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

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Abstract

Cournot models of oligopolistic interaction in forward and spot markets have shown that firms may sell forward for strategic as well as for risk-hedging reasons. Using data from the Dutch wholesale market for natural gas where we observe the number of players, spot and forward sales, churn rates and prices, this paper presents evidence that strategic reasons play an important role at explaining the observed firms’ hedging activity. Our test for strategic behaviour is based on the theoretical relationship between the number of sellers and the incentives to sell forward: if risk-hedging is the only motive behind firms’ decision to sell forward, then hedging activity ought to decrease in the number of firms; otherwise, if strategic reasons are relevant, then firms incentives to sell forward must increase in the number of competitors.

Keywords: forward contracts, risk-hedging, strategic contracting, market power, spot market, churn rates.

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1 Introduction

The economics literature has shown that facilitating forward transactions has the potential to deliver social benefits on two accounts, namely, risk-hedging and strategic commitment. First, the existence of forward markets enables a firm to hedge risks. By fixing the terms of trade before delivery, a risk-averse firm mitigates its exposure to price shocks in the spot market. Central results in the literature relate to the decisions of a competitive risk-averse firm facing price uncertainty (see e.g Baron, 1970; Holthausen, 1979; and Sandmo, 1971). In the absence of a futures market, price risk leads this type of firm to restrict its output relative to what the firm would produce under certainty. The opening of a forward market restores the level of output that would prevail if uncertainty were removed.

Second, forward markets can deliver further social benefits in situations where firms wish to sell forward for strategic reasons. In their influential paper, Allaz and Vila (1993) show that, even if there is no uncertainty at all about future market conditions, Cournot firms have incentives to engage in forward trading. The idea is that by selling futures contracts at a pre-specified price, a firm ends up attaching a lower value to a high spot market price thereby effectively committing to an aggressive behavior in the spot market. This raises firm profitability, because competitors respond by adopting a compliant spot market strategy. Selling forward exhibits however the characteristics of a prisoner’s dilemma. Because every seller has incentives to sell (part of) its output forward, the resulting equilibrium aggregate production is higher (and the price lower) than in the absence of a futures market.

Notwithstanding the fact that the Allaz and Vila result relies on a number of particular assumptions, when restructuring electricity and natural gas markets, it is widely held that spot markets must necessarily be complemented with forward markets (e.g. Borenstein, 2002; Bushnell, 2004; Ausubel and Cramton, 2010). In an attempt to aid firms to contract forward, platforms have been created where property rights are more easily transferred among the participants. In addition, in some

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1 The pro-competitive role of forward contracting has been disputed by several authors. For example, Mahenc and Salanié (2006) demonstrate that selling forward may have anticompetitive effects when firms compete in prices instead of quantities. Liski and Montero (2006) find that the forward institution increases the likelihood with which firms can sustain collusive outcomes. Holmberg and Willems (2012) show that forward contracting can be anticompetitive in markets where spot market competition is in supply schedules and firms are allowed to hold a portfolio of forward and option contracts.

2 One development in natural gas has been the creation of virtual hubs, for example the NBP and TTF, as opposed to the more traditional physical hubs, like the Henry Hub and the Zeebrugge Hub. A physical hub is a location where several pipelines come together, so that total physical throughput is delivered at this point. By contrast, virtual hubs contain several entry and exit points that are interconnected, which implies that not all the gas traded has to flow through a single point in the pipeline system.
energy markets we have witnessed the creation of exchanges for the trading of futures contracts.\footnote{Examples of markets for electricity futures are CALPX in California and EEX Power Derivatives in Austria, France, Germany and Switzerland; ICE Endex runs markets for German and Dutch natural gas futures as well as for Belgian and Dutch electricity derivatives.}

The power of the Allaz and Vila’s (1993) strategic commitment mechanism, however, heavily depends on whether forward contracts are observable or not (Kao and Hughes, 1997).\footnote{This observation has also been made in the context of strategic delegation games by Fershtman and Kalai (1997). Moreover, in a recent paper Ritz (forthcoming) shows that the standard delegation game of Fershtman and Judd (1987) is strategically equivalent to the Allaz and Vila (1993) model.} When contracts are observable, by selling forward a firm drives the rival firms to adjust their spot strategies. By contrast, selling output forward in markets where these contracts are not observed does not trigger the reaction of the rival firms in the spot market so in the absence of risk considerations the firms would not sell forward at all. In real-world (energy) markets we observe quite a lot of forward contracting. The question that arises is: \textit{What does explain the portfolio of forward contracts of a firm? Is it risk-hedging or is it strategic commitment?}\footnote{A great deal of these markets are over the counter (OTC) and, as explained by Duffie (2012, p.5), while agents do not have access to the complete record of transactions as in exchanges they are also not completely in the dark because information agencies such as Argus Media, ICIS, Reuters, etc. provide partial information on recently selected trades.}

In order to empirically address this question we revisit the Allaz and Vila’s (1993) and Hughes and Kao’s (1997) models by allowing for risk-aversion, CARA utility and an arbitrary number of players. The analysis yields a clear-cut and empirically testable implication. When firms sell forward exclusively for risk-hedging reasons (Hughes and Kao (1997)), the share of forward sales in total production (i.e. the hedge ratio) \textit{decreases} as the number of firms increases. By contrast, when firms sell forward for strategic reasons too (Allaz and Vila (1993)), the hedge ratio of a firm \textit{increases} as the number of players goes up. This contrasting comparative statics result arises because the (marginal) gains from affecting the rivals’ spot market strategy rise with the number of competitors, while the incentives to risk-hedge decrease. Both theoretical models deliver additional results. In particular, the equilibrium hedge ratio of a firm decreases as demand slope goes up, and increases as the firms become more risk-averse, or as demand volatility decreases. While these results cannot be used to discern among models of forward contracting, they can be used to test whether the theory is borne by the data more broadly.

To the best of our knowledge, empirical research in this area has been circumscribed to the study of energy markets. Most of the work, which we describe below in some detail, has focused on testing whether forward contracting results in tougher spot market competition. However, as far as we know, the determinants of the portfolio of contracts of an oligopolistic firm have not yet been studied...
empirically. One obvious reason for this is that a great deal of the contracts we have observed in energy markets has not been dictated by market forces but imposed by the regulators in the form of gas release programs or vesting electricity contracts (Borenstein, 2002; Wolfram, 1999). A second reason is that data requirements to conduct empirical work in this area are significant, because forward trades are often not observed by the econometrician and, even if they are observed, they often include speculative trades that involve no actual deliveries of the commodity. A third reason is that, as far as we know, heretofore there has not been a clear empirical strategy to disentangle the two rationales motivating firms to sell forward – strategic commitment and risk-hedging.

This paper contributes to the literature by empirically studying the determinants of forward contracting in the Dutch wholesale natural gas market. For this we put together a novel dataset by collecting information from various sources. Our dataset combines information obtained from ICIS Heren about a fairly large amount of (forward, spot and speculative) trades conducted at the Dutch gas hub Title Transfer Facility (TTF) with information obtained from the transport service operator (GTS) about the number and type of trading parties and the net volumes delivered, from April 2003 until September 2008. In contrast to data from restructured markets elsewhere, our data have three advantages. First, the Dutch natural gas market is one where futures contracts have not been forced upon the producers and wholesalers by the regulator so we can consider observed forward contracting as endogenous to the market process. Second, we have information on almost all forward and spot transactions so we are able to see the extent to which the firms hedge in this market. Third, we have collected the TTF churn rates (i.e. the number of times a contract changes hands before delivery takes place) for the entire sample period.

We perform a regression analysis of the daily industry hedge ratios on demand and cost shifters, the number of wholesalers, and a measure of price volatility. In our regressions, we account for the possible endogeneity of the number of firms. Since traders are typically more prone to become active in markets where liquidity is high, we use churn rates as instruments for the number of firms. Our empirical findings provide relatively strong support for the model of Allaz and Vila (1993). Variables that relate to demand slope (such as current and lagged electricity prices) appear to have

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6The TTF is a virtual market place that offers market participants the possibility to buy and sell gas that is either already injected into the Dutch gas transmission pipeline system, or for which transportation capacity has been already booked and confirmed by the transport service operator. ICIS Heren (www.icis.com) is an information agency that collects data from the trading parties in order to produce price assessments, indices, news and analysis for a number of oil, gas, liquefied natural gas, carbon and coal markets. GTS (www.gasuniettransportservices.nl) is the gas transport operator in the Netherlands.

7Unfortunately, these data are handled confidentially by the data providing firms and we have not been able to obtain the data disaggregated at the firm level.
a significant positive effect on the amount of hedging. Moreover, an increase in the number of active wholesalers or a raise in the extent of price volatility increases the fraction of output that is sold forward. We also find that the effect of the number of players on the incentives to sell forward is less pronounced when demand volatility and/or risk aversion is high, which is also in line with the theoretical prediction of the Allaz and Vila model.

Our paper adds to a growing empirical literature on the effects of forward contracting on spot market strategies and energy market outcomes. Most of the literature so far has focused on testing the effects of forward contracts on spot market competition. The evidence is mixed. Green (1999) for example relates the observed low wholesale prices for electricity in the UK Pool at the beginning of the 1990s to the large amount of forward contracting in the industry. Wolfram (1999), using data from the UK Pool market for the 1992-1994 period, finds little support for the idea that forward contracts are responsible for the highly competitive prices she observes; instead, evidence is presented in favour of the idea that the threat of entry and the threat of regulatory intervention constrained the prices. Wolak (2000) uses proprietary information on the contract cover of one of the generators operating in the Australian National Electricity Market 1 and shows that the contract positions of the generator made its bidding in the real-time market more aggressive. Bushnell et al. (2008) study the impact of long-term contracting in the form of vertical arrangements on three markets, namely, the California, New England and the Pensylvania, New Jersey and Maryland (PJM) markets. For the three markets, they find that observed prices are broadly consistent with the Cournot prediction after accounting for vertical arrangements. For the New England and PJM markets, they find that prices would have been much higher in the absence of the vertical relations, as it happened in California. Brandts et al. (2008) set up laboratory experiments to study the efficiency effects brought about by the possibility of forward contracting. They observe that significant price decreases and efficiency gains are obtained compared to the case in which only spot market trading is possible.

The rest of the paper is organized as follows. Next section reviews and extends the theoretical models. Section 3 is dedicated to our empirical application. The paper closes with some concluding remarks.

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9Evidence of collusive behaviour has been found by Fabra and Toro (2005) for the Spanish electricity market and by Sweeting (2007) for the UK.
2 Cournot models of forward and spot contracting

We next present the results from two well-known oligopoly models of strategic behavior in forward and spot markets. The first model is by Allaz and Vila (1993)\textsuperscript{10} the second is by Hughes and Kao (1997). In the model of Allaz and Vila (1993), the forward positions of the firms are perfectly observable and therefore forward contracting has commitment value. Under these circumstances, firms are expected to sell forward both for risk-hedging and strategic reasons. By contrast, in the model of Hughes and Kao, forward contracts are unobservable and firms engage in forward sales just for risk-hedging considerations. Except in that forward contracts may or may not be observable by the rival firms, the models are otherwise similar. However, as we will demonstrate, the two models deliver a totally different prediction regarding the effect of entry; we build on such a prediction our test for strategic behaviour in section 3.

2.1 Observable forward contracts (Allaz and Vila (1993))

Consider a Cournot oligopolistic market with n symmetric risk-averse firms selling a homogeneous good\textsuperscript{11} We assume that market demand is random and given by the linear-normal specification

\[ p = a - bQ + \epsilon, \quad \epsilon \sim N(0, \sigma^2), \]  

where \( Q = \sum_{i=1}^{n} q_i \) denotes the aggregate output delivered to consumers and \( \epsilon \) is a zero-mean random shock normally distributed with standard deviation \( \sigma \).\textsuperscript{12} Let \( c \) denote the constant marginal cost of production of a typical firm, and let \( \rho \) be its risk-aversion parameter\textsuperscript{13} Firms can first sell (or buy) output in a forward market; after this, they compete in the spot market\textsuperscript{14} Let \( x_i \) and

\textsuperscript{10}The Cournot model of Allaz and Vila has been adapted to suit the particular organization of power markets in the UK by von der Fehr and Harbord (1992, 1993), Powell (1993), Newbery (1998), Green (1999) and Wolak (2000). However, Bushnell et al. (2008) find that, after accounting for vertical arrangements and contracting, Cournot behaviour approximates very well actual prices in the California, New England and PJM electricity markets.

\textsuperscript{11}Allaz and Vila (1993) study a duopoly model with risk-neutral firms; here we consider an n-firm version with risk-averse firms that maximise their CARA utility functions. Allaz (1992) uses a mean-variance utility function instead. As we will see later, because both the price and the spot sales are random, monetary profits are not normally distributed. In such a case, maximizing CARA utility is not equivalent to maximizing the corresponding mean-variance specification. Qualitatively speaking, however, the results are similar. Bushnell (2007) also studies the n-firm model but with risk-neutral firms and increasing marginal cost.

\textsuperscript{12}Using the Gaussian assumption for the random demand shocks is mathematically convenient but has the well-known problem that prices and quantities may become negative. Nevertheless, the chance that this occurs can be made very small by appropriately choosing the variance parameter \( \sigma^2 \) (see e.g. Vives, 1984).

\textsuperscript{13}The model can readily be generalised to allow for asymmetries in risk-aversion and in marginal cost (see our working paper van Eijkel and Moraga-González (2010)).

\textsuperscript{14}In Allaz and Vila (1993) the forward market can open a finite number of periods \( T \) and they show that industry output converges to the competitive output when \( T \to \infty \). However, Ferreira (2003) shows that when the futures market opens for infinitely many periods any outcome between perfect competition and Cournot can be sustained in equilibrium. As long as \( T \) is finite, our test based on the impact of the number of firms on the incentives to hedge is valid.
s_i be, respectively, firm i’s spot and forward market sales; the total output firm i supplies on the market will be denoted by \( q_i = s_i + x_i \). Let f denote the forward price.

At the forward market stage, firms are uncertain about the price that will prevail in the market. Because of this, at that stage, a firm views its monetary flow of profits as a random variable. We assume firms have constant absolute risk aversion (CARA) utility functions. Let

\[
\pi^f_i \equiv (f - c)x_i + (p - c)s_i
\]

be the realized (forward and spot) monetary profits of a firm i. The utility function of a firm i is then

\[
u(\pi^f_i) = \frac{1}{\rho} (1 - e^{-\rho \pi^f_i}).
\]

Denote by \( f(\epsilon) \) the density function of the normal distribution with zero mean and standard deviation \( \sigma \). A firm i will choose its forward sales \( x_i \) to maximize its expected utility

\[
E[u(\pi^f_i)] = \frac{1}{\rho} \int \left( 1 - e^{-\rho (f - c)x_i + (p - c)s_i} \right) f(\epsilon) d\epsilon,
\]

(2)

taking as given the forward sales of the rival firms and anticipating their behaviour in the spot market.

At the spot market stage demand uncertainty is resolved and a firm i chooses its spot sales \( s_i \) to maximize its realised spot market profits, denoted

\[
\pi^s_i \equiv (p - c)s_i.
\]

In doing this, a firm i takes as given the spot sales of the other firms and of course factors the observed contract positions of the rivals into its spot strategy. For simplicity, future spot market profits are not discounted.

The forward price is formed by the outcome of price competition between a fringe of risk-neutral speculators. These speculators do not have transportation rights so they must undo their positions before delivery takes place. Under the assumption that speculators are undifferentiated, they have an incentive to overbid one another until the equilibrium bid is equal to the price they expect in the spot market. Therefore, the equilibrium bid in the forward market is \( f = E[p] \).

In the jargon or game theory, this is a three-stage simultaneous moves game where firms first choose their forward sales, then speculators bid for those sales and, finally, firms compete in the spot market. The appropriate solution concept is subgame perfect equilibrium. We now solve the game by backward induction.
Spot market stage

At the time the spot market opens, demand is certain and firms know the contract positions of their rivals. Let $X_{-i} = \sum_{j \neq i} x_j$ be the aggregate forward position of firms other than $i$. A firm $i$ chooses its spot sales $s_i$ to maximize its spot market profits:

$$\pi^s_i \equiv (p - c)s_i = \left( a - b \left( s_i + \sum_{j \neq i} s_j + x_i + X_{-i} \right) + \epsilon - c \right) s_i$$

(3)

taking the spot market strategies of the rival firms as given. Standard derivations give the equilibrium spot market sales of the firms as a function of its own forward sales and the aggregate forward sales of the rival firms:

$$s_i = \frac{a - c - bx_i - bX_{-i} + \epsilon}{b(n + 1)}, \ i = 1, 2, ..., n.$$  

(4)

This equation reveals that when a firm increases its forward sales then it lowers its spot sales, but it does so to a lower extent the higher the number of competitors. Its total production increases though:

$$\frac{dq_i}{dx_i} = 1 - \frac{1}{n + 1} > 0.$$  

Substituting the equilibrium spot sales into the demand function gives the equilibrium spot market price:

$$p = \frac{a + nc - bx_i - bX_{-i} + \epsilon}{n + 1}.$$  

(5)

Forward market stage

At the forward market stage, firms sell (or buy) part of their total output in the futures market to maximize their expected utility, anticipating speculator bidding behavior and rivals' response in the spot market. It is instructive to write the forward first order conditions (FOC) as follows:

$$\int e^{-\rho \pi^f_i} \left( \frac{\partial \pi^f_i}{\partial x_i} + \frac{\partial \pi^f_i}{\partial s_i} \frac{\partial s_i}{\partial x_i} + \sum_{j \neq i} \frac{\partial \pi^f_i}{\partial s_j} \frac{\partial s_j}{\partial x_i} \right) f(\epsilon) d\epsilon = 0.$$  

(6)

The first term of this equation (after the integral sign) represents the marginal utility from (monetary) profit, while the term between parentheses is the marginal monetary profit from selling futures contracts. A firm $i$ chooses its amount of futures $x_i$ to make the expected value of the product of marginal utility and marginal monetary profit equal to zero.

Observing this FOC immediately reveals that putting one unit in the forward market affects the monetary profit both directly and indirectly via the spot market quantities of the rival firms.
The direct effect, which we call the *risk-hedging effect*, is given by the first two terms inside the parentheses. The first term is equal to
\[
\frac{\partial \pi_f}{\partial x_i} = f - c - bs_i - bx_i
\] (7)
and gathers the direct impact that putting one unit in the forward market has on the forward profit of a firm \( i \). Selling one unit in the forward market first increases the profit of a firm \( i \) by the forward margin \( f - c \); the spot margin however decreases and this lowers the profit by \( -bs_i \); finally, speculators, anticipating a greater output to be delivered to the market lower their bids in the forward market and this lowers the forward profit by \( -bx_i \). The second term inside the parenthesis, which captures the profits implication of the adjustment firm \( i \) makes in the spot market to internalize the additional unit sold forward, is equal to
\[
\frac{\partial \pi_f}{\partial s_i} \frac{\partial s_i}{\partial x_i} = -\left( p - c - bs_i - bx_i \right) \frac{1}{n+1}.
\] (8)
Putting one unit of output in the forward market results in a decrease in the spot quantity by \( 1/(n+1) \); this decreases the profit by the spot margin \( p - c \) per unit and profits thus fall by \( (p - c)/(n+1) \); however, both the forward and the spot margins increase because fewer units are brought to the market, which increases the spot and forward profit by \( bs_i/(n+1) \) and \( bx_i/(n+1) \), respectively.

The indirect effect of selling forward arises because the rival firms adjust their own spot strategies in the continuation game, and we refer to this effect as the *strategic effect*. This indirect effect is given by
\[
\frac{\partial \pi_f}{\partial s_j} \frac{\partial s_j}{\partial x_i} = (bs_i + bx_i) \frac{1}{n+1} \quad \text{for all } j \neq i.
\] (9)
When a firm \( i \) puts one unit in the forward market, the rival firms cut their spot production by \( 1/(n+1) \) each. This increases the forward and spot margins and correspondingly firm \( i \)'s profits increase by \( b(s_i + x_i)(n - 1)/(n + 1) \).

Plugging the previous expressions into the FOC (6) and using the facts that \( f = E[p] \) and \( p - c = bs_i \) in equilibrium gives
\[
\int e^{-\rho \pi_i} \left( -\frac{bmx_i}{n+1} - \frac{\epsilon}{n+1} + \frac{b(n-1)}{n+1} (x_i + E[s_i]) + \frac{(n-1)\epsilon}{(n+1)^2} \right) f(\epsilon) d\epsilon = 0 \quad (10)
\]
The incentives of a firm \( i \) to sell forward are thus shaped by the interaction between the risk-hedging effect and the strategic effect. Suppose we are in a monopoly so \( n = 1 \). In this case the strategic
effect vanishes and the only incentive to sell forward arises from risk-hedging. For monopoly, the
FOC is \( e^{-\rho \pi_i} \left( -\frac{bx_i}{2} - \frac{\epsilon}{2} \right) f(\epsilon) d\epsilon = 0 \). The deterministic component in the parenthesis, \(-bx_i/2\), captures the fall in the price that ensues after the monopolist puts one unit in the forward market. This effect dampens the incentives to put futures in the market, and explains why a risk-neutral monopolist would choose not to engage in forward contracting at all (see Tirole, 2006, p. 216-17). The random component picks up the effect that when the monopolist increases its contract cover then its exposure to demand shocks decreases. This random component is negatively correlated with \( \epsilon \) and so is the marginal utility from monetary profit (since profit increases in \( \epsilon \) and the utility function is concave). As a result, the covariance between marginal utility and marginal profit is positive, which gives a risk-averse monopolist incentives to sell forward.

Under oligopoly, the risk-hedging motive is also present but in addition there is the strategic effect of selling futures. This effect also has a deterministic component and a random component. Suppose the firms are risk-neutral. By the strategic effect, a firm that puts units in the forward market positively affects its profit via the spot market strategies of the rival firms. This gives firm \( i \) an incentive to sell forward, since by doing so it benefits from rival firms’ cuts in their spot sales. The additional random term has a positive sign and this implies that it works counter to the risk-hedging effect discussed above. This is because, given the fact that the rival firms cut their spot sales, selling forward becomes less effective at lowering exposure to price shocks. However, the aggregate random component in equation (10) is still negative and decreasing in \( n \). This tells us that firms’ incentives to hedge against risk become weaker the more firms are around.

After some algebra, the first order condition (10) simplifies to:

\[
(a - c - bx_i - bX_{-i}) \left( \frac{1}{n+1} - \frac{2b}{2\rho \sigma^2 + b(n+1)^2} \right) - \frac{b}{n+1} x_i = 0
\]

Imposing symmetry, \( x_i = x^* \) for all \( i \), and solving for \( x^* \) gives:

\[
x^* = \frac{(a - c)(2\rho \sigma^2 + b(n^2 - 1))}{b(n+1)(2\rho \sigma^2 + b(n^2 + 1))}
\]

Plugging \( x^* \) in (1) gives

\[
s^* = \frac{(a - c)(2\rho \sigma^2 + b(n + 1)^2)}{b(n+1)^2(2\rho \sigma^2 + b(n^2 + 1))} + \frac{\epsilon}{b(n+1)}
\]

We are particularly interested in the ratio of output that is hedged but it is more convenient to compute what we call the inverse hedge ratio. This is given by

\[
\Gamma^O \equiv \frac{s^* + x^*}{x^*} = 1 + \frac{1}{n+1} + \frac{2b}{b(n^2 - 1) + 2\rho \sigma^2} + \frac{2\rho \sigma^2 + b(n^2 + 1)}{(a - c)(2\rho \sigma^2 + b(n^2 - 1))} \epsilon
\]
As can been seen from equation (12), the inverse hedge ratio is normally distributed.\textsuperscript{15} The following proposition discusses some more properties of the equilibrium inverse hedge ratio.

**Proposition 1** Suppose that the forward positions of the firms are observable as in Allaz and Vila (1993). Then firms sell forward both for risk-hedging and strategic reasons. In equilibrium, the mean of the inverse hedge ratio of a typical firm, defined as total-to-forward-sales ratio, is given by

\[
E[\Gamma^O] = 1 + \frac{1}{n + 1} + \frac{2b}{b(n^2 - 1) + 2\rho\sigma^2},
\]

and satisfies the following properties:

(i) It is independent of the demand intercept parameter \(a\) and of the firm marginal cost \(c\), but increases in the demand slope parameter \(b\).

(ii) It decreases as the risk-aversion parameter of the firm \(\rho\) goes up, or as demand volatility \(\sigma^2\) increases.

(iii) It decreases in the number of firms \(n\) and it does so at a lower rate the larger risk-aversion and demand volatility are.

The proof of the properties follows straightforwardly from differentiation and is therefore omitted. The main properties of the inverse hedge ratio need some further explanation. First, the inverse hedge ratio does not depend on the demand parameter \(a\) and the cost parameter \(c\). This means that firms’ inverse hedge ratios in periods of demand expansion are similar to those in periods of demand contraction. We note that this result, however, rests on the linearity assumptions of the demand and cost functions (see Bushnell, 2007).\textsuperscript{16} Inverse hedge ratios go down when firms becomes more risk averse or when demand uncertainty increases. These two results are driven by the risk-hedging rationale: the higher the degree of risk aversion (or the greater the price uncertainty), the more a firm wants to hedge.

\textsuperscript{15}Note that the (direct) hedge ratio is not normally distributed, as the error term enters the denominator of this ratio. This is the reason why we choose to work with the inverse hedge ratio in the remainder.

\textsuperscript{16}In our application to the natural gas industry, the constant marginal cost assumption is probably a good approximation for the costs of wholesalers, since they typically import gas from producers in countries such as Norway and Russia and have long-term take-or-pay contracts with them. Take-or-pay contracts stipulate that the buyer pays a price typically indexed to the oil price for a pre-specified minimum amount of gas, irrespective of whether the gas is actually taken (Masten and Crocker, 1985). Take-or-pay contracts also include a variety of (daily and yearly) flexibility clauses (Asche et al., 2002; IEA, 2002); these clauses provide wholesalers with the necessary flexibility to adjust supply to demand shocks. Moreover, because wholesalers book import capacity assuming extreme weather conditions, transport capacity is typically not binding. Pipelines also allow for *line-pack*, that is, for the increase in the amount of gas the system can carry by temporarily raising its pressure. Concerning the costs of producers, Chermak and Patrick (1995) estimate that marginal costs of natural gas production are decreasing.
The most interesting features of the inverse hedge ratio, at least for our purposes, are that firm entry lowers hedging activity and that this effect is weaker when demand volatility and risk aversion are high. The intuition why more firms results in greater hedging activity is as follows. Note that an increase in the number of firms makes the risk-hedging effect weaker and the strategic effect stronger. To see that an increase in \( n \) makes the risk-hedging effect weaker, observe that the random term in the parenthesis of equation (10) becomes smaller if more suppliers enter the market. Because demand uncertainty is revealed before the spot market opens, the demand shock is partly absorbed by the rivals’ spot strategies. As a result, the residual demand of a particular firm at the spot market stage is less susceptible to demand shocks the higher the number of competitors. This pushes up the inverse hedge ratio of an individual firm. By contrast, the strategic effect becomes more prominent as more players are active in the market. This is because a firm’s marginal gains from committing output and affecting its rivals’ spot market strategies are higher the more competitors it faces.\(^{17}\) While the risk-hedging effect weakens as the number of competitors goes up, the strategic effect strengthens instead; the Proposition shows that the strategic effect has a dominating influence though.

Finally, we note that the impact of an increase in the number of competitors on the incentives to hedge is smaller when risk-aversion and/or demand volatility are higher. This is because when risk-aversion and/or demand volatility are higher, the risk-hedging effect is quite strong and less sensitive to changes in the number of firms.

2.2 Unobservable forward contracts (Hughes and Kao (1997))

In this section, following Hughes and Kao (1997), we assume that firms do not observe each other’s actions in the forward market.\(^{18}\)

Spot market stage

Let \( x^* \) be the equilibrium forward position of a typical firm and let \( X^*_{-i} = (n - 1)x^* \). In the spot market, a firm \( i \) will choose a spot quantity \( s_i \) to maximize

\[
\pi_i^s = (p - c)s_i = \left( a - b \left( s_i + \sum_{j \neq i} s_j + x_i + (n - 1)x^* \right) + \epsilon - c \right) s_i,
\]

\( (14) \)

\(^{17}\)This is reminiscent of the Stackelberg game. The gains from becoming a leader are larger the higher the number of competitors.

\(^{18}\)Hughes and Kao (1997) study a duopoly model; here we extend it to the case of an \( n \)-firm oligopoly. In our working paper, we further allow for asymmetries in risk-aversion and in marginal costs.
taking the spot market strategies of the rival firms as given.

Standard derivations give the equilibrium spot market outputs of the firms as a function of its own forward sales and the equilibrium conjectures of the rivals’ forward sales:

\[ s_i = \frac{a - c - b(n + 1)x_i/2 - b(n - 1)x^*/2 + \epsilon}{b(n + 1)}, \quad i = 1, 2, \ldots, n, \] (15)

Plugging these spot sales into the demand function gives:

\[ p = \frac{a + nc - b(n + 1)x_i/2 - b(n - 1)x^*/2 + \epsilon}{n + 1}. \] (16)

**Forward market stage**

As before, a firm \( i \) chooses its contract cover \( x_i \) to maximize expected utility (2) and, in doing so, it takes as given the forward and spot quantities of the rival firms. Because the rival firms do not react to changes in the forward position of a firm \( i \) the first order condition is:

\[
\int \rho_i e^{-\rho_i f} \left( \frac{\partial \pi^f}{\partial x_i} + \frac{\partial \pi^f}{\partial s_i} \frac{\partial s_i}{\partial x_i} \right) f(\epsilon) d\epsilon = 0
\] (17)

As explained above, in parentheses we see the risk-hedging motive of selling forward. Using (15) and (16), and following the reasoning above, we obtain

\[
\frac{\partial \pi^f}{\partial x_i} = f - c - bs_i - bx_i
\]

and

\[
\frac{\partial \pi^f}{\partial s_i} \frac{\partial s_i}{\partial x_i} = -(p - c - bs_i - bx_i) \frac{1}{2}
\]

so we can rewrite the FOC as

\[
\int \rho_i e^{-\rho_i f} \left( -\frac{bx_i}{2} - \frac{\epsilon}{n + 1} \right) f(\epsilon) d\epsilon = 0.
\] (18)

Upon observing this FOC we see that a risk-neutral oligopolist would behave exactly like a monopolist and opt out of the contract market altogether. We also see that the incentives to hedge of a risk-averse oligopolist are weaker than those of a monopolist. The intuitive reason is that, because rival firms condition their spot sales on the observed random shock, the residual demand of an oligopolist is less volatile than the demand of a monopolist.

After some algebra, the first order condition (18) simplifies to:

\[
(a - c - bx_i - b(n - 1)x^*) \left( \frac{1}{n + 1} - \frac{b(n + 1)}{2\rho \sigma^2 + b(n + 1)^2} \right) - \frac{b}{2} x_i = 0
\]
Applying symmetry, \( x_i = x^* \), and solving for \( x^* \) gives:
\[
x^* = \frac{4(a - c)\rho \sigma^2}{b(b(n + 1)^3 + 2(3n + 1)\rho \sigma^2)}
\] (19)

Using equation (15), we obtain the equilibrium spot sales:
\[
s^* = \frac{(a - c) \left[ 2\rho\sigma^2 + b(n + 1)^2 \right]}{b \left[ b(n + 1)^3 + 2(3n + 1)\rho \sigma^2 \right]} + \frac{1}{b(n + 1)}\epsilon
\]

In this case the inverse hedge ratio is given by:
\[
\Gamma_{NO} \equiv \frac{s^* + x^*}{x^*} = \frac{6\rho \sigma^2 + b(n + 1)^2}{4\rho \sigma^2} + \frac{b(n + 1)^3 + 2(3n + 1)\rho \sigma^2}{4(a - c)\rho \sigma^2(n + 1)}\epsilon
\] (20)

Again, this ratio is normally distributed.

**Proposition 2** Suppose that the forward positions of the firms are not observable as in Hughes and Kao (1997). In this case firms sell forward only for risk-hedging reasons and the average inverse hedge ratio of a typical firm is given by
\[
E[\Gamma_{NO}] = \frac{6\rho \sigma^2 + b(n + 1)^2}{4\rho \sigma^2}.
\] (21)

\( E[\Gamma_{NO}] \) satisfies properties (i) and (ii) in Proposition 1. However, (iii) \( E[\Gamma_{NO}] \) increases in the number of firms and it does so at a lower rate the higher risk-aversion and demand volatility are.

The proof is again omitted. The impact of the number of firms on the inverse hedge ratio is diametrically opposed to the result in Proposition 1. When contracts are not observed by the rival firms, an individual firm continues to sell forward till the utility gains from lowering the variability of the monetary profits are equal to the losses from the ensuing price fall. In that situation the incentive to hedge against demand shocks becomes weaker (see equation (18)) if more suppliers enter the market. As mentioned above, this is because the volatility of the residual demand of a firm at the spot market stage is lower the higher the number of competitors. Moreover, this weakening effect of the number of players on the incentives to sell forward turns out to be smaller the larger demand volatility and/or risk-aversion are. This is because when firms are very risk-averse they already tend to hedge a lot of their output and their hedging decision is less sensitive to the number of firms. In fact in the limit when risk-aversion goes to infinity the inverse hedge ratio does not depend on \( n \) any longer.

The relationship between the number of firms and forward contracting clearly depends on whether the forward positions of the firms are observable or not. Moreover, the effects of more risk on the
sensitivity of the inverse hedge ratio to the number of firms also depends on whether contracts are observable or not. These effects are illustrated in Figure 1. In panel 1a we see how the average inverse hedge ratio decreases in \( n \) when contracts are observable while it increases in \( n \) when contracts are unobservable. This result provides us with a powerful test to determine whether firms sell forward for strategic reasons. If entry of firms results in higher hedging activity (and therefore lower inverse hedge ratios), everything else constant, it must be the case that strategic considerations play an important role. Otherwise we should observe less hedging activity (and therefore higher inverse hedge ratios). In panel 1b we observe that in both cases the response of the inverse hedge ratio to an increase in the number of firms is weaker the higher risk aversion is.

![Figure 1: Inverse hedge ratio under observable (\( \Gamma^O \)) and unobservable (\( \Gamma^{NO} \)) forward positions](image)

We now proceed to test empirically if contracting in the Dutch wholesale natural gas market is due to strategic reasons.

### 3 An application to the wholesale natural gas market

In our empirical application, we use data from the Dutch wholesale natural gas market to test the predictions derived in Propositions 1 and 2 about how the inverse hedge ratio of a firm relates to different market variables. For this purpose, we regress inverse hedge ratios on number of active firms, a measure of demand volatility, an interaction term between these two variables, and various demand and cost shifters. To deal with potential endogeneity problems, we instrument for the number of wholesalers operating in the industry. As we will see later, the predictions of the Allaz and Vila’s (1993) model are largely borne out by the data. In particular, we find that inverse
hedge ratios *decrease* in the number of active wholesalers, which suggests that firms sells forward contracts for strategic reasons.

### 3.1 The data

We use data from the Dutch wholesale market for natural gas. For the purpose of this paper, these data are very useful because forward contracts have not been imposed by the regulator so they can be considered *endogenous* to the market process. In addition, for this market, we have been able to collect data on the aggregate level of contracting activity, the number of active firms, spot prices and churn rates.

#### 3.1.1 Institutional background

As in many other countries, traditionally, gas supply in the Dutch wholesale market was controlled by a single integrated network company –the *NV Nederlandse Gasunie*.\(^{19}\) Gasunie did not only own the transmission network, but also had control over the national distribution pipelines and the gas supplies. Gas originated from the Dutch gas fields or was imported from foreign producers.\(^ {20}\) Gasunie sold the gas to industrial customers and distribution companies.

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* of the European Union in 1998. This ruling abolished import monopolies, forced the opening of markets and imposed the accounting unbundling of vertically integrated network companies. The *Second Gas Directive* of the European Union in 2003 furthered the liberalisation process 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 of this directive, Gasunie was split up into two independent companies: *Gas Transportation Services (GTS)*, which controls the national transmission network, and *Gasterra*, which is engaged in gas wholesaling. The second directive also required the creation of national energy regulators.

To attain a well-functioning wholesale gas market in The Netherlands, the *Title Transfer Facility (TTF)* was created in 2003. The TTF is a virtual trading hub that offers market parties/shippers

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\(^{19}\) Gasunie was a joint venture between De Staatsmijnen (DSM), Shell, Esso and the Dutch State.

\(^{20}\) The sources of supply are similar in recent days. In 2008 there were 35 production fields and 17 import entry points (GTS, 2008). 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 governmental concession to explore and exploit 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.
the possibility to buy and sell gas that is already injected into the national gas transmission grid, or for which transportation capacity has already been booked. Thanks to the TTF gas can easily change hands before it is extracted at a specific local or export exit point. This triggered the entry of new players into the Dutch market. The TTF made the emergence of gas exchanges possible. Since 2005 APX Gas NL B.V. runs an exchange for spot contracts. At APX, market parties can trade standardized contracts for gas delivery one day ahead and within the same day. Since the end of 2006 ENDEX N.V. runs an exchange for a variety of gas futures contracts. At the end of 2008 ENDEX N.V. was taken over by APX B.V., which is also the owner of APX Gas NL B.V. As of March 2013, the Intercontinental Exchange (ICE) is the majority shareholder of ENDEX and as a result, the name of ENDEX has changed to ‘ICE Endex’.

The TTF allows gas buyers in the wholesale market to hold a portfolio of different types of gas products. Long-term take-or-pay contracts used to be the dominant contract type in the industry. Nowadays a buyer can buy gas on a short term basis at the trading hub. Since gas demand typically has a seasonal pattern, firms gain in flexibility by participating in this new market. Over the years we have witnessed an increase in volumes traded at the TTF. By 2008, a substantial share of 20 percent of gas that flows through the GTS transport system reached the trading hub. The Dutch regulator expects that in the future the TTF will be sufficiently liquid so as to offer market participants all the hedging opportunities they need.

3.1.2 Data description

Our data set consists of a substantial fraction of all forward and spot contracts traded at the Dutch TTF for the period from April 2003 until September 2008. These data were provided by the company ICIS Heren. In addition, we obtained data from the transport operator GTS on the number of wholesalers active every month, on the daily churn rates and on the total daily volumes. Unfortunately, we do not have information on the identity of the trading parties so we

\[\text{21} \text{New players include new wholesale companies such as Gaz de France, BP, EON, Gazprom, RWE, Statoil, Total, etc., as well as new financial players such as JP Morgan, The Royal Bank of Scotland, BNP Paribas, Morgan Stanley, Citygroup, Barclays Bank, etc. By contrast, there has not been much entry of new retailers in the TTF. What has happened is that the existing distribution companies (Essent, Nuon, Eneco, GDF Suez, etc.) have become active outside their traditional territories as well as abroad.}

\[\text{22}\text{The minimum length of a contract is one month and the maximum length is one (calendar) year. Contracts can range from a month ahead to three years ahead of delivery. In Appendix A, we provide more details on the types of contracts traded at the TTF.}

\[\text{23}\text{ICIS Heren (http://www.icis.com/heren/) is a leading specialized information provider for energy markets. The company publishes price assessments, indices, news and analysis for various energy markets. ICIS Heren gathers daily price and quantity information from brokers and directly from the participants in the industry via telephone calls.}

\[\text{24}\text{The participants in the industry must make nominations to the transport operator before delivery at the TTF. Comparing the total nominations with the net deliveries, the transport operator computes churn rates. It turns out}
are unable to perform the analysis at the firm level. As explained earlier, if firms do not differ much in their aversion to risk, they will hedge in a similar fashion, even if there exist significant cost differences across them.

Transactions can either be exchange-based or OTC and the latter can be facilitated by brokers or not. Both types of transactions are included in our data set, but we cannot distinguish between them in the sense that we cannot tell whether a transaction is over-the-counter or has occurred at a centralized exchange (ENDEX or APX). As said before, there are several types of contracts traded at TTF. For a given trading day, we are interested, on the one hand, in the total volume of gas delivered and, on the other hand, in the amount that has been sold forward. To compute all the gas delivered on a given date, we sum all the quantities specified in different contracts that call for delivery on such a day. To compute how much of this volume is contracted forward, we need to make an assumption about the nature of uncertainty in this market. We make the assumption that only day-ahead and within-day contracts form the spot market so the rest of the contracts are considered futures contracts.  

To be clear, suppose that in year 2003, three products have been traded: (i) a forward contract traded on November 3 that calls for delivery of 720 MegaWatt hour (MWh) each day in December 2003, (ii) a day-ahead contract traded on December 8, 2003 for delivery of 4,320 MWh the next day, and (iii) a spot contract traded on December 22, 2003 for delivery of 1,440 MWh the same day. Then, except for two days, December 9 and 22, for each day in December 2003 the delivery volume is 720 MWh. On December 9, the total delivery volume equals (720+4,320=) 5,040 MWh while on December 22, the delivery volume is (720+1,440=) 2,160 MWh. In this way, we have determined the total forward and spot deliveries for each trading day in our sample period. In total we have 1406 observations of the hedge ratio.

One difficulty of the data at hand is that a substantial part of the transactions we observe concerns contracts that are traded with or between speculators. Since financial traders must have zero net that the total volumes we obtain from our data on transactions are quite close to the total nominations reported by the transport operator.

We have discussed the validity of this assumption with participants in this industry. At the margin, the main driver of demand is temperature. Therefore, if any, the main source of uncertainty here is due to temperature fluctuations. According to the participants, the weather predictions one day ahead are quite accurate. Moreover, within-day and day-ahead deals are conducted at one and the same exchange (APX) while contracts with longer duration are traded on a different exchange (ENDEX). This suggests that the industry considers day-ahead and within-day contracts as being of similar type.

Since we include lagged values of the electricity price as regressors in our estimation, only 1362 out of these 1406 observations of the hedge ratio are used. Note also that weekend days (as well as some holidays) are not included in our data set, since no TTF trade is reported for such days.
positions before delivery, many of the contracts we see are re-trades and do not involve volumes that are finally brought to the market. If we had data on the churn rates (i.e. net-to-gross-volume ratios) for the different maturity contracts, we could determine both the net forward volumes and the net spot quantities supplied to the market. Unfortunately, we only have churn rates for the aggregate delivered volumes (i.e. the sum of spot and forward quantities) so in our baseline regressions we proceed under the assumption that daily churn rates for forward contracts are equal to those for spot contracts. Though we believe this is a reasonable assumption based on the fact that the list of financial speculators reported at the spot exchange APX is similar to the list reported at the futures exchange ENDEX, in order to verify the robustness of our results, we also test our theoretical predictions by considering different churn rates across markets.

As discussed earlier, identification of the key parameters of the model is aided if there is variation in the number of wholesalers operating in the market. The TTF is a market where in fact there has been a steady increase in the number of participants. However, from our data on transactions we cannot extract the number of wholesalers since we do not have information on the identity of the traders engaged in a transaction. We obtained data on the number of active wholesalers in a given month from the GTS. Since some wholesalers are probably very small and have no market power whatsoever, we also asked for the number of active wholesalers making up for 60 and 80 percent of total delivery. Figure 2 shows the evolution of the total number of active wholesalers, as well as the development of the number of suppliers that account for more than 60 and 80 percent of the gas delivered in the TTF. Note that not only more gas wholesalers have entered the TTF in the period under analysis, but also that, as time has elapsed, the 60 and 80 percent market share has become distributed over more firms. This suggests that the supply of gas has become less concentrated in the Netherlands over time.

One other potential problem of our data is that we only have information about the change in the number of active players from month to month, while new wholesalers can enter the TTF on any (trading) day in a month. We deal with this issue by assuming that the entry of a new firm is uniformly distributed over the trading days in the month in which the firm enters the TTF. That is, if we observe entry in a particular month we compute the expected number of firms for each day.

\(^{27}\)To conduct transactions at the TTF, participants must first subscribe with the TTF either as wholesalers, industrial customers, retailers or pure traders. The subscription can be made for a single gas month or for a full calendar year. Subscribing involves the payment of some fixed fees and, in addition, traders have to pay some variable fees for the volumes traded.
Figure 2: Number of wholesalers active at TTF (blue) and number of wholesalers that account for 60 percent of the trade (red) and for 80 percent of the trade (yellow)

of that month, based on the assumption that entry follows a uniform distribution. Nevertheless, for robustness purposes, in Appendix B we report results based on monthly observations of the number of active wholesalers.

Finally, in order to capture the degree of demand uncertainty, we construct a measure of demand volatility based on spot market prices. By substituting the equilibrium values in Equation (1), we can write the equilibrium spot price as follows:

\[ p_t = a_t - b \sum_i \Gamma_{it} x_{it} + \epsilon_t \]  

(22)

From this expression we can compute a measure of demand volatility:

\[ \sigma_t^2 = \sigma_{p_t}^2. \]  

(23)

To determine the volatility of demand shocks, we thus need a measure of price variability. We construct two measures of monthly price volatility as follows. We first proxy daily spot prices by computing a weighted price index for day-ahead contracts. Then we compute the monthly variance of prices, which we use as one of our measures of price volatility in the estimations. Figure 3 plots the daily spot prices at the TTF. As it can be seen, there is a number of price hikes in our data. Therefore, in order to dampen the influence of these price hikes, we construct a second measure of price variability by first taking the natural logarithm of the spot prices and then computing the
monthly variance of the log of prices.\textsuperscript{28}

![Daily spot prices at the TTF](image)

Figure 3: Daily spot prices at the TTF

Table 1 provides some descriptive statistics of our data.\textsuperscript{29} Moreover, Figure 4 displays the forward sales as well as the spot market sales and Figure 5 shows the daily inverse hedge ratios at the TTF.\textsuperscript{30}

The descriptive statistics reveal four interesting aspects of the data. First, volumes traded at the TTF have gone up a great deal.\textsuperscript{31} In fact, by 2008 the TTF became the second largest gas trading

\textsuperscript{28}Notice that using ex-post price variation as a proxy for demand uncertainty relies on the assumption that firms have ex-ante perfect foresight about future (spot) price uncertainty. Campa and Goldberg (1993) use this approach to study the effect of exchange rate volatility on entry of foreign firms in the US market during the 1980s.

\textsuperscript{29}Besides data on traded volumes, Table 1 also contains information on forward prices and spot prices. To determine forward prices, we look at transaction prices for monthly contracts. We calculate various weighted indices of prices, depending on the time span in which the monthly contracts are traded. That is, we compute weighted-price indices for monthly contracts traded: 1) more than one month before delivery; 2) in the first half of the month preceding the month of delivery; 3) in the last half of the month that precedes the delivery month and 4) on the last two days before delivery. This gives us four different measures of the forward price. In Table 1 we only report the weighted-price index for monthly contracts traded in the first half of the month preceding the delivery month. The other measures for the forward price show however a very similar pattern. Spot prices are determined by computing a weighted index of prices for day-ahead deals that are included in our data set. All prices are in real terms using 2003 as the base year.

\textsuperscript{30}To improve visualization in Figure 5 we limit the vertical axis to 2; however, we note that there were only two dates in which the inverse hedge ratio was higher than 2.

\textsuperscript{31}Currently net volumes in the TTF are approximately equal to the total supplies of natural gas to large industrial users in The Netherlands, including the electricity generating companies. This is about 10% of the total amount of gas that enters the Dutch pipeline system (about 43% of the gas that enters the Netherlands is ‘transit’ gas, i.e., exports to other countries).
Figure 4: Daily net forward sales (red) and spot sales (blue) in gigawatt hour (GWh)

Figure 5: Daily inverse hedge ratios
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<th>Max</th>
<th>Mean</th>
<th>Std. Dev.</th>
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<td>10.05</td>
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<td>12.69</td>
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<tr>
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<td>Forward (GWh)</td>
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<td>987.82</td>
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<td>1.06</td>
<td>0.04</td>
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<td>16.70</td>
<td>29.20</td>
<td>23.39</td>
<td>2.30</td>
</tr>
</tbody>
</table>

Notes: For the year 2003, the descriptive statistics for only the last nine months are displayed as the first three months of 2003 are not included in our sample period. Likewise, the table only shows the descriptive statistics for the first nine months of the year 2008.

The spot price and forward price are averaged over month; for all other variables, we use daily observations.

Table 1: Descriptive Statistics (monthly averages)
hub in Europe, both in terms of traded volume and net (physical) flow. A first explanation for this phenomenon is that, as compared to for example the Zeebrugge hub in Belgium, the TTF benefits from the absence of third-party access exemptions to the Dutch pipeline system. A second issue is that the entry/exit points to the Dutch pipeline system are well interconnected and this allows for the TTF to function as a virtual hub, which relaxes the physical constraints imposed by the capacities of the various pipelines. Finally, adding to the attractiveness of the Dutch trading hub as compared to signing long-term contracts is the opening of the BBL pipeline in 2006, which connects the Netherlands and the UK. The BBL pipeline allows TTF-traded gas to be shipped to the UK and this brings TTF prices down and more in line with UK prices.

A second aspect of the data is that a significant part of the total volume traded at the TTF is hedged (between 60 and 90%). It is also interesting to see that, even though volumes have increased massively during the sample period, the inverse hedge ratio shows much less variation. Moreover, the ratio of interest has gone up in the last year of our sample period which could be due to the decrease in the number of wholesalers that year. Furthermore, we note that the standard deviation of the inverse hedge ratio seems to have gone down over the sample period. Finally, it can be seen from Table 1 that forward prices and spot prices are closely linked, though the former are in general somewhat higher than the latter.

### 3.2 Empirical results

To test the predictions of Proposition 1, we estimate the following relationship:

\[
\sum_{i=1}^{n} q_{it} / \sum_{i=1}^{n} x_{it} = \beta_0 + \beta_1 WHOLE_t + \beta_2 VOLAT_t + \beta_3 INTERACT_t + \beta_X X_t + \nu_t. \tag{24}
\]

Where \( WHOLE_t \) denotes the number of wholesalers that account for 80 percent of total delivery on day \( t \). \( VOLAT_{it} \) is one of the measures of demand volatility at time \( t, i = 1, 2 \). We also include an interaction term (\( INTERACT_{it} \)) between these two variables as our theoretical model predicts that the incentives to sell forward for strategic reasons depend on how volatile demand is. The vector \( X_t \) includes a number of covariates. Finally, \( \nu_t \) is an error term.

As covariates we first include a number of demand and cost shifters. To control for demand shocks we include the Dutch wholesale price of electricity at time \( t \) (\( ELECPRICE_t \)) and the electricity

---

\(^{32}\)The National Balancing Point (NBP) in the UK, introduced in 1996, has long since been the most liquid hub in Europe.

\(^{33}\)Using the four different measures of the forward price, we perform an ANOVA test to see whether the means of the spot price and forward price are significantly different. The hypothesis that the means of both prices are the same can only be rejected (at the 5 percent significance level) when we take the forward price index that is obtained from transactions that take place more than month before delivery.

---

23
prices one and two months prior to day $t$\textsuperscript{34} We also add a seasonal dummy ($SEASON$) taking on value one for the months October to March and on value zero for the rest of the months, which is meant to capture demand fluctuations during the year due to changing weather conditions. Even though our theoretical model predicts that costs do not influence hedge ratios, we also include the oil price at time $t$ as a regressor ($OILPRICE_t$). We do this because in practice firms might have risk-preferences other than CARA and therefore their hedge ratios may depend on their costs. In order to control for possible changes in market transparency over time, we include a dummy variable ($EXCHANGE$) taking on value one for the years in our data in which the centralized futures exchange has been active (2007 and 2008) and zero otherwise.

If our covariates do not fully control for demand and cost shocks, the number of active firms may be an endogenous regressor in Equation (24). For instance, high demand elasticity (low $b$) yields relatively high hedge ratios, but at the same time makes the market less attractive for potential entrants. To address this potential endogeneity bias, we instrument for the number of wholesalers and the interaction term in Equation (24). As instruments we propose to use one and two months lagged values of the churn rate and the one month lagged oil price. We assume lagged churn rates are appropriate instruments because they are expected to correlate positively with the number of active wholesalers and not to affect directly the hedge ratios. Moreover, there is no a priori reason to believe that churn rates are also correlated with unobserved demand shifters that affect the demand elasticity. The lagged value of the oil price is also expected to be a valid instrument for the number of active wholesalers since it does affect the expectations firms form about future profitability and does not influence current hedging decisions.

We first estimate Equation (24) using OLS. Since the residuals from the OLS regression exhibit both (positive) autocorrelation and heteroskedasticity, we estimate Newey-West standard errors with six lags included\textsuperscript{35} The results can be found in the first four columns of Table 2, with the standard errors being reported between parentheses. The first two columns use the monthly variance of the log of prices, denoted $VOLAT_{1_t}$, as a regressor. Columns 3 and 4 give the estimates when using

\textsuperscript{34}Specifically, we use the price (index) of day-ahead contracts for baseload electricity to be delivered on the Dutch power grid, which are traded on the APX-ENDEX exchange. Prices are in real 2003 euros. We add lagged electricity prices up to two months prior to day $t$ because a great deal of the forward contracts are traded within two months before delivery and thereby producers might ground their decision of how much gas to buy forward on the price of electricity at that moment. Since all weekend days (and some holidays) are excluded from the data set, we use the average number of observations per month to determine a lag. This average equals 22 for our data set, so in the sequel $t - 22$ refers to one month prior to the day of delivery and $t - 44$ to two months before the delivery date.

\textsuperscript{35}The choice of the number of lags is based on the common selection rule $L \approx T^{1/4}$, where $L$ is the number of lags and $T$ the number of observations (see e.g. Greene, 1993).
instead the variance of the price levels, denoted $VOLAT^2_t$. The variable $EXCHANGE$ is meant to control for transparency.

We then estimate the coefficients in Equation \ref{eq:24} by two-stage least squares (2SLS). To account for heteroskedasticity and serial correlation in our data, we also estimate our reduced-form model by the generalized method of moments (GMM).\footnote{More specifically, we perform the standard two-step GMM procedure where the weight matrix is chosen to be heteroskedasticity and autocorrelation consistent (HAC).} The estimates obtained from both methods are displayed in columns 5 to 12 of Table \ref{tab:results}.

\footnote{To check for the validity of the instruments used, we perform the Hansen’s test of overidentifying restrictions. Since the lowest Hansen’s $J$ statistic we obtain for the different specifications equals 2.273 (with a corresponding p-value of 0.132), we do not reject the null that the lagged values of the churn rate and the lagged value of the oil price are valid instruments for the number of suppliers at the TTF and for the interaction term. Moreover, to test whether the instruments are correlated with the endogenous regressors we run the Kleibergen-Paap Lagrange Multiplier test of underidentification. The lowest test statistic obtained for the different models equals 6.554 and has a corresponding p-value of 0.0377, so we reject the null that our econometric model is underidentified when instrumenting for the number of firms and the interaction term.}
## Table 2: Results from the reduced-form regressions

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<th>Variable</th>
<th>OLS (1)</th>
<th>OLS (2)</th>
<th>OLS (3)</th>
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<th>GMM (9)</th>
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</table>

*Notes: n equal to wholesalers 80% of market (daily data)*

*, **, ***: Significant at the 10, 5, and 1 percent level
As can be seen from Table 2, the results provide relatively strong evidence that an increase in the number of active wholesalers leads to a fall in the inverse hedge ratio. The fall in the industry’s inverse hedge ratio due to a new firm entering the TTF is between 0.02 (0.02) not controlling for the endogeneity bias and 0.03 (0.01) instrumenting for the number of active wholesalers, using \( VOLAT_1 \) (\( VOLAT_2 \)) in the interaction term. This effect is quite substantial given that the average spot-to-sales ratio is around 1.10 in our sample period. This result, which is line with our result in Proposition 1, suggests that strategic considerations play an important role in firms’ decisions to sell forward.

Regarding the risk-hedging incentives, we find a negative and significant relationship between the two measures of demand volatility and the inverse hedge ratio. This suggests that the portfolio of forward contracts of the typical firm is also driven by risk hedging motives. The positive and significant interaction effect tells us that the risk-hedging motive somewhat weakens the firms’ incentive to trade forward for strategic reasons. As can be seen from Proposition 1, this result lends additional support to the Allaz and Vila model of forward selling.

With respect to the variables that relate to demand, our model predicts that an increase in demand slope has a positive impact on the inverse hedge ratio. Table 2 shows that all coefficients of the demand shifters have the expected sign. As natural gas is used by electricity firms to produce power, we expect the electricity price to have a negative effect on the ratio of interest. This indeed appears to be the case, as can be seen from Table 2. The coefficient of the seasonal dummy appears negative and significant in the regressions that use the variance of the log of prices as a proxy for demand uncertainty, but is no longer significant in the regressions that use the alternative measure for volatility. Due to these mixed results, we do not draw any strong conclusions about it. The results for the dummy \( EXCHANGE \) suggest that the introduction of the forward exchange ENDEX has reduced firms’ incentives to trade forward.

The regression results using the monthly measure of number of wholesalers are quite similar (see Table 3 in Appendix B). The results obtained when we compute the hedge ratios using the assumption that the forward market churn ratios is 50% higher than the spot market churn ratios show similar patterns. To save on space, we do not report the full Table. Nonetheless, the coefficients of the number of firms corresponding to the specifications in columns 2, 6 and 10 are equal to \(-0.03702\), \(-0.05857\) and \(-0.06157\) respectively and are all significant at the one percent level.

\[38\] If electricity prices increase, we expect power firms to increase their demand for natural gas, which can be modelled as a decrease in \( b \).
4 Concluding remarks

This paper has delved into the question why do oligopolistic firms sell forward contracts. While existing oligopoly theories suggest that firms will engage in forward contracting for strategic reasons, and, correspondingly, policy has been shaped to facilitate forward transactions, little work has presented evidence of this. Reasons for this lack of evidence include the facts that in many of the markets studied so far forward contracts are exogenous to the market process, or hardly observed by the researcher. Moreover, to the best of our knowledge, there has not been a clear empirical strategy to address the question whether forward contracting is strategic or just due to risk-management issues. This paper has tried to fill this gap.

We have used data from the Dutch wholesale market for natural gas where we observe the number of producers and wholesalers, forward and spot sales, churn rates and spot prices. Our empirical results are broadly consistent with the theoretical predictions derived from strategic models of forward and spot contracting. We have found evidence that a decrease in demand slope has a positive impact on hedging activity; moreover, firms hedge more when demand is more volatile. We have also found relatively strong evidence that an increase in the number of active wholesalers increases firms’ incentive to hedge. Seen from the perspective of the theory, this result lends support to the idea that forward contracting has an important element of strategic behaviour.

We make two remarks about this finding. First, from a policy perspective, it is important to understand the nature and strength of firms’ incentives to engage in forward trading. In order to foster entry and competition in the early stages of energy markets deregulation, regulators have typically forced incumbents to grant new entrants access to part of their production capacity on a forward basis. In the natural gas industry for example, this has taken the form of gas release programs. Our study shows that firms themselves have strong incentives to sell the bulk of their output in forward markets, which indicates that the market itself may provide a reasonable solution to the newcomers’ problem of gaining adequate access to supplies and/or capacity in the early stages of market reform.

Second, seen from the perspective that most of the forward transactions in the Dutch natural gas market occur OTC, the fact that strategic considerations play an important role behind the forward-selling strategy of a typical firm is interesting. To increase transparency in the Dutch market for natural gas, the Dutch government did set up ENDEX, an exchange for natural gas futures. A complete cost-benefit analysis of ENDEX is outside the scope of this paper but our
study suggests that the OTC market by itself may provide the firms with sufficient incentives to sell forward for strategic reasons.\footnote{39}

Futures markets exist for a number of commodities, including electricity, natural gas, emission trading permits, copper, iron ore, aluminium, steel etc. Though we have applied our model to the natural gas market in the Netherlands, we believe the general message of this paper is broader. Our insights, and in particular our methodology to address the question whether firms trade futures for strategic motives, should be applicable to other markets where firms have significant market power.

\footnote{39The costs of operating a futures market are non-negligible even in a time where virtual market places have displaced the more traditional physical hubs. In fact, personnel and ICT costs, along with the insurance and financial costs of dealing with default and other risks involved may render a marketplace unprofitable. ENDEX has been making losses for 5 out of its 6 or 7 years of existence. At the end of 2009, ENDEX was taken over by the APX Group, which owns various platforms for spot trading of natural gas and electricity in the NL, Belgium and the UK.}
Appendix A: TTF contracts

All contracts traded in the TTF call for physical delivery of natural gas at the GTS transmission grid. Concerning forward transactions, the most prominent types of contracts are the ones that are also eligible at ENDEX:

- Single-month contracts; these contracts can be traded from three months ahead till the expiration date, which is, with the exception of holidays, the penultimate working day of the month that precedes the month of delivery. The monthly contract then moves into delivery at the GTS transmission grid.

- Single-quarter contracts (quarters being defined as January-March, April-June, July-September and October-December); trade in these contracts starts four quarters ahead and continues till the moment the contract expires. For this product, the day of expiration is the last but two working days of the last quarter before physical supply takes place. After expiration, the quarterly contract converts into three monthly contracts.

- Single-season contracts (seasons being defined as April-September and October-March); these contracts can change hands from four seasons ahead till the day of expiration, which is the last but two working days of the season preceding the delivery period. When the seasonal contract expires, it falls into three monthly contracts and one quarterly contract.

- Single-calendar-year contracts (calendar year being defined as January-December); these contracts can be traded from three calendar years ahead till the moment of expiration, which is the last but two working days of the last year before the gas is delivered. After the contract expires, it cascades into three monthly contracts and three quarterly contracts.

The minimum volume that can be specified in quarterly, seasonal and calendar contracts is 10 MWh/h; for monthly contracts, this minimum volume equals 30 MWh/h.

Next to forward contracts, participants also trade spot contracts at TTF. Two types of spot market contracts can be distinguished:

- Day-ahead contracts; the trading market for these contracts opens two working days before physical supply takes place and closes two hours prior to the start of delivery.

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There exist also some contracts that can be traded OTC but not in the centralized exchange ENDEX. Among them are the Balance-of-Month (BOM) and Working-Days-Next-Week (WDNW) contracts. These kind of forward products constitute only a tiny share of the total number of the transactions in the TTF.
Within-day contracts; these contracts can be traded from 26 hours prior to delivery till two hours before the gas is physically supplied.

Appendix B: Regression results using monthly observations for the number of active wholesalers

As explained in the empirical section, for our baseline regressions we construct daily observations for the number of active wholesalers by assuming that the entry of a new firm is uniformly distributed over the trading days in the month in which this firm enters the TTF. In Table 3, we report the results in case we use the monthly observations for the number of firms as an explanatory variable in our empirical model. As can be seen from this table, the results discussed in the main text of the paper are robust to using this alternative measure for the number of TTF sellers.
<table>
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Notes: $n$ equal to wholesalers 80% of market (monthly data)
*; **; ***: Significant at the 10, 5, and 1 percent level

Table 3: Results from the reduced-form regressions using the monthly number of wholesalers
References


