Chapter 4

Do firms sell forward for strategic reasons? An application to the wholesale market for natural gas

4.1 Introduction

In the previous chapter, we have developed an empirical strategy to test whether oligopolistic firms use forward contracts for strategic motives, for risk-hedging, or for both. We have shown this empirical strategy is based on the the properties of a firm’s expected inverse hedge ratio. Particularly, the identification of the strategic motive to sell forward relies on variation in the number of participants in the industry.

In this chapter, we apply this strategy to the Dutch wholesale market for natural gas. In contrast to restructured markets elsewhere, the Dutch natural gas market is one where forward contracts have not been forced upon the producers and wholesalers by the regulator. This is important because otherwise it would be difficult to learn whether the market by itself provides the players with the necessary hedging and commitment opportunities.\(^1\)

\(^*\)This chapter is based on van Eijkel and Moraga-González (2010).

\(^1\)Our empirical strategy is therefore built upon a theoretical framework where the supply of forward contracts depends on the firms’ incentives and is thus endogenous to the model. This is in contrast to situations where regulators impose forward obligations on large energy suppliers. One
Our data set consists of a fairly large fraction of all (forward, spot and speculative) trades conducted at the Dutch gas hub Title Transfer Facility (TTF), from April 2003 until June 2008. The TTF is a virtual trading hub that offers market participants the possibility to transact ‘entry-paid gas’, both on a forward and spot basis. At the TTF, gas can be traded at high speed before it leaves the pipeline system at a specific exit point. This has triggered the entry of new players into the Dutch market and the creation of centralized exchanges where standardized contracts change hands. Since we also have data on the number of active wholesalers at the TTF, we can exploit this information to estimate the restrictions on the inverse hedge ratios imposed by the theoretical model. Despite the recent emergence of gas exchanges, the bulk of TTF trade is conducted over-the-counter, either via bilateral negotiations or through brokers. Since there is a widespread belief that transactions in the OTC market are not as visible as in centralized exchanges, the question arises whether the TTF provides gas wholesalers the possibility to trade forward contracts for strategic purposes.

Our results lend support to the hypothesis that wholesalers in the Dutch gas industry find opportunities to sell on a forward basis for strategic reasons. Given that the lion’s share of TTF trade takes place in the OTC market, we think this is an important result. OTC markets are often criticized for being relatively opaque, impeding the development of efficient markets where prices contain a high level of information about market conditions. However, for the strategic commitment value of forward trading to exist the contract market has to be relatively transparent. Hence, at least for the Dutch gas industry it seems that at the wholesale level OTC...
transactions convey sufficient information about firms’ forward decisions. Moreover, we also observe that the strategic motive has become somewhat more important over time which may indicate that the TTF has gained in transparency. Another interpretation of this result is that there exists a learning effect, that is, market players have become more competent to infer from price changes what is happening in the market.

Surprisingly, we find no statistical evidence that in the Dutch gas market wholesale firms hedge their output for risk-hedging reasons. As can be read in the previous chapter, one potential problem that makes it more complicated to estimate the degree of risk aversion precisely is that without further information on spot price volatility, one cannot identify the risk aversion parameter separately from the variability of the (spot) price shocks. To address this issue, we run a regression using data on the volatility of spot prices. Still, we do not find that firms use forward contracts to hedge against price shocks in the spot market.

This result becomes even more interesting when comparing it to insights from research on risk-hedging in electricity industries. Amongst others, Longstaff and Wang (2004) and Bessembinder and Lemmon (2006) provide empirical evidence that market participants in power markets do trade on a forward basis to hedge against spot price shocks. Bessembinder and Lemmon use data on the Pennsylvania, New Jersey and Maryland (PJM) and the California Power Exchange (CALPX) wholesale electricity markets to test the hypotheses derived from their theoretical model on forward trading and pricing. They find some preliminary evidence that in periods with higher demand, more price variability and greater price skewness forward premia are higher than at other times. Having a more extensive data set at their disposal than Bessembinder and Lemmon, Longstaff and Wang also conclude that for the PJM power market intertemporal changes in the forward premia are driven by market risk fundamentals.

One could think that the different attitude towards risk across the two different industries is due to the allegedly higher volatility in electricity prices compared to price variability in the gas market. The explanation that is usually put forward to

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6There is some further empirical evidence that forward contracting has a pro-competitive effect (Green, 1999; Wolak, 2000; Fabra and Toro, 2005; Hortaçsu and Puller, 2008; Bushnell, Mansur and Saravia, 2008). These papers have focused on electricity markets where forward contracts have often been imposed by regulators and can therefore be considered exogenous to the equilibrium process. As already being pointed out, we deal instead with a market where forward contracts are endogenous which enables us to see whether the market by itself provides the necessary incentives to the firms to engage in strategic contracting.
defend this claim is the non-storable nature of electricity, which eliminates the value of holding inventories to accommodate demand fluctuations. As a result, sudden price shocks are more likely to occur. Though in principle natural gas can be stored, we however also observe significant volatility in gas prices, at least at those market levels where the link to the oil price has been removed and prices have become more in line with changes in supply and demand conditions. A reason for this could be that the opportunities to store gas are limited and relatively costly, so that for its most part production, delivery and consumption take place contemporaneously.\footnote{Regnier (2007) shows that in recent years, the price volatility of fuel gas in the U.S. is actually much higher than the variability in electricity prices.}

As we will see later in this chapter, also at the TTF market participants are frequently confronted with quite severe price shocks.\footnote{To provide some first insight in the price fluctuations on the TTF, we note that in the first two days of March '05 the spot price index was around 27 €/MWh, after which it increased to 31 €/MWh on the third day and rose further to 51 €/MWh on the 4th of March. On the sixth trading day of March '05 the gas price index was back on a low level of 18 €/MWh.} This suggests that the degree of price variability in the Dutch gas market cannot explain the lack of risk-hedging incentives for wholesale firms in this market. Later in this chapter, we will discuss in somewhat more detail that the most plausible reason for the fact that we do not find a significant hedging incentive is that the strategic motive is present. Our results suggest that when firms sell forward for strategic reasons, the residual volatility in the market is small so risk-hedging plays no longer a fundamental role.

This chapter is structured as follows. The next section gives a short overview of the Dutch wholesale market for natural gas, where we particularly look at the role of the TTF in this market. In Section 4.3 we discuss the data set we use for our empirical study and provide some descriptive statistics of the data. Section 4.4 is the core of this chapter and contains the main empirical analysis. Then in Section 4.5 we investigate a few further issues, most of them being merely robustness checks. This chapter ends with some concluding remarks. The Appendix provides some more information about the different types of contracts that are traded at the TTF.

### 4.2 The Dutch wholesale market for natural gas

We use data from the Dutch wholesale market for natural gas. For the purpose of this chapter, 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.

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.\textsuperscript{9} 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.\textsuperscript{10} Gasunie sold the gas to industrial customers and distribution companies.

Market deregulation in the Netherlands started back in the late 1990s with the \textit{Price Transparency Directive}, but gained full momentum with the \textit{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 \textit{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 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.\textsuperscript{11} The TTF made the emergence of gas exchanges possible. 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

\textsuperscript{9}Gasunie was a joint venture between De Staatsmijnen (DSM), Shell, Esso and the Dutch State.  
\textsuperscript{10}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.  
\textsuperscript{11}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.
the same day. 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.

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.

4.3 Data

Our data set consists of a substantial fraction (approximately 75 percent) of all forward and spot contracts traded at the Dutch TTF for the period from April 2003 until June 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 partners so we 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 be either facilitated by brokers, or exchange-based, or the out-

\footnote{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 4.4 we provide more details on the types of contracts traded at the TTF.}

\footnote{Most of the TTF-traded gas is high-calorific, which is gas that is mostly used for industrial and exporting purposes. High-calorific can also be converted into low-calorific gas, which is the gas intended for domestic residential usage.}

\footnote{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.}

\footnote{The participants in the industry must make ‘nominations’ to the transport operator once the gas changes hands. In this way, the transport operator receives the necessary information to compute total traded volumes and the churn rates. Using the data on total volumes delivered at the TTF, we estimate that our data contains well above 50 percent of the total market.}
come of bilateral negotiations. All these three 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 the centralized exchange ENDEX. 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 in 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.\footnote{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.}

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 6, 2003 for delivery of 4,320 MWh the next day, and (iii) a spot contract traded on December 20, 2003 for delivery of 1,440 MWh the same day. Then, except for two days, December 7 and 20, for each day in December 2003 the delivery volume is 720 MWh. On December 7, the total delivery volume equals \((720+4,320=)\) 5,040 MWh while on December 20, the delivery volume is \((720+1,440=)\) 2,160 MWh. As a result, the hedge ratio is 1 for all days of December 2003 except for December 7, with an inverse hedge ratio of 8, and December 20, with an inverse hedge ratio of 3.

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 positions before delivery, many of the contracts we see are re-trades and do not involve volumes that are finally brought to the market. Fortunately, we can deal with this issue using data on churn rates (net-to-gross-volume ratios). Churn rates are reported by GTS. These rates do not distinguish between forward trades and spot market trades. Obviously, actual churn rates for spot market transactions are much lower than those corresponding to forward trades, since the
length of time to resell contracts is rather short in the spot market. In what follows, we assume forward transactions have a churn rate equal to the churn rate reported by GTS; for spot market trades, we assume the churn rate equals one. Table 4.1 provides some descriptive statistics of our data and Figure 4.1 displays the forward sales adjusted for the churn rate, as well as the spot market sales.

The descriptive statistics reveal four interesting aspects of the data. First, volumes traded at the TTF have gone up a great deal. In fact, by 2008 the TTF

In different words, we are assuming speculators do not take positions during the time the spot market is open. If we had information on the identity of the traders, we could check the validity of this assumption.

Besides data on traded volumes, Table 4.1 also contains information on forward prices and spot prices. The forward price indices we report concern monthly contracts. We compute four different forward price indices: the price index obtained using all transactions that take place (1) more than one month before the month of delivery; (2) in the first half of the month preceding delivery; (3) in the last half of the month before delivery (4) in the last two days before delivery. In Table 4.1 we only report the index for monthly contracts traded in the first half of the month preceding the delivery month. The other indices show a very similar pattern. Spot prices are determined by computing an index for all the day-ahead deals included in our data set.

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 20% 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).
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<th>Min</th>
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<td></td>
<td>Spot price</td>
<td>22.73</td>
<td>26.64</td>
<td>24.70</td>
<td>1.44</td>
</tr>
</tbody>
</table>

Notes: Year 2003 averaged over 9 months. Year 2008 over 6 months.
became the second largest gas trading 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 U.K. The BBL pipeline allows TTF-traded gas to be shipped to the U.K. and this brings TTF prices down and more in line with U.K. 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 remarkable that the hedge ratio has increased over time but, by no means, it has changed by the order of magnitude the volumes have changed. Furthermore, we note that the standard deviation of the inverse hedge ratio seems to have gone down over the sample period. The latter two observations appear to be in line with our model of firm behavior (inverse hedge ratios are mean independent of the strength of the demand parameter and have a standard deviation negatively correlated with it, see Proposition 3.1). Finally, it can be seen from Table 4.1 that forward prices and spot prices are closely linked, though the former are in general somewhat higher than the latter.

As discussed earlier, identification of the key parameters of the model requires 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

---

20The National Balancing Point (NBP) in the U.K., introduced in 1996, has long since been the most liquid hub in Europe.

21Using the four different forward price indices, we perform an ANOVA test of the null hypothesis that spot and forward prices are statistically similar to each other. For three out of the four forward price indices, the hypothesis cannot be rejected (the only index that appears to be significantly different than the spot price index is the one computed from transactions that take place longer than a month before delivery).

22To 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.
whatsoever, we also asked for the number of active wholesalers making up for 60 and 80 percent of total delivery. Figure 4.2 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.

![Figure 4.2: Number of wholesalers active at TTF](image)

Given the monthly nature of our data on the number of active wholesalers, we compute aggregate monthly delivery forward and spot volumes and conduct the analysis using 63 monthly observations. 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 that serve 80% of the market is the same and compute the average hedge ratio for those months. We then regress the hedge ratio on a constant and on the number of wholesalers. Figure 4.3 displays the relation between the number of wholesalers trading at the TTF and the average ratio of interest. The dots in the figure represent the average ratio for a given number of wholesale firms in our data set, while the dashed line shows the estimated relation between the number of wholesalers and the inverse hedge ratio. The results of the regression indicate that this relation is negative, which, according to the theoretical model, suggests that forward contracts are used as strategic instruments.\(^\text{23}\) Since

\[^{23}\text{More precisely, we estimate by OLS the model } \hat{\Gamma}_n = \alpha + \beta n + u_n, \text{ where } \hat{\Gamma}_n \text{ is the average}\]
this regression does not allow us to learn the extent to which the players’ positions are observed, we proceed by estimating the model structurally.

The relation to be estimated can be written as (see Equation (3.15))

$$\frac{n_t + 1}{n_t} \sum_{i=1}^{n} s_{it} = \frac{n_t + 1}{n_t} \left( \Gamma(n_t, \gamma, \lambda) - 1 \right) \sum_{i=1}^{n} x_{it} + \frac{\epsilon_t}{b}, \quad \epsilon_t \sim N(0, \sigma^2),$$

where \( t \) indexes the time period (month) and \( \gamma \) and \( \lambda \equiv \frac{\nu \sigma^2}{b} \) are the parameters of interest. The NLS regression results are summarized in Table 4.2.

As can be seen from Table 4.2, the estimate for the observability parameter, \( \hat{\gamma} \), is equal to 0.83 and is highly significant. We view this result as a first piece of evidence that strategic considerations play an important role in explaining the hedge ratios observed in the data. As said above, this can be interpreted as if firms attached approximately 80 percent probability to the event that their forward positions are

4.4 Results

Figure 4.3: Inverse hedge ratio and the number of wholesalers

---

inverse hedge ratio for a given number of wholesale firms, \( n \) the number of wholesalers and \( u_n \) the usual error term. The estimates become \( \hat{\alpha} = 1.36 \) and \( \hat{\beta} = -0.01 \), with standard errors being equal to 0.06 and 0.006, respectively.
correctly forecasted by the rival firms upon observing the forward price. Seen from
the perspective that most transactions at the TTF occur OTC, we find the result
that the forward market is quite transparent interesting. It actually means that the
market by itself is able to activate the role of forward sales as a commitment device.

The estimate for the risk aversion parameter, $\hat{\lambda}$, turns out not to be significant.
This suggests that there is not clear evidence that risk-hedging is a key factor ex-
plaining observed hedge ratios in the Dutch natural gas market.\[^{24}\]

The previous regression assumes demand volatility is constant over the sample
period. If demand has become more (or less) volatile as time has elapsed, not con-
trolling properly for such variation may lead to some form of omitted variable bias.
Of course, changes in $\sigma^2$ are controlled for by changes in the forward sales. However,
since $\sigma^2$ affects (4.1) directly, this control may be insufficient.

To explore this issue, we first construct a measure of demand volatility using
spot market prices and use it to increase the variation in the data. Using Equation
(3.10), and rearranging, we can write the equilibrium spot price as follows:

$$p_t = a_t - b \sum_i \Gamma_{it} x_{it} + \frac{1}{(n_t + 1)} \epsilon_t.$$  

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

$$\sigma_t^2 = (n_t + 1)^2 \sigma_{p_t}^2.$$  

To determine the monthly volatility of demand shocks, we thus need some measure
for price variability. For this, we first proxy daily spot prices by computing a weighted
price index for day-ahead contracts. Then, monthly demand volatility, $\sigma_t^2$, is obtained
by calculating the variance of the spot prices within a given month and multiplying

\[^{24}\text{We have also estimated Equation (4.1) for the case where } n \text{ equals the number of all active
wholesalers. We obtain similar results. The estimate for } \gamma \text{ is equal to 0.76 and is significant at the
1 percent level, while } \lambda, \text{ in this case becoming nearly zero, is again non-significant.}\]
Do firms sell forward for strategic reasons? An application to the wholesale market for natural gas

this measure by \((n_t + 1)^2\).

Figure 4.4 plots (the natural logarithm of) our estimate for the monthly demand volatility. The graph shows that in some months the (estimate for the) demand variability is much higher than in other months and that demand has become more volatile over the sample period. This should explain part of the observed decrease in the inverse hedge ratios and, as a result, we would expect to obtain a lower estimate of the transparency parameter \(\gamma\). The new estimates of equation (4.1) are in Table 4.3. In fact, the new estimate of the transparency parameter \(\gamma\) is somewhat lower and continues to be highly significant. Again we do not obtain significant evidence that risk is an important issue in this market.

![Figure 4.4: measure of demand uncertainty](image)

It is conceivable that forward market transparency has increased over time. First, one can imagine that market participants’ ability to interpret price signals has improved as time has elapsed. Second, it is also reasonable to believe that the quality and the quantity of the price indices available in the market has increased over time. Price information is now provided by information agencies such as ICIS Heren and Argus Media Ltd., brokers’ associations such as LEBA, as well as the centralized

---

25Notice that using \textit{ex post} price variation as a proxy for demand uncertainty relies on the assumption that firms have \textit{ex ante} perfect foresight about the volatility of future (spot) prices. Campa and Goldberg (1993) use this approach to study the effect of exchange rate volatility on entry of foreign firms in the U.S. market during the 1980s.

26\url{www.argusmedia.com}

27London Energy Brokers’ Association (\url{www.leba.org.uk})
Table 4.3: NLS regression with demand volatility measure

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho/b$</td>
<td>9189.1</td>
<td>$2.37 \cdot 10^7$</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.70*</td>
<td>0.02</td>
</tr>
</tbody>
</table>

$R^2 = 0.70$

Notes: $n$ equal to wholesalers 80% of market
* Significant at the 1 percent level

marketplace ENDEX. Finally, the share of trades conducted (or cleared) at the gas exchange (vis-à-vis OTC) has increased over time and, since the exchange may be considered a more transparent marketplace than the OTC market, this adds to the supposition that the forward market as a whole has become more transparent. If this conjecture is borne by the data, we should observe an increase in the observability parameter $\gamma$ over time.

To test this learning hypothesis, we introduce year dummies into the empirical model in (4.1). We continue to use the proxy for changes in demand volatility. As can be seen from Table 4.4, the new estimates show a positive trend in the observability parameter. When testing for differences between the year dummies, we find that the estimate for $\gamma$ in 2004 is significantly lower than the estimates for $\gamma$ in 2007 and 2008 at the 10 percent level. The results suggest that wholesalers’ ability to infer deviations from equilibrium play has indeed increased over time, although this effect is not very strong.

Table 4.4: NLS regression with demand volatility measure and year dummies.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho/b$</td>
<td>9967.8</td>
<td>$1.65 \cdot 10^7$</td>
</tr>
<tr>
<td>$\gamma_{2003}$</td>
<td>0.81</td>
<td>0.68</td>
</tr>
<tr>
<td>$\gamma_{2004}$</td>
<td>0.30</td>
<td>0.30</td>
</tr>
<tr>
<td>$\gamma_{2005}$</td>
<td>0.67*</td>
<td>0.09</td>
</tr>
<tr>
<td>$\gamma_{2006}$</td>
<td>0.66*</td>
<td>0.05</td>
</tr>
<tr>
<td>$\gamma_{2007}$</td>
<td>0.71*</td>
<td>0.04</td>
</tr>
<tr>
<td>$\gamma_{2008}$</td>
<td>0.71*</td>
<td>0.03</td>
</tr>
</tbody>
</table>

$R^2 = 0.72$

Notes: $n$ equal to wholesalers 80% of market
* Significant at the 1 percent level
We have searched for explanations for the result that there is no evidence that risk-hedging is an important factor to explain the observed inverse hedge ratios. One possible explanation is that being the strategic effect present and relatively strong, the incentives to hedge become rather weak. In fact, when $\gamma$ is close to one, and for the firm numbers in our data (from 4 to 14 players), the share of the hedged quantity in total sales is already relatively large so the residual demand of a firm is quite low. This makes it rather difficult to precisely estimate the risk aversion parameter. To substantiate this observation, we plot the fit of the estimated model (with and without a proxy for $\sigma^2$), along with those which would prevail if the wholesalers were risk-neutral ($\lambda = 0.01$) or very risk averse ($\lambda = 100,000$). The graph illustrates that the inverse hedge ratios predicted by the different levels of risk aversion are somewhat similar; as a result, one would need a very rich data set to precisely estimate the risk aversion parameter.

Finally, we note that most TTF-trade is on high-calorific gas, for which demand is mainly industrial and for exporting purposes and therefore less subject to unpredictable weather shocks (see NMa/DTe, 2007). The other type of gas sold at the TTF is low-calorific gas. Demand for this type of gas is weather-driven to a larger extent.

---

28To plot the fit of the regression with a proxy for demand volatility included, we take the sample mean of $\sigma^2$ and multiply this measure by the estimated $\rho/b$ to get an estimate for $\lambda$. 

---

Figure 4.5: Fit of the model
extent because this type of gas is meant for household usage; however, due to limited conversion capacity, most of the low-calorific gas delivered in the Netherlands does not pass the TTF.

4.5 Discussion and further results

4.5.1 Uncertain spot market

In the previous chapter, we also studied the case in which firms do not observe price shocks before the spot market opens. We now take this variation to the data in order to see whether the estimation results for the basic model are robust to changes in the assumption on when the price shock becomes known. Applying the inverse hedge ratio obtained in the previous chapter (see Proposition 3.2), we start by fitting the relation

$$
\frac{q_t}{x_t} = \frac{\gamma(n_t - 1) + (n_t + 1 + \rho \sigma^2)(1 + 3 \rho \sigma^2 + \left(\frac{\rho \sigma^2}{b}\right)^2)}{(2 + \rho \sigma^2)(\gamma(n_t - 1) + \frac{\rho \sigma^2}{b}(n_t + 1 + \frac{\rho \sigma^2}{b}))} + \varepsilon_t,
$$

where $\varepsilon_t$ is an error term. The NLS regression results are given in Table 4.5. The results are similar in that the estimate for the observability parameter is relatively high and highly significant. The estimate for the risk aversion parameter is again non-significant. The relatively low $R^2$ indicates that this model does less well in explaining the observed variation in inverse hedge ratios than the model estimated in Section 4.4.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\lambda$</td>
<td>0.64</td>
<td>0.54</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.72*</td>
<td>0.12</td>
</tr>
</tbody>
</table>

$R^2 = 0.12$

Notes: $n$ equal to wholesalers 80% of market

* Significant at the 1 percent level

Table 4.5: NLS regression results; no proxy for $\sigma^2$

To control for variation in demand volatility, as before, we add the appropriate proxy. In this case, using the equilibrium equations we observe that $\sigma_t^2 = \sigma_{p_t}^2$, so we just take the within-month variation in spot prices to proxy for the degree of demand uncertainty. The new estimates of Equation (4.2) are given in Table 4.6. Again, controlling for month-to-month changes in demand volatility does not seriously affect the regression results; the estimate for $\gamma$ is still highly significant, while the estimate
for $\lambda$ seems not to be able to explain any variation in the observed inverse hedge ratios.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho/b$</td>
<td>0.004</td>
<td>0.25</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.85*</td>
<td>0.06</td>
</tr>
</tbody>
</table>

$R^2 = 0.07$

Notes: $n$ equal to wholesalers 80% of market
* Significant at the 1 percent level

Table 4.6: NLS regression with demand volatility measure

Finally, we look at the effects of including year dummies. The results are given in Table 4.7. We see that the learning effect becomes less prominent than in the model we estimate in the previous section.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho/b$</td>
<td>0.002</td>
<td>0.59</td>
</tr>
<tr>
<td>$\gamma_{2003}$</td>
<td>0.98*</td>
<td>0.12</td>
</tr>
<tr>
<td>$\gamma_{2004}$</td>
<td>0.77*</td>
<td>0.20</td>
</tr>
<tr>
<td>$\gamma_{2005}$</td>
<td>0.87*</td>
<td>0.11</td>
</tr>
<tr>
<td>$\gamma_{2006}$</td>
<td>0.86*</td>
<td>0.10</td>
</tr>
<tr>
<td>$\gamma_{2007}$</td>
<td>0.84*</td>
<td>0.10</td>
</tr>
<tr>
<td>$\gamma_{2008}$</td>
<td>0.86*</td>
<td>0.10</td>
</tr>
</tbody>
</table>

$R^2 = 0.28$

Notes: $n$ equal to wholesalers 80% of market
* Significant at the 1 percent level

Table 4.7: NLS regression with demand volatility measure and year dummies.

In sum, we conclude that our results in the main body of this chapter are robust to this change in the modeling of the spot market. Irrespective of whether firms observe the demand shocks before they supply gas in the spot market or not, we find that strategic considerations are important at explaining the observed hedge ratios in the industry. By contrast, risk-hedging appears not to have a large explanatory power. Comparing the fit of the two models to the data, we note that the model where spot strategies can be tuned to accommodate the demand shocks has a much higher explanatory power.

In Figure 4.6 we show the fit of the two models to the data, where we have used
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the estimates reported in Tables 4.3 and 4.6 to construct the fitted curves. Both models suggest that the forward market is rather transparent, as the two estimated curves predict a fall in the ratio of interest when more firms become active at the TTF. However, the model that does not allow firms to condition their spot strategies on the realized demand shock predicts a higher impact of firm entry on the inverse hedge ratio. This clearly gives a less good fit of the data, as can be concluded from comparing the $R^2$ of both regressions.

![Figure 4.6: Fit of the different models](image)

4.5.2 Endogeneity of the number of wholesalers

In our main model we have assumed demand is linear and this has implied that the relation to be estimated, Equation (3.15), does not depend directly on the demand intercept parameter and the marginal cost of the firms. As a result, data on demand and costs are not essential to estimate Equation (4.1) because changes in these variables are captured by changes in the forward sales. A related implication is that the estimates reported in Tables 4.2, 4.3 and 4.4 assume that the number of wholesalers is exogenous.

If, instead, we had used other demand specifications, the demand and cost parameters would probably have entered directly in the equilibrium condition we want...
to estimate. Omitting these variables, together with the fact that market profitability – and therefore the number of active wholesalers – at the TTF depends on market characteristics such as demand strength, the cost of supplying gas and the cost of entering the hub, raises the issue that the number of active wholesalers is not exogenous from an econometrics point of view. To address this potential endogeneity issue, we propose to use a free-entry condition that we estimate together with Equation (4.1).

We assume that gas wholesalers enter the TTF till the last firm that enters makes zero profit in expectation. By substituting the equilibrium forward sales, given by Equation (3.10), into the expression for profits we obtain the following zero-profit condition:

\[(a - c)^2 \Omega(b, \gamma, \rho, \sigma^2, n)/b - F + \nu = 0, \quad \nu \sim N(0, \sigma^2_\nu),\]  

(4.3)

where \(F\) denotes a firm’s cost of entry, \(\Omega = \omega_1 \omega_2\), with

\[
\omega_1 = \frac{(n + 1 - \gamma(n - 1))(n + 1)^2 + 2\lambda}{(n + 1)^2},
\]

\[
\omega_2 = \frac{(n + 1)^2(n + 1 + \gamma(n - 1)) + 2(3(n + 1) - \gamma(n - 1))\lambda}{(n + 1)^2(n + 1 - \gamma(n - 1)) + 2\gamma n(n^2 - 1) + 2(n(3 - \gamma) + 1 + \gamma)\lambda^2}
\]

and the term \(\nu\) is a random shock normally distributed with mean equal to zero and standard deviation given by \(\sigma_\nu\).

To add the information provided by the free entry condition (4.3) we need additional data. As a proxy for the demand intercept parameter \(a\), we take monthly average prices of electricity spot contracts traded at the Dutch spot electricity exchange APX. In particular, we assume \(a_t = a_0 + a_1 \epsilon_t\) where \(a_0, a_1\) are free parameters and \(\epsilon_t\) is the spot price of electricity in period \(t\). On the cost side, we consider the oil price as being informative for the marginal production cost of a gas wholesaler. The rationale behind this is that prices in long-term contracts between gas producers and wholesalers are often indexed by the oil price. We therefore proxy the monthly

---

29 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 is 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.

30 As mentioned above, a great deal of the gas traded in the TTF is high-calorific gas whose main use is in industrial applications such as the production of ammoniac as well as in the production of electricity.
marginal cost by \( c_t = c_0 + c_1 o_t \), where \( c_0, c_1 \) are free cost parameters and \( o_t \) is the monthly world oil price.

It is difficult to obtain information on entry costs. Wholesalers operating in the TTF have to pay a fixed fee of 1,263 Euros to register at the TTF for a single gas month. In addition, if these wholesale firms also want to participate in the centralized exchanges, they have to pay an extra fixed fee of 2083 Euros per month.

We thus estimate the following system of equations:

\[
\begin{pmatrix}
  y_t \\
  0
\end{pmatrix} = \begin{pmatrix}
  g(n_t, \sum_{i=1}^n x_{it}, \gamma, \sigma_t^2, \rho, b) \\
  \xi r(a_t, c_t, F_t, n_t, \gamma, \sigma_t^2, \rho, b)
\end{pmatrix} + \begin{pmatrix}
  \epsilon_t \\
  \xi \nu_t
\end{pmatrix}, \quad \begin{pmatrix}
  \epsilon_t \\
  \xi \nu_t
\end{pmatrix} \sim \begin{pmatrix}
  0 \\
  0
\end{pmatrix}, \quad \begin{pmatrix}
  \sigma_{\epsilon_t}^2 \\
  0
\end{pmatrix},
\]

where

\[
y_t \equiv \frac{n_t + 1}{n_t} \sum_{i=1}^n s_{it}
\]

\[
g \left( n_t, \sum_{i=1}^n x_{it}, \gamma, \sigma_t^2, \rho, b \right) \equiv \frac{n_t + 1}{n_t} \left( \Gamma(n_t, \gamma, \sigma_t^2, \rho, b) - 1 \right) \sum_{i=1}^n x_{it}
\]

\[
r(a_t, c_t, F_t, n_t, \gamma, \sigma_t^2, \rho, b) \equiv (d + a_1 \epsilon_t - \beta_1 c_t)^2 \Omega(n_t, \gamma, \sigma_t^2, \rho, b) - F_t
\]

and \( d = a_0 - c_0 \) and \( \xi \) is a weighting parameter 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 \( \xi \) equal to the ratio of the standard deviations of the two error terms in (4.4), \( \xi = \sigma_{\epsilon_t}/\sigma_{\nu} \). The new regression results are summarized in Table 4.8.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \rho/b )</td>
<td>3.5 \cdot 10^5</td>
<td>5.26 \cdot 10^8</td>
</tr>
<tr>
<td>( \gamma )</td>
<td>0.70*</td>
<td>0.02</td>
</tr>
</tbody>
</table>

\( R^2 = 0.68 \)

Notes: \( n \) equal to wholesalers 80% of market
* Significant at the 1 percent significance level

Table 4.8: NLS regression results with endogenous \( n \)

The estimates of the key parameters do not change much if we include the

31Next to the fixed fee, participants pay a variable tariff for each MWh traded in the TTF. These variable fees are picked up by the constant \( c_0 \) in our estimation.

32We conduct a feasible weighted NLS regression (see Greene, 1993, p. 209-211). The estimate of the weight \( \xi \) is given by \( \hat{\xi} = \sqrt{\frac{\hat{\epsilon}^2}{\hat{\nu} / \nu}} \), which is the square root of the ratio of the sums of squared residuals.
stochastic zero-profit conditions in the regressions. The strategic effect is again highly significant, while the risk-hedging motive is still non-significant.

4.5.3 Imperfect observability by financial traders

In the analysis so far we have assumed that financial traders are informed about the wholesalers’ forward positions at all times. The implication of this assumption is that a strong version of arbitrage (off and on the equilibrium path) between forward and spot markets holds. In this Section we explore the importance of this assumption. If, instead, speculators do not observe the wholesalers’ forward positions at all, they do not react to out of equilibrium deviations. As a result, the forward price is rigid and does not change off the equilibrium path. Of course in equilibrium traders’ beliefs are correct, so that $f = E(p)$ still holds true.

To explore the role of this assumption, we propose to consider the case in which financial traders observe wholesalers’ forward positions imperfectly. We model this idea by introducing a new Bernoulli random variable, denoted $I_s$, with parameter $\mu$. If $I_s = 1$ deviations in the forward market become observed by the financial traders; this occurs with probability $\mu$. If $I_s = 0$, forward positions remain opaque and the forward and the spot price need not coincide off the equilibrium path. The parameter $\mu$ can then be interpreted as the extent to which the forward transactions are observed by the financial traders/speculators.

In this case, the average hedge ratio is

$$\Gamma_i = \frac{b(n+1)^2((n-1)(2-\mu)+(1+n)\mu)-2(2+\mu(1+\gamma)+(2+\mu(1-\gamma))n)p_i\sigma^2}{2(n+1)(b(n^2-1)\gamma+2p_i\sigma^2)}.$$  \hspace{1cm} (4.5)

Note that

$$\frac{\partial \Gamma_i}{\partial \mu} = \frac{(1+\gamma+n(1-\gamma))(b(n+1)^2+2p_i\sigma^2)}{2(n+1)(b(n^2-1)\gamma+2p_i\sigma^2)} > 0.$$  

Therefore, as the probability that traders observe deviations goes up, a smaller fraction of a firm $i$’s output is hedged. The intuition or this result is simple: everything else equal, the negative price effect brought about by a firm’s forward sales (referred to above) strengthens as the forward market becomes less opaque for the speculators (spot and forward price falls only if this deviation is anticipated by the traders).

We now estimate this extension where the traders observe forward positions with probability $\mu$. This amounts to fitting Equation (4.1) modified by the fact that the average hedge ratio is now given by (4.5). We obtain an estimate of speculators’ observability parameter $\mu$. The new estimates are in Table 4.9.
Table 4.9: NLS regression results with imperfect financial traders

The new results show a somewhat weaker strategic effect, though, in line with the previous results, it is still highly significant. We continue not obtaining conclusive evidence that the risk-hedging effect is relevant in our market. Finally, the observability parameter of the financial traders equals 0.47, though it is not estimated with much precision.

Lastly, we estimate the model with imperfect trader observability by including year dummies for $\gamma$. The results are displayed in Table 4.10. We again observe an increase in the year dummies, which suggests that the strategic motive has gained more importance over the years. However, since none of the estimates is significant we do not want to draw any strong conclusion from these results.

Table 4.10: NLS regression results with imperfect trader observability and year dummies

\[ R^2 = 0.73 \]

Notes: $n$ equal to wholesalers 80% of market

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33When instead of using 80% of the wholesalers we use all of them, we obtain an estimate of $\gamma$ equal to 0.76, with a standard error of 0.05, an estimate of $\lambda$ equal to 0.00, with a standard error of 712.21, and an estimate of $\mu$ equal to 1.00, with a standard error of 521.73.
4.6 Concluding remarks

Using data from the Dutch wholesale market for natural gas where we observe the number of producers and wholesalers, forward and spot sales, and churn rates, we find evidence that strategic reasons play an important role at explaining the observed firms’ hedge ratios. By contrast, the data do not support the idea that risk-hedging motives are an important aspect behind the observed firms’ hedge ratios. Seen under the perspective that most of the forward transactions in the Dutch natural gas market occur OTC we think this is an important result. We also document a (moderate) learning effect, which is probably related to the development of the market.
4.A Appendix

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.34

• 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:

34There 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.
• 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.

• Within-day contracts; these contracts can be traded from 26 hours prior to delivery till two hours before the gas is physically supplied.