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Strategic Investment, Forward Markets and Competition

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Abstract

I model the strategic interaction between firms, that face decisions on investment, forward contracts and spot market quantities. For an investment decision that takes place after firms have contracted forward but before firms compete on the spot market (medium term investment), competition becomes fierce. Thus, the efficiency gains from forward trading found by Allaz and Villa (1993) still are present. However, for an investment that takes place before firms contract forward (long term investment), competition becomes rather weak. When investment matters, from a welfare point of view the desirability of forward trading critically depends on the structure of decision making.

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1 Introduction

Commodity markets like that for oil, gas, power and steel show several characteristics of imperfect competition. Due to the very specialized knowledge needed as well as the high requirement of capital and the economics of scale, there exist entry barriers and as a result commodity markets are often dominated by few oligopolistic firms.
Especially on commodity markets investment decisions play a crucial role for strategic competition. There are very long lasting investments like that for building up a plant, exploring a mine, building up a pipeline or introducing a cost-reducing new technology. Other investments like that for building up capacities in an existing plant, distributing or advertising the product have

a shorter time horizon. The importance of investment decisions on these markets can in particular be illustrated by the German power market. The annually investment costs for the ongoing turnaround to a sustainable energy supply are estimated by The German Institute for Economic Research (DIW Berlin) (Blazejczak, Diekmann, Edler, Kemfert, Neuhoff, and Schill, 2013) up to 38. billion Euro. From this total amount of 38 billion Euro approximately 26 billion Euro are needed for investments in power and heating supply and 7 billion Euro for investments in the electricity network.

Another market characteristic of many commodity markets and especially for the power market is the fact that a substantial proportion of firms' output is not sold directly to consumer on a spot market but rather to speculators on a futures market, who sell the commodity in the end to consumers. For example on the European Energy Exchange in 2012 339 terawatt-hours (tWh) have been traded on the spot market, whereas 931 tWh have been traded on the forward market. Thus, about 73% of the total market volume has been traded forward (European-Energy-Exchange, 2012).

The contribution of the presented paper is twofold: Firstly it contributes to the economic literature in modeling simultaneously two especially for commodity markets important strategic decisions: The decision on investment and on forward trading. Secondly it contributes to the ongoing debate about the market design needed for the German energy turnaround as well: It shows that instruments like forward trading, which theirselves increase competition, may lead to anti-competitive effects, since they influence other important strategic decisions like that on investment.

Even though, many markets on which a substantial amount is traded on a futures or forward market are characterized by a structure of few oligopolisitc firms, there exists rather few literature about the strategic aspects of forward trading. To be successful on an oligopolistic market each firm has to incorporate all actions and reactions of it's competitors. Thus, strategic behavior becomes important and the methods typically used in industrial organization are suitable to analyze firms behavior on commodity markets and to predict market results.

Ronald W. Anderson has been one of the first to bridge this gap in discussing the two-way effects of market imperfections and futures trading. At his initiative the conference "The industrial organization of future markets: structure and conduct" was organized in 1982 to discuss the effects of imperfect competition and futures markets. All papers of this conference have been collected and published by Anderson (1984) under the title "The Industrial

Organization of Futures Markets". Most of the papers focus the possibility of market manipulations with forward contracts (e.g. Newbery (1998) and Kyle (1984)) or disadvantageous self regulation Saloner (1984). However, one contribution, namely that of Anderson and Sundaresan (1984), directly addresses the problem of imperfect competition and market power on futures markets.

At the same time Greenstone (1981) described in detail how coffee exporting countries formed pancafe and the bogota group to collude on a higher world market coffee price. One popular tool, which has been used for their coordination, were forward contracts. However, it needed more ten twenty years, until Liski and Montero (2006) analyzed the effects of forward trading on colluding firms in a theoretical framework. They modeled for price as well as for quantity competition collusive incentives of one period forward contracts in a deterministic market environment. Then Green and Coq (2010) analyzed in a similar setting the collusive effects of forwards with varying contract length. Based on these papers Aichele (2013) models the collusive incentives for price-setting firms in a stochastic and volatile market environment. He shows the negative effect on firms profit, when a collusive agreement is stabilized with forward contracts.

The effects of forward trading on (imperfectly) competing firms, are modeled by Mahenc and Salanié (2004) for price setting firms with a heterogeneous good and by Allaz and Villa (1993) for quantity setting firms and a homogenous product. The welfare effects of both models contradict each other, since for price competition and heterogenous products (Mahenc and Salanié, 2004) forward trading leads to weaker competition, whereas for homogenous products and quantity competition (Allaz and Villa, 1993) forward trading leads to fiercer competition. In an "infinite horizon, discrete time dynamic game of forward trading with storage" Thille (2003, p.652) shows that the welfare enhancing effects found by Allaz and Villa (1993) still are present in a mitigated fashion, when storage of the commodity is possible. Another interesting paper on this issue that discusses theoretically as well as empirically the question whether forward contracts are mainly used for strategic or risk hedging motives is that of van Eijkel and Moraga-González (2010).

There recently have been contributions about investment incentives in complex market structures of network industries, of which especially three contributions should be mentioned here. Choi and Kim (2010) focus on the interaction between net neutrality and investment incentives for Internet service providers and conclude "that the relationship between the net neutrality regulation and investment incentives is subtle" (Choi and Kim, 2010, p.34). Valletti and Cambini (2005) model the interaction between investments and network competition for telecommunication operators and find tendencies for strategic underinvestment in network quality. Fabra, von der Fehr, and de Frutos (2011) study the interaction between market design and investment incentives for energy markets. Therefore, they model the investment incentives for a discriminatory and for a uniform-price auction. Even though their contribution leads to important insights concerning investment decisions and energy markets, the important strategic decision about forward contracts cannot be analyzed. The presented paper fills this gap, even though at the cost of a much simpler market mechanism on the spot market.

To what extent imperfectly competing firms invest depends mainly on whether the decision variables such as quantity, price and investment are seen as strategic complements or substitutes (see the influential contributions of Fudenberg and Tirole (1984) and Bulow, Geanakoplos, and Klemperer (1985)). As will be shown in the presented paper, the market performance additionally depends significantly on the time horizon of firms investment decision. For a long lasting investment decision that takes place before firms trade forward and compete in quantities competition is rather weak and a rather low social welfare is achieved. In contrast to this, for shorter investment decisions, that take place after firms have traded forward but before firms compete in quantities, competition becomes fierce and social welfare becomes rather high.

The remaining paper is organized as follows. In section 2 the main assumptions and the structure of the model are presented. In section 3 a long term strategic investment is modeled. Therefore, in a first stage firms choose their investment before in a second stage firms engage in forward contracts and in a third stage they compete in quantities. In section 4 a mid term strategic investment is modeled. Therefore, in the first stage firms engage in forward contracts before they decide about an investment in the second stage and before they compete in quantities in the third stage.

In section 5 the results of both decision structures are compared to another. They are also compared to the results of a two stage game consisting of a forward trading stage followed by quantity competition as well as to a two stage game consisting of an investment decision followed by quantity competition. The results of both two stage games are derived in a simple and concise form in the appendix. Section 6 concludes.

2 The model

The model that is presented in this paper adds an additional third stage of investment decision to the two stage model of Allaz and Villa (1993). In the contribution of Allaz and Villa (1993), in a first stage firms can engage in contracts (forward market stage) and in a second stage firms serve these contracts and sell an additional quantity to the customers (spot market stage). In order to compare the results of the presented paper with the results of Allaz and Villa (1993) all underlying assumptions are chosen closely to the assumptions made by Allaz and Villa (1993).

Firms compete in quantities and face a linear (inverse) demand function $p = a - x_i - x_j$, where the production that is sold by firm i either via forward contracts or directly on the spot market is denoted by x_i, x_j respectively. There is perfect foresight of all market participants and in equilibrium the forward market has to be efficient, which means "the forward price as a function of the forward positions must be equal to the price that will result from cournot competition on the spot market given these positions" (Allaz and Villa, 1993). The total production x_i of each firm i can either be sold by a firm via a binding and observable forward contract denoted by f_i or directly on the spot market. Thus, the amount that is sold on the spot market by firm i is given by the difference of the total production and the amount already traded forward before ($x_i^{sm} = x_i - f_i$).

To focus exclusively on the strategic aspects of investment decisions, forward trading and quantity competition on the spot market, this papers works with deterministic market conditions. Alternatively the results could be interpreted as the results of a model with risk neutral agents competing under uncertainty.

In the presented model firms decide about an investment I_i, that increases their contribution margin linearly by exactly I_i but produces quadratic costs of I_i^2, I_i^2. This investment I_i can either by interpreted as a level of technology, that decreases marginal costs $(c - I_i)$ or as an advertising campaign, that increases the prohibitive price $(a + I_i)$.

In section 3 the market results from competition of a long term strategic investment is derived. Therefore, following three stage game is solved by backward induction:

Structure of decision making for a long term strategic investment

Stage 1. (Cost reducing) Investment:

Firms decide about an (cost reducing) investment. They anticipate the effect on the quantities being delivered on the forward market as well as on the spot market.

Stage 2. Forward market:

Firms decide about the quantity they contract forward. They take the investment of both firms as given and anticipate all effects on the quantity competition on the spot market.

Stage 3. Quantity competition:

Firms take the investment as well as the forward contracts of both firms as given and decide about the (additional) quantity they want to supply on the spot market.

In section 4 the market results from competition of a mid term strategic investment is derived. Therefore, following three stage game is solved by backward induction:

Structure of decision making for a mid term strategic investment

Stage 1. Forward market:

Firms decide about the quantity they contract forward. They anticipate the effects on the investment decisions as well as on the quantities delivered on the spot market.

Stage 2. (Demand increasing) Investment:

Firms decide about their investment. They take as given the amount contracted forward in the first stage and anticipate all effects on the quantity competition on the spot market.

Stage 3. Quantity competition:

Firms take as given the forward contracts as well as the investment of both firms as given and decide about the (additional) quantity they want to supply on the spot market.

3 Long term strategic investment

3.1 Quantity competition, in which firms take costs and forward contracts as given

In the third stage, each firms' investment as well as the forward contracted amount is given. Thus, the profit of each firm can be stated as:

$$\Pi_i = (a - x_i - x_j)(x_i - f_i) - (c - I_i)\, x_i \tag{1}$$

In the third stage, each firm i decides about the quantity it supplies on the spot market ($x_i^{sm} = x_i - f_i$), where the forward traded amount f_i is given from the decision made in the first stage. The cost for each unit sold (either to consumers or to speculators) are given by the marginal cost less the level of technology $c - I_i$. The marginal cost, which have been reduced by the level of technology $c - I_i$, incur to the total output x_i. Maximizing the spot market profit of each firm, given by equation 1, in respect to the total quantity x_i, yields the best quantity response of a firm. This reaction function of firm i depends on the prohibitive price a, the marginal costs c the amount traded forward by each firm f_i, f_j, the own investment I_i and the quantity set by the rival firm x_j. For the reaction function of firm j the same holds true except that i has to be changed in j and vice versa.

$$x_i = \frac{1}{2}(a + f_i - c + I_i - x_j) \tag{2}$$

Both firms perfectly take into account the quantity set by the rival. The Nash-equilibrium ($x_{i,j}^*$), in which neither firm has an incentive to set another quantity, is found in the intersection point of both reaction functions.

$$x_i^* = \frac{1}{3}(a + 2f_i - f_j + 2I_i - I_j - c) \tag{3}$$

The quantity set in equilibrium by firm i depends positively on the prohibitive price a, the own forward contracted amount f_i and the own investment I_i. The quantity depends negatively on the competitors forward traded amount f_j, the competitors investment I_j and marginal cost c. The same functional form holds true for the quantity set by firm j. With these optimal quantities in the third stage the (reduced form) spot-market equilibrium price p^*_{sm} can easily be determined as:

$$p^*_{sm} = \frac{1}{3}\left(a + 2c - f_i - f_j - I_i - I_j\right) \tag{4}$$

The (reduced form) spot-market equilibrium price p^*_{sm} depends positively on the prohibitive price a as well as on marginal costs c. It depends negatively on each firms' forward traded amount f_i, f_j and each firms investment I_i, I_j.

3.2 Decision on forward contracts, in which firms take cost structure as given

I the second stage, firms anticipate the spot market quantities that are additionally to the forward contracted amount supplied $x^{sm}_i = x^*_i - f_i$, $x^{sm}_j = x^*_j - f_j$. This reduces the problem of profit maximization to the optimal choice of the own forward traded amount f_i, for a given own investment I_i, for a given investment of the competitor I_j as well as for a given competitor's forward traded amount f_j. In the second stage firms take the investment decision as given, since it is made in the first stage.
The price for each firms forward traded amount is given by the anticipated spot market price, since speculators, which are taking the counterpart on the forward market, have perfect foresight and build rational expectations. Thus, no additional arbitrage profit or loss is made by a firm when it is trading forward. Therefore, all forward sales are perfectly offset by the same amount that cannot be delivered on the spot market and both firms profit functions in the second stage look as follows:

$$\begin{aligned}\Pi_i &= \left(p^*_{sm} - c + I_i\right)\left(x^*_i - f_i\right) + f_i\left(p^*_{sm} - c + I_i\right)\\ &= \frac{1}{9}\left(a - f_i - f_j - I_i - I_j - c\right)\left(a - c + 2f_i - f_j + 2I_i - I_j\right)\end{aligned} \tag{5}$$

In the second stage the firms decide about their contracted amount. Thus, the optimal forward traded amount is found by maximizing both firms (reduced) profit function with respect to the forward contracted amount:

$$f_i = \frac{1}{4}(a - c - f_j - 4I_i - I_j) \tag{6}$$

The optimal forward traded amount of each firm in the second stage depends positively on the prohibition price a but negatively on the marginal costs c, the competitor's forward traded amount f_j and the investments made by each firm in the first stage I_i, I_j. The equilibrium forward positions are found in the intersection of both firms best response functions.

$$f_i = \frac{1}{5}(a - c - 5I_i) \tag{7}$$

With the equilibrium forward contracts the quantities that emerge from the forward and the spot market game can be determined.

$$x_i = \frac{1}{3}\left(a + \frac{2}{5}(a - c - 5I_i) - \frac{1}{5}(a - c - 5I_j) + 2I_i - I_j - c\right) = \frac{2}{5}(a - c) \tag{8}$$

The equilibrium price in the second stage is easily determined either by setting these quantities into the inverse linear demand function or by setting the second stage forward traded amount into the equilibrium spot market price given in equation 4:

$$p_F = \frac{1}{5}(a - c) + c \tag{9}$$

When firms are trading forward and subsequently compete in quantities, a classical prisoners dilemma forces firms to sell forward contracts, even though in equilibrium this makes both firms worse off (Allaz and Villa, 1993, p.5). When firms invest, trade forward and compete in quantities this is not the case. Then the optimal choice of forward contracts, that depend on the first stage investment decision, exactly offsets the effect of the investment made in the first stage for every combination of subgame perfect forward contracts and investments. Thus, in the second stage each firms' forward traded amount "neutralizes" the investment decision made in the first stage. This result independently of the functional form of the technology and its investment costs holds, since the investment decision is made in the first stage.

3.3 Decision on the level of technology, under anticipation of the forward and the spot market amount

In the first stage firms perfectly anticipate the forward and spot market decisions made by both firms. The first stage profit for each firm is found by putting the quantity resulting from the forward and spot market competition into the first stage profit function. The first stage reduced form profit function looks as follows:

$$\begin{aligned} \Pi_i &= (a - x_i - x_j - c + I_i) * x_i - I_i^2 \\ &= \frac{2}{25}(a-c)(a-c+I_i) - I_i^2 \end{aligned} \tag{10}$$

The quantity of each firm sold to the consumers does neither depend on the own investment nor on the competitior's investment. The profit maximization of each firm just is given by the trade-off between a higher contribution margin and the investment therefore needed (without any effect on quantities). Thus, competition in a narrow sense does not take place, when firms decide about their investment and anticipate the amount traded on the forward and the spot market. In this section a coefficient of 1 is assumed for the costs of the investment. The results for any coefficient γ of the investment costs can be found in the Appendix.
Remark: To avoid negative marginal costs after the decision on the level of technology ($c - I_i = c - \frac{1}{25}(a-c) > 0$) it has to be assumed, that $c > \frac{1}{26}a$. For the interpretation of the investment as an advertising campaign this assumption is not needed.
This leads to following investment of each firm in the first stage

$$I_i = \frac{1}{25}(a-c) \tag{11}$$

With the subgame-perfect investment and the subgame perfect quantity, the subgame-perfect forward traded amount, the subgame-perfect price, each firms profit, the consumer surplus σ as well as the social welfare ω, given by both firms profit and the consumer surplus can be determined.
For each subgame-perfect outcome of the decision structure investment, forward trading and quantity competition the letters I,F,Q are added. This will be helpful to compare the market results with the results for other structures of decision. For example $p_{I,F,Q}$ means the price that emerges, when (as

described in this section) firstly the investment, then forward trading and afterwards quantity competition takes place.

$$\begin{gathered}
x_{I,F,Q} = \frac{2}{5}\left(a-c\right), \quad p_{I,F,Q} = \frac{1}{5}(a-c)+c \quad f_{I,F,Q} = \frac{4}{25}\left(a-c\right) \\
I_{I,F,Q} = \frac{1}{25}\left(a-c\right) \quad \Pi_{I,F,Q} = \frac{59}{625}(a-c)^2, \quad \sigma_{I,F,Q} = \frac{8}{25}\left(a-c\right)^2 \\
\omega_{I,F,Q} = \frac{318}{625}\left(a-c\right)^2
\end{gathered} \tag{12}$$

4 Mid-term strategic investment

4.1 Quantity competition, in which firms take demand and forward contracts as given

In the third stage, each firms' prohibitive price and forward contracted amount is given. Thus, the profit of each firm can be stated as:

$$\Pi_i = \left(a - x_i - x_j\right)\left(x_i - f_i\right) - \left(c - I_i\right) x_i \tag{13}$$

Remark: In the context of advertising, the profit function should rather look like $\Pi_i = (a + I_i - x_i - x_j)(x_i - f_i) - cx_i$. To ensure comparability with the long term investment decision, the profit function used above is taken. This can be done without loss of generality, since both profit functions are equivalent.
The best quantity response of a firm due to the quantity set by the competitor firm is given by:

$$x_i = \frac{1}{2}\left(a + f_i - c + I_i - x_j\right) \tag{14}$$

The quantities set by each firm in Nash-equilibrium is given by $x^*_{i,j}$. The quantities depend on both firms forward contracted amount and both firms investment.

$$x^*_i = \frac{1}{3}\left(a + 2f_i - f_j + 2I_i - I_j - c\right) \tag{15}$$

With the equilibrium quantities x_i^*, x_j^* the spot-market price p_{sm}^* can be determined.

$$p_{sm}^* = \frac{1}{3}\left(a + 2c - f_i - f_j - I_i - I_j\right) \tag{16}$$

4.2 Investment decision, in which firms take forward contracts as given

In the second stage firms decide about their investment, knowing each firms forward contracted amount and anticipating the quantity decision each firm makes in the third stage. Thus, the profit functions can be reduced to a relationship of forward contracts, amount of investment, marginal costs and the prohibitive price and look as follows:

$$\begin{aligned}\Pi_i &= \left(p_{sm}^* - c + I_i\right) x_i^* - I_i^2 \\ &= \frac{1}{9}\left(a - c - f_i - f_j + 2I_i - I_j\right)\left(a - c + 2f_i - f_j + 2I_i - I_j\right) - I_i^2\end{aligned} \tag{17}$$

The best investment response of each firm in the second stage due to the investment of the competitor is given by:

$$I_i = \frac{1}{5}\left(2a - 2c + f_i - 2f_j - 2I_j\right) \tag{18}$$

Each firms' investment depends positively on the prohibitive price a and on the own forward traded amount f_i. Each firms' investment depends negatively on competitor's forward traded amount f_i, competitor's investment I_j and on marginal costs c.
Remark: Again, for the cost cutting interpretation positive marginal costs after the investment have to be ensured. When interpreting the investment decision in the second stage as advertising, this is not necessary. Therefore and to ensure comparability with the results of section 3, this is not explicitly modeled in the presented paper.
The investment chosen by each firm in Nash-equilibrium is given by I_i^*, I_j^* and found in the intersection of the best investment reaction functions.

$$I_i^* = \frac{1}{7}(2a - 2c + 3f_i - 4f_j) \tag{19}$$

Each firms' investment depends positively on the prohibitive price a and the own forward traded amount f_i. It depends negatively on competitor's forward traded amount f_j.
With the equilibrium of investments the quantities of each firms can easily be determined as:

$$x_i = \frac{1}{7}(3a - 3c + 8f_i - 6f_j) \tag{20}$$

Each firms' quantity x_i depends positively on the prohibitive price a and positively on the own forward traded amountf_i. It depends negatively on competitor's forward traded amount f_j and marginal costs c.
The equilibrium price in the second stage is easily determined either by inserting these quantities into the inverse linear demand function or by inserting the second stage forward traded amount into the equilibrium spot market price given in equation 15.

$$p_I^* = \frac{1}{7}(a - c - 2f_i - 2f_j) + c \tag{21}$$

The price in the second stage depends positively on the prohibitive price a and the marginals costs c. It depends negatively on each firms forward traded amount f_i, f_j.

4.3 Decision on forward contracts, under anticipation of investment and spot market competition

In the first stage firms decide about the amount of forward contracts they supply on the market. In doing so they perfectly anticipate the consequences on both firms' investments as well as on the quantity supplied on the spot market. Thus, the profit can be reduced to a function solely depended on each firms amount contracted forward as well as the fundamental market conditions, which are given by marginal costs and the prohibitive price. The profit function is given by the contribution surplus multiplied by the amount sold to the market less the investment costs resulting from both firms position on the forward market.

$$\begin{aligned}\Pi_i &= (p_I^* - c + I_i)\, x_i - I_i^2 \\ &= \frac{1}{49}\,(3a - 3c + f_i - 6f_j)\,(3a - 3c + 8f_i - 6f_j) - \frac{1}{49}\,(2a - 2c + 3f_i - 4f_j)^2\end{aligned} \tag{22}$$

The optimal amount of forward contracts of each firm in the second stage due to the forward contracted amount of the rival is given by:

$$f_i = \frac{1}{2}\left(15a - 15c - 30f_j\right) \tag{23}$$

The Nash-equilibrium forward traded amount is found in the intersection of both firms' forward contract best response function.

$$f_i^* = \frac{15}{32}\left(a - c\right) \tag{24}$$

With the subgame-perfect forward traded amount f_i^*, the subgame-perfect quantity, the subgame-perfect investment, the subgame-perfect price, each firms profit, the consumer surplus σ as well as the social welfare ω can be determined.
Note: For each subgame-perfect outcome of the decision structure forward trading, investment and quantity competition the letters F,I,Q are added. This will be helpful to compare the market results with the results for other structures of decision. For example $p_{F,I,Q}$ means the price that emerges, when (as described in this section) firstly forward trading, then the investment and afterwards quantity competition takes place.

$$\begin{gathered} x_{F,I,Q} = \frac{18}{32}\left(a - c\right), \quad p_{F,I,Q} = -\frac{1}{8}\left(a - c\right) + c, \quad f_{F,I,Q} = \frac{15}{32}\left(a - c\right) \\ I_{F,I,Q} = \frac{7}{32}\left(a - c\right), \quad \Pi_{F,I,Q} = \frac{5}{512}\left(a - c\right)^2, \quad \sigma_{F,I,Q} = \frac{81}{128}\left(a - c\right)^2 \\ \omega_{F,I,Q} = \frac{167}{256}\left(a - c\right)^2 \end{gathered} \tag{25}$$

5 Comparison of results

Table 1 gives as a benchmark the market outcome for the decision structure first investment and then quantity competition as well as for the decision structure first forward trading and then quantity competition (Allaz and Villa, 1993). The derivation of all results for the case of investment and then quantity competition is shown from equation A.1 to equation A.7 in the Appendix. The derivation of all results for the case of forward trading

	Investment, Competition	Forwards, Competition
Price	$p_{I,Q} = 0,1429\,(a-c)+c$	$p_{F,Q} = 0,2\,(a-c)+c$
Quantity	$x_{I,Q} = 0,4286\,(a-c)$	$x_{F,Q} = 0,4\,(a-c)$
Forwards	$f_{I,Q} = 0$	$f_{F,Q} = 0,2\,(a-c)$
Investment	$I_{I,Q} = 0,2857(a-c)$	$I_{F,Q} = 0$
Cons. surplus	$\sigma_{I,Q} = 0,3673\,(a-c)^2)$	$\sigma_{F,Q} = 0,32\,(a-c)^2$
Profit	$\Pi_{I,Q} = 0,1020\,(a-c)^2$	$\Pi_{F,Q} = 0,08\,(a-c)^2$
Welfare	$\omega_{I,Q} = 0,5714\,(a-c)^2$	$\omega_{F,Q} = 0,48\,(a-c)$

Table 1: Benchmark prices, quantities etc

and then quantity competition is shown from equation A.8 to equation A.14 in the Appendix. Table 2 gives the market outcome for the decision structure first forward trading, then investment and then quantity competition as well as for the decision structure first investment, then forward trading and then quantity competition. The results for the decision structure forward trading, then investment and subsequently quantity competition have been derived in section 3 and can be found in a concentrated form in equation 12.
The results for the decision structure, investment, forward trading and then quantity competition have been derived in section 4 and can be found in a concentrated form in equation 25. For the sake of comparability all results in table 1 and 2 are shown in decimal numeration.

The price chosen by each firm, when firms are able to invest, trade forward and compete in quantities is equal to the price when they solely trade forward and compete in quantities ($p_{I,F,Q} = p_{F,Q} = \frac{1}{5}(a-c)+c$). This price ($p_{I,F,Q} = p_{F,Q}$) is above the price resulting from competition with an investment decision before quantity competition ($p_{I,Q} = \frac{1}{7}(a-c)$. The lowest price results from forward trading, decision on investment and quantity competition ($p_{I,F,Q} = -\frac{1}{8}\,(a-c)+c$).

	Forwards, Investment, Competition	Investment, Forwards, Competition
Price	$p_{F,I,Q} = -0,125\,(a-c)+c$	$p_{I,F,Q} = 0,2\,(a-c)+c$
Quantity	$x_{F,I,Q} = 0,5625\,(a-c)$	$x_{I,F,Q} = 0,4\,(a-c)$
Forwards	$f_{F,I,Q} = 0,4686\,(a-c)$	$f_{I,F,Q} = 0,16\,(a-c)$
Investment	$I_{F,I,Q} = 0,2188\,(a-c)$	$I_{I,F,Q} = 0,04\,(a-c)$
Cons. surplus	$\sigma_{F,I,Q} = 0,6328\,(a-c)^2$	$\sigma_{I,F,Q} = 0,32\,(a-c)^2$
Profit	$\Pi_{F,I,Q} = 0,0098\,(a-c)^2$	$\Pi_{I,F,Q} = 0,0944\,(a-c)^2$
Welfare	$\omega_{F,I,Q} = 0,6523\,(a-c)^2$	$\omega_{I,F,Q} = 0,5088\,(a-c)^2$

Table 2: New results: Forward Trading, Investment and Quantity

Thus, the resulting prices can be ordered as:

$$p_{F,I,Q} < p_{I,Q} < p_{I,F,Q} = p_{F,Q} \tag{26}$$

For the quantities supplied by both firms the order is the other way round. The quantity when both firms decide about their investment, choose their forward contracts, decide and compete in quantities equals the quantity supplied when both firms decide about forward contracts ($x_{I,F,Q} = x_{F,Q} = 0.4\,(a-c)$). This quantity is below the quantity chosen by firms when both firms decide about their investment and compete in quantities ($x_{I,Q} = \frac{3}{7}\,(a-c)$). The highest quantity results from forward trading, decision on investment and quantity competition ($x_{F,I,Q} = \frac{18}{32}\,(a-c)$).
Thus, the resulting quantities can be ordered as:

$$x_{F,Q} = x_{I,F,Q} < x_{I,Q} < x_{F,I,Q} \tag{27}$$

When firms solely decide about their investment and compete in quantities, by definition the amount traded forward is zero ($f_{I,Q} = 0$). Then the smallest (positive) amount is traded forward when firms decide about their

investment, trade forward and compete in quantities ($f_{I,F,Q} = \frac{15}{32}(a-c)$). When firms solely decide about forward contracts and compete in quantities, a larger amount is traded forward ($f_{F,Q} = \frac{2}{5}(a-c)$). When firms firstly decide about the amount traded forward, then decide about their investment and subsequently compete in quantities, the largest amount is traded forward ($f_{F,I,Q} = \frac{15}{32}(a-c)$).
Thus, the forward traded amount can be ordered as:

$$f_{I,Q} < f_{I,F,Q} < f_{F,Q} < f_{F,I,Q} \tag{28}$$

For strategic reasons firms choose a relatively low forward traded amount, when the investment decision takes place in the first round, whereas firms choose a relatively high amount traded forward, when the decision on the forward traded amount takes place in the first round. Following the strategic taxonomy of Fudenberg and Tirole (1984) one can state: Firms under-invest in the strategic variable (forward traded amount), when the investment decision takes place in the first round. Firms over-invest in the strategic variable (forward traded amount), when the decision on the forward traded amount takes place in the first round.
When firms solely decide about their forward traded amount and compete in quantities, by definition the investment is zero ($I_{I,Q} = 0$). Then the smallest (positive) amount is invested when firms decide about their investment, trade forward and compete in quantities ($I_{I,F,Q} = \frac{1}{25}(a-c)$). When firms firstly decide about the amount traded forward, then decide about their investment and subsequently compete in quantities, a larger investment is done ($I_{F,I,Q} = \frac{7}{32}(a-c)$). When firms solely decide about their investment and compete in quantities, the highest investment is done($I_{I,Q} = \frac{2}{7}(a-c)$).
Thus, the resulting investment can be ordered as:

$$I_{F,Q} < I_{I,F,Q} < I_{F,I,Q} < I_{I,Q} \tag{29}$$

For strategic reasons firms choose a relatively low investment, when the investment decision takes place in the first round, whereas firms choose a relatively high investment, when the decision on the forward traded amount takes place in the first round. Due to the strategic taxonomy of Fudenberg and Tirole (1984) one can state in turn: Firms under-invest in the strategic variable (investment), when the investment decision takes place in the first round. Firms over-invest in the strategic variable (investment), when the decision on the forward traded amount takes place in the first round.

Thus, firms under-invest in both strategic variables (forward traded amount and investment) and choose a "puppy-dog strategy", when the investment decision takes place in the first round, whereas firms strategically over-invest and choose a "top-dog strategy", when the decision on the forward traded amount takes place in the first round. The different strategic behavior of the competitors can mainly be explained by the cost of their investment and the anticipation of (fierce) competition.
A long-term decision on the technology in the first stage is associated with investment costs, but an increase in profitability. When there exists fierce competition in the second stage, that is induced by the existence of a forward market, the profit of each firm is mainly determined by the forces of competition and not by the contribution margin. Firms anticipate that and are reluctant to invest.
For a mid-term decision on the strategic investment, firms decide in the first stage about the amount they want to trade forward. The forward traded amount does not lead to direct costs and firms do not incorporate the negative externality on the price. However, with forward contracts each firm increases the quantity sold. Thus, in equilibrium the prisoners dilemma described by Allaz and Villa (1993) occurs. After the decision on the forward traded amount in the second stage, firms decide about their investment. This investment is below the investment for the two-stage investment and then quantity competition game, since the demand to meet on the spot market is decreased by forward sales. However, it is above the investment for a long-term investment decision, since firms have due to the upcoming quantity competition a rather large incentive to invest.
The smallest consumer surplus results when firms either solely trade forward and compete in quantities or firms invest, trade forward and compete in quantities ($\sigma_{I,F,Q} = \sigma_{F,Q} = \frac{8}{25}$). A larger consumer surplus results, when firms solely decide about their investment and and compete in quantities ($\sigma_{I,Q} = \frac{2}{7}(a-c)$). The highest consumer surplus results when firms trade forward, then decide about their investment and subsequently compete in quantities ($\sigma_{F,I,Q} = \frac{81}{128}\left(a-c\right)^2$).
Thus, the resulting consumer surplus can be ordered as:

$$\sigma_{I,F,Q} = \sigma_{F,Q} < \sigma_{I,Q} < \sigma_{F,I,Q} \tag{30}$$

The lowest profit is realized by firms when they trade forward, decide about their investment and subsequently compete in quantities ($\Pi_{F,I,Q} = \frac{5}{512}$).

A higher profit is realized by firms, when they trade forward and compete in quantities ($\Pi_{F,Q} = \frac{2}{25}(a-c)$). When firms invest, then trade forward and subsequently compete in quantities, they earn a slightly higher profit($\Pi_{I,F,Q} = \frac{59}{625}(a-c)$), even though the quantities and prices are the same as when they trade forward and compete in quantities. This comes from the fact, that the higher contribution surplus (through reduction of marginal costs or a demand increase) induced by the investment is not passed over to the consumers. The difference of both profits is exactly given by the gain in contribution surplus from the investment times the quantity sold by each firm less the cost of investment $\Delta\Pi = x_{I,F,Q}\ I_{I,F,Q} - I_{I,F,Q}^2 = \frac{1}{25}(a-c)\frac{4}{10}(a-c) - \frac{1}{25^2}(a-c)^2 = \frac{9}{625}(a-c)^2$. The highest profit is earned by each firm, when firms invest and subsequently compete in quantities ($\Pi_{I,Q} = \frac{5}{49}(a-c)$). Thus, the resulting profits can be ordered as:

$$\Pi_{F,I,Q} < \Pi_{F,Q} < \Pi_{I,F,Q} < \Pi_{I,Q} \tag{31}$$

The lowest welfare results when firms first decide about forward contracts and then compete in quantities ($\omega F, Q = \frac{12}{25}(a-c)$). When firms invest, then trade forward and subsequently compete in quantities, the welfare is slightly higher ($\omega I, F, Q = \frac{318}{625}(a-c)^2$). This increase comes from the gains of the investment, which increase firms' profits but do not alter the consumer surplus. A higher welfare is realized, when firms decide about the investment and then compete in quantities ($\omega_{I,Q} = \frac{4}{7}(a-c)^2$). The highest welfare is realized, when firms firstly decide about their forward contracts, then decide about their investment and subsequently compete in quantities ($\omega_{F,I,Q} = \frac{167}{256}(a-c)$).
Thus, the resulting welfare can be ordered as:

$$\omega_{F,Q} = \omega_{I,F,Q} < \omega_{I,Q} < \omega_{F,I,Q} \tag{32}$$

6 Conclusion

The aim of this paper is the strategic interaction between competing firms and its influence on their investment decisions, on their forward traded amount and on spot market competition. Therefore, in section 3 a long term

strategic investment decision, that takes place before firms engage in forward contracts and compete in quantities on the spot market has been modeled. For this kind of long-term investment decision, firms choose a "puppy-dog strategy" for their investment as well as for their forward traded amount.
In section 4 a mid term strategic investment decision, that takes place after firms have choosen their forward contracts but before firms compete in quantities on the spot market has been modeled. For this kind of mid-term investment decision, firms choose a "top-dog strategy" for their investment as well as for their forward traded amount.
Section 5 compared the results, found in section 3 and section 4 with each other as well as with the results of a two stage game, where in the first stage firms either decide about investment or on the amount traded forward and in a second stage firms compete in quantities.
For a long-term investment decision the "the-puppy dog strategy" with it's rather small forward traded amount and investment leads to a relatively small amount supplied to the market, a relatively high price, relatively high profits of firms, a low consumer surplus and a relatively small social welfare. Therefore, when firms investments mainly can be viewed as long-term, introduction of a forward market has a welfare decreasing effect.
For a mid-term investment decision the "top-dog strategy"' with it's rather large forward traded amount and investment leads to a relatively high amount supplied to the market, a relatively low price, relatively low profits of firms, a higher consumer surplus and a relatively large social welfare. Therefore, when firms investments mainly can be viewed as mid-term, introduction of a forward market has an welfare enhancing effect.
Looking at strategic aspects, forward trading and competition one can conclude: The social desirability of a forward market, where firms additionally to the spot market supply their commodity, critically depends on the typical time horizon of the investments made by firms:
For investment decisions, that mainly have a mid-term time horizon, the introduction of a forward market is social favorable. However, for investment decisions, that mainly have a long-term time horizon, the introduction of a forward market significantly decreases social welfare!
For the policy makers of the German Energy turnaround there is following more general insight: The overall effect of a pro-competitive instrument critically depends on it's influence on other strategic decisions and their time-horizon.

7 Appendix

7.1 Benchmark: Investment Decision and Quantity Competition

When firms have to decide in the first stage on an investment decision and in the second stage on the quantity they supply to the market, the market results again can be found by backward induction.

Stage 1. Cost reducing investment:
Firms decide about a cost reducing investment. They anticipate the effect on the quantities being delivered on the spot market.

Stage 2. Quantity competition:
Firms take the cost structure of both firms as given and decide about the quantity they want to supply on the spot market

Stage 1. profit function:

$$\Pi_i = (a - x_i - x_j - c + I_i)\, x_i - I_i^2 \tag{A.1}$$

Stage 2. profit function:

$$\Pi_i = (a - x_i - x_j - c + I_i)\, x_i \tag{A.2}$$

Stage 2. reaction function:

$$x_i = \frac{1}{2}(a - x_j - c + I_i) \tag{A.3}$$

Stage 2. Nash-Equilibrium

$$\begin{aligned} x_i^* &= \frac{1}{3}(a - c + 2I_i - I_j) \\ p^* &= \frac{1}{3}(a - c - I_i - I_j) + c \end{aligned} \tag{A.4}$$

Stage 1. reduced profit function

$$\Pi_i = \frac{1}{9}(a - c + 2I_i - I_j)^2 - I_i^2 \tag{A.5}$$

Stage 1. reaction function:

$$I_i = \frac{2}{5}(a - c - I_i) \tag{A.6}$$

Stage 1. Nash-Equilibrium

$$\begin{gathered} I_i^* = I_j^* = \frac{2}{7}(a-c) \quad p^* = \frac{1}{7}(a-c) + c, \quad x_i = x_j = \frac{3}{7}(a-c) \\ \Pi_i = \Pi_j = \frac{5}{49}(a-c)^2, \quad \sigma = \frac{18}{49}(a-c)^2, \quad \omega = \frac{4}{7}(a-c)^2 \end{gathered} \tag{A.7}$$

7.2 Benchmark: Forward Trading and Quantity Competition

Stage 1. Forward trading:
Firms decide about the amount they want to trade on the forward market. They anticipate the effect on the quantities being delivered on the spot market.

Stage 2. Quantity competition:
Firms take the forward traded amount as given and decide about the quantity they want to supply on the spot market

Stage 1. profit function:

$$\Pi_i = (a - x_i - x_j - c)\, x_i \tag{A.8}$$

Stage 2. profit function:

$$\Pi_i = (a - x_i - x_j - c)(x_i - f_i) - cx_i \tag{A.9}$$

Stage 2. reaction functions

$$x_i = \frac{1}{2}(a - c + f_i - x_j) \tag{A.10}$$

Stage 2. Nash-Equilibrium

$$\begin{aligned} x_i^* &= \frac{1}{3}(a - c + 2f_i - f_j) \\ p^* &= \frac{1}{3}(a - c - f_i - f_j) + c \end{aligned} \tag{A.11}$$

Stage 1. reduced profit function

$$\Pi_i = \frac{1}{9}\left(a - c - f_i - f_j\right)\left(a - c + 2f_i - f_j\right) \tag{A.12}$$

Stage 1. reaction function:

$$f_i = \frac{1}{4}\left(a - c - f_j\right) \tag{A.13}$$

Stage 1. Nash-Equilibrium

$$\begin{aligned} f_{F,Q}* &= \frac{1}{5}\left(a - c\right) \quad p_{F,Q} = \frac{1}{5}\left(a - c\right) + c, \quad x_{F,Q} = \frac{2}{5}(a - c) \\ \Pi_{F,Q} &= \frac{2}{25}\left(a - c\right)^2, \quad \sigma_{F,Q} = \frac{8}{25}\left(a - c\right)^2, \quad \omega_{F,Q} = \frac{12}{25}\left(a - c\right)^2 \end{aligned} \tag{A.14}$$

7.3 Variable coefficient of the quadratic costs of investment

The presented specification of the model in section 3 has a coefficient of 1 in front of the investment costs. Here I show, that the results hold true for any coefficient γ in front of the investment costs. In stage 2 and in stage 3 the costs of investments do not influence any result, since the level of technology I_i is taken as given. In stage 1 firms decide about their investment in technology. The profit function looks as follows:

$$\Pi_i = \frac{2}{25}\left(a - c\right)\left(a - c + I_i\right) - \gamma I_i^2 \tag{A.15}$$

Profit maximization with respect to the level of technology I_i leads to:

$$I_i = \frac{1}{25\gamma}\left(a - c\right) \tag{A.16}$$

Leading to a total output x_i, to a forward traded amountf_i and to the amount traded on the spot market $x_i - f_i$ of:

$$x_i = \frac{2}{25}\left(a - c\right), \quad f_i = \frac{1}{25\gamma}\left(a - c\right)\left(5\gamma - 1\right), \quad x_i - f_i = \frac{5\gamma + 1}{25}(a - c) \tag{A.17}$$

Hence, the total output of a firm x_i is unchanged, from a different coefficient of the cost of investment. However, the coefficient γ changes the proportion of the output sold on the spot market and total output as well as the proportion of the output sold on the forward market and total output.

References

Aichele, M. F. (2013): "Abuse of Forward contracts to semi-collude in volatile markets," *40th annual conference of the European Association for Research in Industrial Economics (EARIE)*, 40.

Allaz, B., and J.-L. Villa (1993): "Cournot Competition, Forward Markets and Efficiency," *Journal of Economic Theory*, 59 Issue 1, 1–16.

Anderson, R. (1984): *The industrial organization of futures market: A Survey Published in: The Industrial Organization of Futures Markets (Editor: R. Anderson)*. Lexington books.

Anderson, R., and M. Sundaresan (1984): *Futures Markets and Monopoly Published in: The Industrial Organization of Futures Markets (Editor: R. Anderson)*. Lexington books.

Blazejczak, J., J. Diekmann, D. Edler, C. Kemfert, K. Neuhoff, and W.-P. Schill (2013): "Energiewende erfordert hohe Investitionen," *DIW Wochenbericht*, Issue 26, 19–30.

Bulow, J., J. Geanakoplos, and P. Klemperer (1985): "Multimarket Oligopoly: Strategic Substitutes and Complements," *Journal of Political Economy*, 93(3), 488–511.

Choi, J. P., and B.-C. Kim (2010): "Net neutrality and investment incentives," *RAND Journal of Economics*, 41(3), 446–471.

European-Energy-Exchange (2012): "At the Centre of European Energy Trading," *Annual Report*, 1, 1–147.

Fabra, N., N.-H. von der Fehr, and M.-A. de Frutos (2011): "Market Design and Investment Incentives," *The Economic Journal*, 121, 1340–1360.

Fudenberg, D., and J. Tirole (1984): "The Fat-Cat Effect, the Puppy-Dog Ploy, and the Lean and Hungry Look," *American Economic Review*, 74 Issue 2, 361–366.

Green, R., and C. L. Coq (2010): "The lenght of contracts and collusion," *International Journal of Industrial Organization*, 28 Issue 1, 21–29.

Greenstone, W. D. (1981): "The coffee cartel: Manipulation in the public interest," *Journal of Futures Markets*, 1 Issue 1, 3–16.

Kyle, A. S. (1984): *A Theory of Futures Market Manipulations Published in: The Industrial Organization of Futures Markets (Editor: R. Anderson).* Lexington books.

Liski, M., and J.-P. Montero (2006): "Forward Trading and collusion in oligopoly," *J. Econ. Theory*, 131 Issue 1, 212–230.

Mahenc, P., and F. Salanié (2004): "Softening Competition through forward trading," *Journal of Economic Theory*, 116 Issue 2, 282–293.

Newbery, D. (1998): "Competition, contracts, and entry in the electricity spot market," *RAND Journal of Economics*, 29 No.4, 726–749.

Saloner, G. (1984): *Futures Markets and Monopoly Published in: The Industrial Organization of Futures Markets (Editor: R. Anderson).* Lexington books.

Thille, H. (2003): "Forward trading and storage in Cournot duopoly," *Journal of Economic Dynamic & Control*, 27, 651 – 665.

Valletti, T. M., and C. Cambini (2005): "Investments and Network Competition," *The RAND Journal of Economics*, 36(2), 446–467.

van Eijkel, R., and J. Moraga-González (2010): "Do firms sell forward for strategic reasons? An application to the wholesale market for natural gas," *IESE Research Papers D/864, IESE Business School.*