses its spot sales to maximize its spot market profits. At the forward market stage, by contrast, firms are uncertain about the price that will prevail in the market. We assume that firm i has a risk-aversion parameter ρ_i and maximizes expected utility:

$$E[u(\pi_i)] = E[-e^{-\rho_i \pi_i}] \tag{2}$$

where π_i denotes firm i's profits.

Next, it is assumed that firms observe each other's forward positions with probability γ. If $\gamma = 1$, we get the standard Allaz and Vila setting where actions in the forward market are fully observable. By contrast, if $\gamma = 0$ we obtain the case of unobservable forward trading, as is discussed by Kao and Hughes (1997). Moreover, our model accommodates intermediate situations where firms, at the time they are active in the forward market, are not certain about whether rivals will become aware of their forward market actions. As we will see, the higher the probability that the contract cover becomes known by the competitors, the stronger the incentive for firms to engage in forward contracting. In strict sense, γ relates to the degree of observability of forward trading. However, another interpretation of this parameter is that it reflects the ability of firms to infer from price fluctuations whether competitors have deviated from the equilibrium path. [7]

We further assume there is a fringe of outside speculators. These traders, which are assumed to be risk-neutral, do not have transmission capacity rights so they cannot physically deliver the commodity to the final customers. As a result, they must offset their positions before actual delivery takes place.

3.1 Spot market stage

At the time the spot market opens, there is no demand uncertainty and firm i maximizes its spot market profits:

$$\pi_i^s = (p(Q_i) - c_i)s_i \tag{3}$$

where $p(Q)$ is the spot market price. We consider a spot market equilibrium with linear strategies for the firms, therefore:

$$s_i = A_i + B_i\epsilon,\ \ i = 1, ...n. \tag{4}$$

With probability γ, firm i knows the forward positions of its competitors and the realization of the spot market price becomes:

$$p = a + \left(1 - \sum_{j\neq i}^{n} B_j\right)\epsilon - x_i - \sum_{j\neq 1}^{n} x_j - s_i - \sum_{j\neq i}^{n} A_j \tag{5}$$

where $\sum_{j\neq 1}^{n} x_j$ is the sum of the *actual* forward positions of firm i's competitors. Profit maximization at the spot market stage gives

$$s_i = \frac{1}{2}\left(a + \left(1 - \sum_{j\neq i}^{n} B_j\right)\epsilon - c_i - x_i - \sum_{j\neq i}^{n} x_j - \sum_{j\neq i}^{n} A_j\right) \tag{6}$$

We know that each firm's spot strategy has the form given by Equation (4); then, we can solve for A_i and B_i:

$$A_i = \frac{a + \sum_{j\neq i}^{n} c_j - nc_i - x_i - \sum_{j\neq i}^{n} x_j}{n+1}$$
$$B_i = \frac{1}{n+1} \tag{7}$$

[7] To be precise, futures markets are typically anonymous and therefore transactions are difficult to observe. However, forward prices are publicized and therefore firms may be able to infer rivals' forward positions upon observation of forward prices. What we are then assuming is that γ is the fraction of times the firms are able to forecast how deviations from the equilibrium forward sales will affect the spot market price. In this sense, firms can be seen as behaving naively $1 - \gamma$ of the times.

We thus obtain that the equilibrium spot market output of firm i equals:

$$s_i^O = \frac{a + \epsilon + \sum_{j \neq i}^n c_j - nc_i - x_i - \sum_{j \neq i}^n x_j}{n+1} \tag{8}$$

The equilibrium spot market price is then equal to:

$$p^O = \frac{a + \epsilon + \sum_i^n c_i - x_i - \sum_{j \neq i}^n x_j}{n+1} \tag{9}$$

With probability $1-\gamma$, firm i does not observe the rivals' actions in the forward market and therefore does not detect any deviations from the equilibrium path. In that case, the price in the spot market is given by:

$$p = a + \left(1 - \sum_{j \neq i}^n B_j\right) \epsilon - x_i - \sum_{j \neq 1}^n \hat{x}_j - s_i - \sum_{j \neq i}^n A_j \tag{10}$$

where $\hat{x}_j$ is firm i's conjecture about the forward sales of firm j. The First Order Condition (FOC) for the spot market stage is given by:

$$s_i = \frac{1}{2}\left(a + \left(1 - \sum_{j \neq i}^n B_j\right) \epsilon - c_i - x_i - \sum_{j \neq i}^n \hat{x}_j - \sum_{j \neq i}^n A_j\right) \tag{11}$$

Note that firm i does not observe deviations from the conjectured (equilibrium) forward sales of the rival firms, so its spot market strategy only depends on its own level of forward sales. We can solve for $\sum_{j \neq i}^n A_j$ and $\sum_{j \neq i}^n B_j$:

$$\begin{aligned} \sum_{j \neq i}^n A_j &= \frac{(n-1)(a + c_i - \hat{x}_i - \sum_{j \neq i}^n \hat{x}_j) - 2\sum_{j \neq i}^n c_j}{n+1} \\ \sum_{j \neq i}^n B_j &= \frac{n-1}{n+1} \end{aligned} \tag{12}$$

The spot market solution for firm i thus boils down to:

$$s_i^U = \frac{a + \epsilon + \sum_{j \neq i}^n c_j + (n-1)\hat{x}_i/2 - nc_i - (n+1)x_i/2 - \sum_{j \neq i}^n \hat{x}_j}{n+1} \tag{13}$$

The spot market price can be written as:

$$p^U = \frac{a + \epsilon + c_i + \sum_{j \neq i}^n c_j + 2(n-1)\hat{x}_i/2 - (n+1)x_i/2 - \sum_{j \neq i}^n \hat{x}_j}{n+1} \tag{14}$$

3.2 Forward market stage

In the forward market stage, firms sell (or buy) part of their total output in a futures market to maximize their expected utility for profits. [8] Note from the solutions for the spot market stage that firm i's total profits depend on whether forward sales become observable. If so, profits are given by:

$$\pi_i^O = \frac{\left(a + \epsilon + \sum_{j\neq i}^n c_j - nc_i - x_i - \sum_{j\neq i}^n x_j\right)^2}{(n+1)^2} + (f - c_i)x_i \tag{15}$$

where f denotes the forward price. In case forward positions remain unobservable once the spot market opens, firm i's profits equal:

$$\begin{aligned}\pi_i^U &= \frac{\left(a + \epsilon + \sum_{j\neq i}^n c_j + (n-1)\hat{x}_i/2 - nc_i - (n+1)x_i/2 - \sum_{j\neq i}^n \hat{x}_j\right)^2}{(n+1)^2} \\ &+ (f - c_i)x_i \end{aligned}\tag{16}$$

The expected utility of firm i is thus given by:

$$E(u(\pi_i)) = -\gamma \int_{-\infty}^{\infty} e^{-\rho_i \pi_i^O(\epsilon, x_i)} f(\epsilon) d\epsilon - (1-\gamma) \int_{-\infty}^{\infty} e^{-\rho \pi_i^U(\epsilon, x_i)} f(\epsilon) d\epsilon \tag{17}$$

where $f(\epsilon)$ is the density function of the normal distribution with zero mean and variance given by σ^2. Integrating Equation (17) yields:

$$E(u(\pi_i)) = -\frac{\gamma}{\sqrt{2\pi\tau^2}} e^{-\frac{\alpha\beta(x_i)^2 + (2\alpha\sigma^2+1)\rho_i\varphi(x_i)}{2\alpha\sigma^2+1}} - \frac{1-\gamma}{\sqrt{2\pi\tau^2}} e^{-\frac{\alpha\delta(x_i)^2 + (2\alpha\sigma^2+1)\rho_i\varphi(x_i)}{2\alpha\sigma^2+1}} \tag{18}$$

where $\alpha = \frac{\rho_i}{(n+1)^2}$, $\beta(x_i) = a + \sum_{j\neq i}^n c_j - nc_i - x_i - \sum_{j\neq i}^n x_j$, $\varphi(x_i) = (f - c_i)x_i$, $\delta(x_i) = a + \sum_{j\neq i}^n c_j + (n-1)\hat{x}_i/2 - nc_i - (n+1)x_i/2 - \sum_{j\neq i}^n \hat{x}_j$ and $\tau^2 = \frac{\sigma^2}{2\alpha\sigma^2+1}$.

The FOC yields:

$$\begin{aligned} E(u(\pi_i))' &= 0 \Rightarrow \frac{\gamma}{\sqrt{2\pi\tau^2}} e^{-\frac{\alpha\beta(x_i)^2 + (2\alpha\sigma^2+1)\rho_i\varphi(x_i)}{2\alpha\sigma^2+1}} \frac{d}{dx_i}\left(\frac{\alpha\beta(x_i)^2 + (2\alpha\sigma^2+1)\rho_i\varphi(x_i)}{2\alpha\sigma^2+1}\right) \\ &+ \frac{1-\gamma}{\sqrt{2\pi\tau^2}} e^{-\frac{\alpha\delta(x_i)^2 + (2\alpha\sigma^2+1)\rho_i\varphi(x_i)}{2\alpha\sigma^2+1}} \frac{d}{dx_i}\left(\frac{\alpha\delta(x_i)^2 + (2\alpha\sigma^2+1)\rho_i\varphi(x_i)}{2\alpha\sigma^2+1}\right) = 0 \end{aligned}\tag{19}$$

Since in equilibrium $\hat{x}_i = x_i$ and $\hat{x}_j = x_j$, we get $\beta(x_i) = \delta(x_i)$. Therefore, the FOC simplifies to:

$$\gamma \frac{d}{dx_i}\left(\frac{\alpha\beta(x_i)^2}{2\alpha\sigma^2+1}\right) + (1-\gamma)\frac{d}{dx_i}\left(\frac{\alpha\delta(x_i)^2}{2\alpha\sigma^2+1}\right) + \rho_i \frac{d\varphi(x_i)}{dx_i} = 0 \tag{20}$$

[8] We do not restrict firms' level of forward trading to be positive. However, in equilibrium each firm will sell a non-negative amount in the forward market.

Now,

$$\frac{d}{dx_i}\left(\frac{\alpha\beta(x_i)^2}{2\alpha\sigma^2+1}\right) = -\frac{2\rho_i\left(a+\sum_{j\neq i}^n c_j - nc_i - x_i - \sum_{j\neq i}^n x_j\right)}{2\rho_i\sigma^2+(n+1)^2} \tag{21}$$

$$\frac{d}{dx_i}\left(\frac{\alpha\delta(x_i)^2}{2\alpha\sigma^2+1}\right) = -\frac{(n+1)\rho_i\left(a+\sum_{j\neq i}^n c_j + 2(n-1)\hat{x}_i/2 - nc_i - (n+1)x_i/2 - \sum_{j\neq i}^n \hat{x}_j\right)}{2\rho_i\sigma^2+(n+1)^2} \tag{22}$$

and

$$\begin{aligned}\frac{d\varphi(x_i)}{dx_i} = f - c + \frac{df}{dx_i}x_i &= \gamma\frac{a+\epsilon+\sum_i^n c_i - x_i - \sum_{j\neq i}^n x_j}{n+1} \\ &+ (1-\gamma)\frac{a+\epsilon+c_i+\sum_{j\neq i}^n c_j + 2(n-1)\hat{x}_i/2 - (n+1)x_i/2 - \sum_{j\neq i}^n \hat{x}_j}{n+1} \\ &- c - \left(\frac{\gamma}{n+1}+\frac{(1-\gamma)}{2}\right)x_i \end{aligned} \tag{23}$$

since $f = E(p) = \gamma p^O + (1-\gamma)p^U$.

Again using the equilibrium conditions $\hat{x}_i = x_i$ and $\hat{x}_j = x_j$, we get the equilibrium amount of forward sales for firm i:

$$x_i^* = \frac{2((n^2-1)\gamma + 2\rho_i\sigma^2)(a+\sum_{j\neq i}^n c_j - nc_i - \sum_{j\neq i}^n x_j)}{((n+1)^3 - (n-1)^2(n+1)\gamma + 2(3+\gamma+n(1-\gamma))\rho\sigma^2)} \tag{24}$$

Suppose that all firms have identical marginal cost, so $c_i = c$. Then the per firm equilibrium forward position is given by:

$$x^* = \frac{2(a-c)((n^2-1)\gamma+2\rho\sigma^2)}{\left((n+1)((n+1)^2+\gamma(n-1)^2) + 2(1+\gamma-n(\gamma-3))\rho\sigma^2\right)} \tag{25}$$

Using Equation (8), we can write firm i's total output $q_i^* = s_i^* + x_i^*$ as:

$$q_i^* = \frac{n}{n+1}x_i^* + \frac{a+\sum_{j\neq i}^n c_j - nc_i - \sum_{j\neq i}^n x_j}{(n+1)} + \frac{\epsilon}{n+1} \tag{26}$$

If we again consider the case where all firms face the same marginal cost, we can write the equilibrium output (per firm) as follows:

$$q^* = \frac{(a-c)\left((n+1)^2(n+1+(n-1)\gamma) + 2(3+\gamma-(\gamma-3)n)\rho\sigma^2\right)}{(1+n)\left((n+1)((n+1)^2+\gamma(n-1)^2) + 2(1+\gamma-n(\gamma-3))\rho\sigma^2\right)} + \frac{\epsilon}{n+1} \tag{27}$$

The variable of interest is the total-to-forward-sales ratio:

$$\frac{q_i^*}{x_i^*} = \frac{(n+1)^2(n+1+(n-1)\gamma) + 2(3+\gamma+(3-\gamma)n)\rho_i\sigma^2}{2(n+1)((n^2-1)\gamma+2\rho_i\sigma^2)} + \frac{1}{(n+1)x_i}\epsilon \tag{28}$$

Let Γ denote the expected total-to-forward-sales ratio; we then get:

$$\Gamma \equiv E\left(\frac{q_i^*}{x_i^*}\right) = \frac{(n+1)^2(1+n+(n-1)\gamma)+2(3+\gamma+(3-\gamma)n)\rho_i\sigma^2}{2(n+1)((n^2-1)\gamma+2\rho_i\sigma^2)} \tag{29}$$

This ratio exhibits some interesting features which are discussed in turn. Firstly, note that this expression does not depend on firm i's marginal cost, which means that firms with similar risk aversion hedge in the same way no matter their marginal cost of production. Therefore, the ratio of interest in the same for each firm in the market. Secondly, despite production levels being increasing with the strength of the demand, this ratio does not depend on the demand parameter a. Thirdly, since

$$\frac{\partial\Gamma}{\partial\rho_i} = -\frac{(n+1-\gamma(n-1))^2\sigma^2}{((n^2-1)\gamma+2\rho\sigma^2)^2} < 0 \tag{30}$$

this ratio is decreasing in the degree of the firm's risk aversion. Fourthly, an increase in the probability of observability has a downward effect on the ratio of interest:

$$\frac{\partial\Gamma}{\partial\gamma} = -\frac{(n-1)((n+1)^2+2\rho_i\sigma^2)^2}{2(n+1)(\gamma(n^2-1)+2\rho_i\sigma^2)^2} < 0 \tag{31}$$

Finally, we look at how firms entering the market affect the total-to-forward-sales ratio. In the extreme case of no observability at all, $\gamma = 0$ and the ratio becomes:

$$\Gamma = \frac{6\rho_i\sigma^2+(n+1)^2}{4\rho_i\sigma^2} \tag{32}$$

It is easy to see that if firms do not observe each other's forward positions, the ratio is increasing in the number of firms on the market. In the other extreme case, where $\gamma = 1$ and forward positions are always observable, we get:

$$\Gamma = 1 + \frac{1}{n+1} + \frac{2}{(n^2-1)+2\rho_i\sigma^2} \tag{33}$$

Note that in this situation, firm market entry has a downward effect on the ratio of interest. For intermediate cases, the direction of the relation between the number of firms and the ratio depends on how likely it is that forward trading will be observed once the spot market opens. More specifically, the total-to-forward-sales ratio decreases in the number of active firms if and only if the degree of observability, captured by the parameter γ, is large enough, that is $\gamma > \tilde{\gamma}(n, \rho_i, \sigma^2)$ for some $\tilde{\gamma} \in [0, 1]$. Otherwise, firm entry leads to a rise in the ratio of interest. Figure 1 shows the relation between the number of firms in the market and the total-to forward-sales ratio for different values of γ.

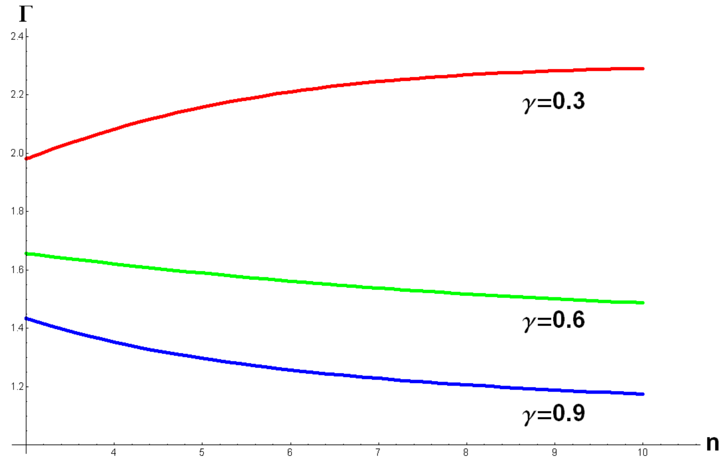

Figure 1: Relation between number of firms and total-to-forward-sales ratio ($\rho_i = 4$, $\sigma^2 = 1$)

4 Empirical analysis

The previous section has shown that the total-to-forward-sales ratio of an individual firm depends on the degree of demand randomness, on the risk aversion of the firm and on the number of firms active in the industry. Irrespective of the degree of observability in the market, the model suggests that an increase in the uncertainty of demand has a positive effect on trade in the forward market as a share of total production. Moreover, the more risk-averse a firm is the greater the incentive of a firm to engage in forward contracting.

More interestingly, the effect of the number of competitors on the incentives to sell futures depends on to what extent forward contracts are used as strategic instruments. We have noted above that when forward positions are observable with high probability, the model predicts that an individual firm responds to entry by *decreasing* its total-to-forward-sales ratio. By contrast, if firms rarely observe the forward sales of the rival firms, then an individual firm *increases* its total-to-forward-sales ratio as a response to entry. It is precisely this differential effect of entry that allows us to test whether firms sell forward contracts for strategic reasons or not.

4.1 Empirical strategy

We now describe the empirical strategy. The random generating process of the total-to-forward-sales ratio of an individual firm is given by

$$\frac{q_i^*}{x_i^*} = \frac{(n+1)^2(1+n+(n-1)\gamma) + 2(3+\gamma+(3-\gamma)n)\rho_i\sigma^2}{2(n+1)((n^2-1)\gamma + 2\rho_i\sigma^2)} + \frac{1}{(n+1)x_i^*}\epsilon \tag{34}$$

which can be rewritten as:

$$q_i^* = \frac{(n+1)^2(1+n+(n-1)\gamma) + 2(3+\gamma+(3-\gamma)n)\rho_i\sigma^2}{2(n+1)((n^2-1)\gamma + 2\rho_i\sigma^2)} x_i^* + \frac{1}{(n+1)}\epsilon \tag{35}$$

Since we do not have individual firm-level data, we proceed by aggregating at the market level. We are therefore led to assume that all firms have similar risk aversion parameters, i.e., $\rho_i = \rho$. We then get:

$$\sum q_i^* = \frac{(n+1)^2(1+n+(n-1)\gamma) + 2(3+\gamma+(3-\gamma)n)\rho\sigma^2}{2(n+1)((n^2-1)\gamma + 2\rho\sigma^2)} \sum x_i^* + \frac{n}{(n+1)}\epsilon \tag{36}$$

Note that $\sum q_i^* = \sum s_i^* + \sum x_i^*$, so that Equation (36) can be rewritten as:

$$\sum s_i^* = \left(\frac{(n+1)^2(1+n+(n-1)\gamma) + 2(3+\gamma+(3-\gamma)n)\rho\sigma^2}{2(n+1)((n^2-1)\gamma + 2\rho\sigma^2)} - 1\right) \sum x_i^* + \frac{n}{(n+1)}\epsilon \tag{37}$$

or

$$\frac{n+1}{n} \sum s_i^* = \frac{n+1}{n} \left(\Gamma(\gamma, \rho, \sigma^2) - 1\right) \sum x_i^* + \epsilon \tag{38}$$

where

$$\Gamma(\gamma, \rho, \sigma^2) = \frac{(n+1)^2(1+n+(n-1)\gamma) + 2(3+\gamma+(3-\gamma)n)\rho_i\sigma^2}{2(n+1)((n^2-1)\gamma + 2\rho_i\sigma^2)} \tag{39}$$

is the expected equilibrium total-to-forward-sales ratio. Note that the parameters ρ and σ^2 enter multiplicatively everywhere in Equation (38), which implies that we cannot identify the two parameters separately. We proceed by introducing another parameter $\lambda \equiv \rho\sigma^2$, which denotes the multiplication of the degree of risk aversion in the market and the variance of the demand shock. We can then estimate the parameters γ and λ by applying Nonlinear Least Squares (NLS) to Equation (38). The regression results tell us whether firms use forward contracts for risk-hedging purposes, for strategic reasons, or for both.

4.2 The data

Before we estimate Equation (38), we first discuss the data we use for our empirical analysis. Our data set consists of a substantial fraction of all contracts traded at TTF, the Dutch gas hub, for the period from April 2003 until June 2008. The data set includes transactions that occurred through brokerage firms as well as exchange-based trades.[9] There are several types of contracts traded at TTF, each type calling for delivery during a different period of

[9] The data were provided by the publishing company ICIS Heren and cover about 50 percent of the total market. Data on more recent months will become accessible in the near future.

time.[10] Since the data we use do not tell us which companies are involved in a trade, we do not know the per-firm forward and total sales. In the previous section, we have shown that if the degree of risk aversion is comparable across firms the ratio of interest is the same for each firm. Therefore, considering only industry level sales does not seem to lead to biased results.

Since we are merely interested in the volume of gas delivered during each day of our sample and the raw data only gives information about the day a particular contract is traded, the original data set needs to be adjusted. The following simple example gives a flavor of how this is done. Suppose that in the year 2003 only two products have been bought and sold: a December contract traded on November 6 that calls for delivery of 720 MegaWatt hour (MWh) each day in December and a day-ahead contract traded on December 6 for delivery of 4320 MWh the next day. Then for each day in December 2003 the delivery volume is 720 MWh, except for December 7, on which the delivery amount equals 5040 MWh. These volumes are the ones we will use when testing the two competing models. Moreover, we want to make a distinction between spot sales and forward sales. The assumption we make is that only day-ahead and within-day contracts are spot-based, the rest is considered as forward trade. So, in the previous example, for December 7, there is 5040 MWh traded on a spot basis and 720 MWh is traded on a forward basis. All the other days in December 2003 only have deliveries based on forward trade.

We then aggregate the daily delivery amounts to get the total spot and forward trade for each month in the period under analysis. This implies that we use 63 monthly observations for the estimation of Equation (38). One caveat of the raw data at hand is that a substantial part of the transactions included in the dataset concerns contracts that are retraded, while our theoretical model suggests we should only use net delivery volumes in the regressions. The ratio of net volume to gross volume is the so-called "churn rate" and is reported by Gas Transportation services (GTS), the Dutch network operator, on a monthly basis. In the remainder, we will assume that for forward trade the churn rate equals to the one reported by GTS, while the the churn rate for spot trade is one. We feel this assumption is plausible, since in the spot market the length of time to resell contracts is rather short. Figure 2

[10] For instance, there are forward-like contracts that stipulate delivery during a whole month or year and there exist more spot-based contracts that call for delivery on the next day or on the very same day the contract is traded.

displays the forward sales (adjusted for the churn rate) as well as the spot market sales. The figure reveals two aspects of the data. One, trade in forward contracts is more prominent than spot market sales and two, the amount of total trade relative to forward market trade is increasing over time.

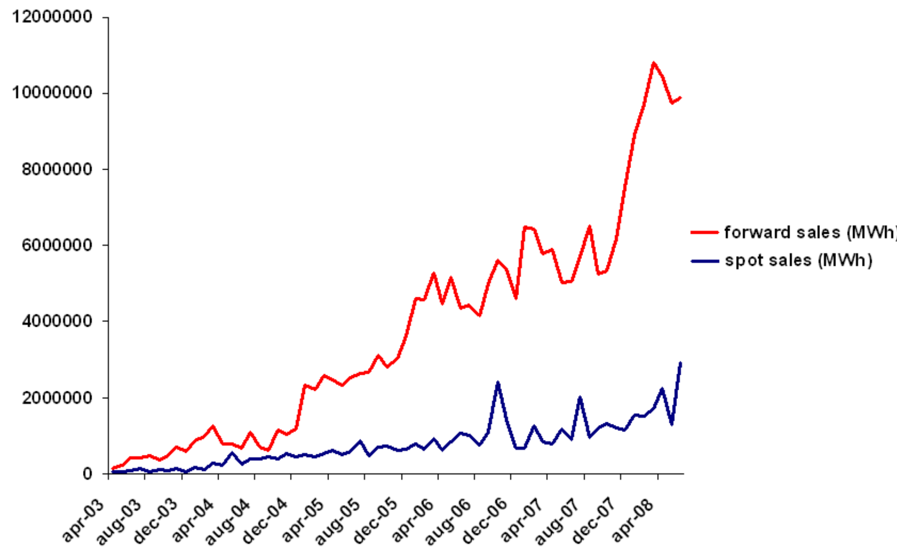

Figure 2: Forward market and spot market sales

Next, data on the number of firms being active at TTF were provided by GTS. One potential problem with these data is there are several types of shippers (e.g. wholesalers, traders, retailers), while according to the theoretical model the ratio of interest only depends on the number of firms that actually supply gas. Fortunately, our data make a distinction between the different kinds of traders, being wholesalers, pure traders and retailers. Another problem may be that several wholesalers serve only a fairly small part of the market and most likely cannot affect prices. Since our theoretical model dictates that we should use variation in the number of active firms who can influence prices, in the regressions we only consider the largest wholesalers who together make up for 80 percent of total delivery. [11] Figure 3 shows the development of the total number of active wholesalers, as well as the evolution of the number of suppliers that account for more than 60 and 80 percent of TTF delivery. Note that not only more gas wholesalers have entered the TTF in the period under analysis, but

[11]However, we also perform a robustness check by estimating the model using all wholesalers that sell at the TTF.

also that over time the 60 and 80 percent market share have become distributed over more firms. This suggests that supply has become less concentrated.

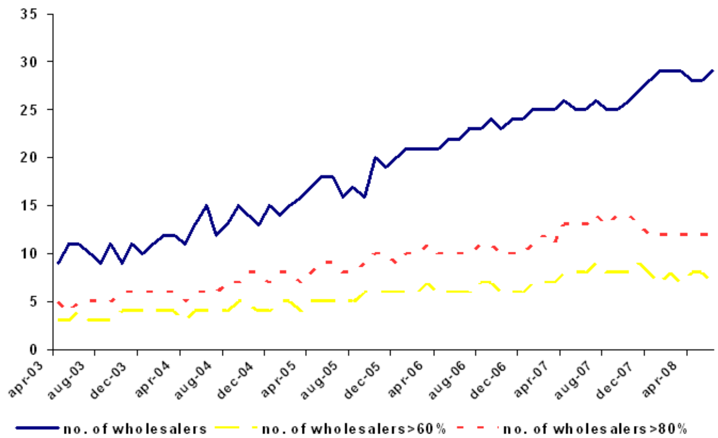

Figure 3: Number of wholesalers active at TTF

To get a first impression of whether gas wholesalers trade forward contracts for strategic reasons, we pool together the months in which the number of active suppliers is the same and compute the the average total-to-forward sales ratio for those months. Figure 4 then displays the relation between the number of wholesalers trading at the TTF and the average ratio of interest. Note that the figure suggests that this relation is negative, which, according to the theoretical model, indicates that forward contracts are used as strategic instruments.

4.3 Results

In order to estimate the structural model developed in the previous section, we rewrite Equation (38) as follows:

$$y_t = g\left(n_t, \sum_{i=1}^{n} x_{it}, \gamma, \lambda\right) + \epsilon_t, \quad \epsilon_t \sim N(0, \sigma_\epsilon^2) \tag{40}$$

where $t = 1, ..., 63$ indexes the time period (month), $y_t \equiv \frac{n_t+1}{n_t}\sum_{i=1}^{n} s_{it}$ and $g(n_t, \sum_{i=1}^{n} x_{it}, \gamma, \lambda) \equiv \frac{n_t+1}{n_t}\left(\Gamma(n_t, \gamma, \lambda) - 1\right)\sum_{i=1}^{n} x_{it}$. We now fit the data to the model by applying the nonlinear least squares (NLS) method.[12] The regression results are summarized in Table 1.

[12]We have used the *lsqnonlin* function in Matlab to perform the regression.

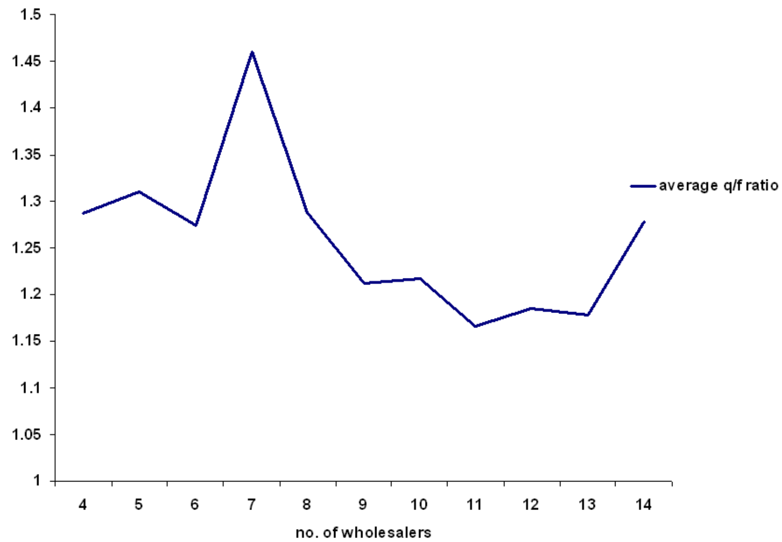

Figure 4: Total-to-forward-sales ratio

Table 1: Regression results

$Variable$	$Estimates$	$t - Statistic$
$\hat{\lambda}$	11.975	0.450
$\hat{\gamma}$	0.828*	25.961
$R^2 = 0.704$		

* Significant at the 1 percent significance level

As can be seen from table 1, the estimate for the "strategic effect" parameter, $\hat{\gamma}$, is highly significant, while the estimate for the "risk aversion parameter", $\hat{\lambda}$, turns out to be insignificant.[13] This suggests that wholesalers in the Dutch gas market engage in forward contracting to affect rivals' strategies rather than to hedge against price risks. Figure 5 displays the residuals of the NLS regression discussed above.

Due to the assumption of linear demand in the theoretical framework, one feature of our empirical strategy is that data on demand and cost are not required to estimate Equation (41). If, however, we were to use other demand specifications, the demand and cost parameters would most likely enter the equilibrium condition we want to estimate. Since the profitability of being active at the TTF depends on market characteristics such as demand

[13]We have also estimated Equation (38) for the case where n equals the number of all active wholesalers. We obtain more or less the same results. The estimate for γ is significant at the 1 percent level, while λ, in this case becoming nearly zero, is again insignificant.

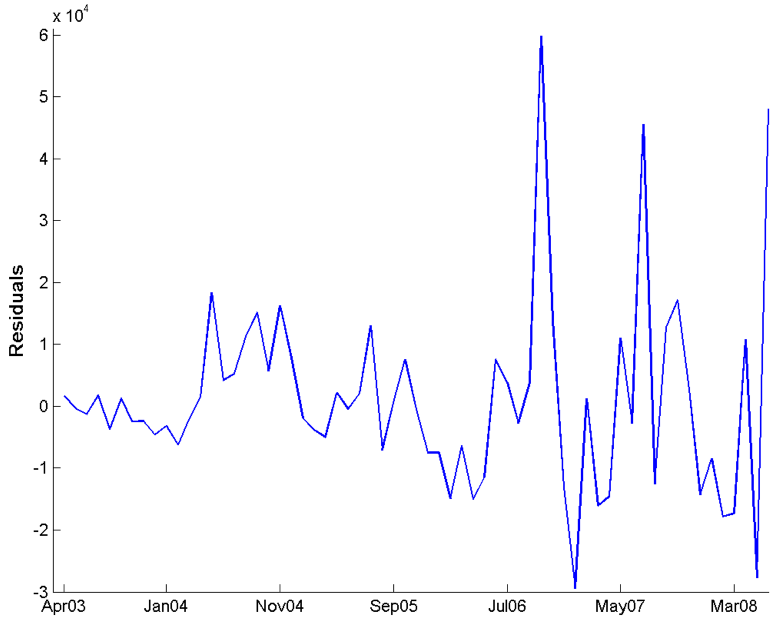

Figure 5: Residuals of the NLS regression

strength, cost of gas supply and cost of entering the hub one may argue that in that case the number of active wholesalers is not exogenous anymore. If we then use data that relate to the attractiveness to enter the TTF, we have an additional source of information to estimate the parameters of the model. More specifically, in case of no serious entry barriers we expect that gas wholesalers will enter the TTF till the last firm that enters makes zero profit in expectation.[14] In this respect, the zero-profit condition tells us what the number of active wholesalers is when neither firm has an incentive to enter or exit. Then, by substituting the equilibrium forward sales, given by Equation (25), into the expression for profits we obtain the following zero-profit condition:

$$(a-c)^2\Omega(\gamma,\lambda,n) - F = 0 \tag{41}$$

where F denotes a firm's cost of entry and

$$\Omega(\gamma,\lambda,n) = \frac{(1+\gamma+n(1-\gamma))((n+1)^2+2\lambda)((n+1)^2(n+1+(n-1)\gamma)+2\lambda(3+\gamma-n(\gamma-3)))}{(1+n)^2(n^2(\gamma-3)-n^3(1+\gamma)+n^{(}\gamma-3)(1+2\lambda)-(1+\gamma)(1+2\lambda))^2} \tag{42}$$

[14] While in our theoretical framework firms maximize expected utility once they have entered the market, we assume that firms base their entry decision on expected profits. A practical reason for doing this is that in case we let firm entry incentives be based on (expected) utility, the entry condition, which we are going to exploit in the estimation, becomes very cumbersome to deal with. One theoretical validation for the dissimilarity between firms' pre-entry and post-entry objectives could be that market entry is decided upon by firm owners, who are typically assumed to be risk neutral, while daily control is delegated to firm managers, who are often considered as being risk-averse.

In practice, zero-profit conditions do not hold perfectly so we are led to consider stochastic zero-profit restrictions. We then get:

$$(a-c)^2\Omega(\gamma,\lambda,n) - F + \nu = 0, \quad \nu \sim N(0,\sigma_\nu^2) \tag{43}$$

Because the zero-profit condition provides additional information on the true values of γ and λ, we estimate Equations (41) and (44) simultaneously. For this, we need data on the demand and cost parameters. Since an important application of natural gas is its use in electricity production, we take monthly average prices of electricity spot contracts traded at the Dutch spot exchange APX as a proxy for the demand strength parameter a. Unfortunately, we do not have data on the wholesalers' entry cost or marginal cost so we consider both types of cost as being fixed throughout the sample period.[15] Given that a depends on the time period, while c and F do not, we can rewrite Equation (44) as follows:

$$(a_t-c)^2\Omega(\gamma,\lambda,n_t) - F + \nu_t = 0, \quad \nu_t \sim N(0,\sigma_\nu^2) \tag{44}$$

We thus estimate the following system of equations:

$$\begin{pmatrix} y_t \\ 0 \end{pmatrix} = \begin{pmatrix} g(n_t, \sum_{i=1}^n x_{it}, \gamma, \lambda) \\ \mu r(a_t, c, F, n_t, \gamma, \lambda) \end{pmatrix} + \begin{pmatrix} \epsilon_t \\ \mu\nu_t \end{pmatrix}, \quad \begin{pmatrix} \epsilon_t \\ \mu\nu_t \end{pmatrix} \sim \left(0, \begin{pmatrix} \sigma_\epsilon^2 & 0 \\ 0 & \sigma_\nu^2 \end{pmatrix}\right) \tag{45}$$

where $r(a_t, c, F, n_t, \gamma, \lambda) \equiv (a_t-c)^2\Omega(\gamma,\lambda,n_t) - F$ and μ is the weight that is attached to the restrictions. Since the degree of informativeness of the zero-profit conditions depends on the variability of these restrictions, we set μ equal to the ratio of the standard deviations of the two error terms in (46), $\mu = \sigma_\epsilon/\sigma_\nu$. [16] The results are summarized in table 2.

Table 2: Regression results; zero-profits conditions included

$Variable$	$Estimates$	$t-Statistic$
$\hat{\lambda}$	12.278	0.6457
$\hat{\gamma}$	0.828*	36.591
$R^2 = 0.846$		

* Significant at the 1 percent significance level

As can be seen from table 2, the estimates do not change much if we include the stochastic zero-profit conditions in the regressions. The strategic effect becomes more significant, while the strategic motive is still insignificant.

[15] We normalize marginal cost c to zero and set the entry cost equal to $F = 5.1$. For these values, the zero-profit condition is just satisfied when $a = 40$ and $n = 5$, which are (approximately) the average values for our sample, and $\gamma = 0.828$ and $\lambda = 11.975$, being the estimates we obtained when excluding the zero-profit condition.

[16] We estimate the weight μ as $\hat{\mu} = \sqrt{\frac{\hat{\epsilon}'\hat{\epsilon}}{\hat{\nu}'\hat{\nu}}}$, which is the square root of the ratio of the sums of squared residuals. This implies that we conduct a feasible weighted NLS regression (see Greene, 1993).

5 Concluding remarks

This paper has presented evidence that wholesalers in the Dutch market for natural gas do use forward contracts to gain a competitive advantage over competitors. This result is in line with the findings of Allaz and Vila (1993), who have shown that by selling forward firms commit to a more aggressive behavior in the spot market. One important assumption in their model is that firms do observe their rivals' actions in the forward market. Despite the anonymous nature of trading at hubs, firms seem to correctly infer from prices how much competitors have traded in the forward market. However, this result relies on the assumption that gas wholesalers are engaged in quantity competition. Whether our results are robust to different modes of competition may be addressed by future research.

Since firms seem to use forward contracts for strategic reasons, the existence of a forward market is beneficial from a societal point of view. However, the risk hedging possibility of forward trading, often being considered as another important welfare-enhancing feature of forward markets, seems to be of less importance in the Dutch market for wholesale gas.

References

[1] Allaz, B. (1992), "Oligopoly, Uncertainty and Strategic Forward Transactions," *International Journal of Industrial Organization* 10, 297-308.

[2] Allaz, B. and J.-L. Vila (1993), "Cournot Competition, Futures Markets and Efficiency," *Journal of Economic Theory* 59, 1-16.

[3] Bessembinder, H. and M.L. Lemmon (2006), "Gains from Trade Uncertainty: The Case of Electric Power Markets," *Journal of Business* 79, 1755-1782.

[4] Eldor, R. and I. Zilcha (1990), "Oligopoly, Uncertain Demand, and Forward Markets," *Journal of Economics and Business* 42, 17-26.

[5] European Commission-EC (2007), '*DG Competition Report on Energy Sector Inquiry*', SEC(2006), 1724, Brussels.

[6] Feder, G., R. E. Just and A. Schmitz (1980), "Futures Markets and the Theory of the Firm under Price Uncertainty," *Quarterly Journal of Economics*, 94, 17-328.

[7] Ferreira, J.L. (2003), "Strategic Interaction between Futures and Spot Markets," *Journal of Economic Theory*" 108, 141-151.

[8] Green, R.J. (1999), "The Electricity Contract Market in England and Wales," *Journal of Industrial Economics* 47, 107-124.

[9] Holthausen, D. M. (1979), "Hedging and the Competitive Firm Under Price Uncertainty," *American Economic Review* 69, 987-995.

[10] Hughes, J.S. and J.L. Kao (1997), "Strategic Forward Contracting and Observability," *International Journal of Industrial Organization* 16, 121-133.

[11] Katz, E. (1984), "The Firm and Price Hedging in an Imperfect Market," *International Economic Review* 25, 215-219.

[12] Longstaff, F.A. and A.W. Wang (2004), "Electricity Forward Prices: A High-Frequency Empirical Analysis," *Journal of Finance* 59, 1877-1900.

[13] Mahenc, P. and F. Salanié (2004), "Softening Competition through Forward Trading," *Journal of Economic Theory* 116, 282-293.

[14] Newbery, D.M. (1998), "Competition, Contracts, and Entry in the Electricity Spot Market," *The RAND Journal of Economics* 29, 726-749.

[15] NMa/DTe (2007), "Versnelling van de Ontwikkeling van TTF en de Groothandelsmarkt voor Gas.

[16] Powell, A. (1993), "Trading Forward in an Imperfect Market: The Case of Electricity in Britain," *Economic Journal* 103, 444-453.

[17] Tirole, J. (2006), *The Theory of Corporate Finance*, Princeton University Press.