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The effect of Counter-trading on Competition in Electricity Markets[1]

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Abstract

In a competitive electricity market, nodal pricing is the most efficient way to manage congestion. Counter-trading is inefficient as it gives the wrong long term signals for entry and exit of power plants. However, in a non-competitive market, additional entry will improve the competitiveness of the market, and will increase social benefit by reducing price-cost margins. This paper studies whether the potential pro-competitive entry effects could make counter-trading more efficient than nodal pricing. We find that this is not the case, and that counter-trading is likely to have a negative effect on overall welfare. The potential benefits of additional competition (more competitive prices and lower production cost) do not outweigh the distortions (additional investment cost for the entrant, and socialization of the congestion cost to final consumers).

Keywords: Congestion management, counter-trading, market power

JEL: L94, L13, C72, D43

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1 Introduction

Internal congestion on the high and medium voltage transmission network is becoming a structural problem in several regions in Europe. For instance, in the Netherlands, congestion required the government to change its regulatory framework in 2009 (Hakvoort *et al.*, 2009). Congestion within Sweden (and pressure from the European Commission) obliged the Swedish network operator in 2010 to subdivide the Swedish electricity market into several zones.[2]

The current legal systems have not been designed to deal with this type of problems as national physical network constraints were often neglected by policy makers. The further integration of green energy and larger energy flows as the consequence of international trade into the system make it harder for policy makers to neglect these physical constraints. Hence, new regulatory frameworks need to be implemented to solve the congestion problem.

There are several ways to deal with congestion. The theoretically most efficient congestion management method recognizes the physical limitations of the network and creates regional (or nodal) electricity markets. Such a method is for instance used in the PJM market (nodal spot pricing). Under nodal spot pricing, electricity prices reflect physical constraints, *i.e.* the capacity limits of the transmission lines and Kirchoff's laws, and hence, scarcity of the transmission network. In the short run, nodal spot prices therefore ensure optimal usage of the transmission network. In the long run, they give the optimal incentives for new investments. This is the option that Sveska Kraftnät, the Swedish network operator will follow.

An alternative way to manage internal congestion is a system of counter-trading. Under this method, once congestion is observed in the network, the network operator will counter-trade against the flow of congestion, thereby reducing the flow over the line, until the congestion is eliminated. This system might be preferred to nodal pricing if congestion problems are expected to last only for a limited number of years (transmission investments will reduce congestion), and implementing nodal spot pricing is considered to be too cumbersome or too costly. This system might also be politically more acceptable. Introducing nodal spot pricing will often involve transfers between agents that are much greater than the net welfare gain. This is likely to make its introduction hard from a political point of view (Green, 2007). Counter-trading reduces those transfers. The counter-trading option was chosen in the Netherlands.

[2] Decision of the European Commission on 14 April 2010, IP/10/425.

In a perfectly competitive market, nodal spot pricing is the most efficient way to deal with congestion. Counter-trading is inefficient as it gives the wrong long term signals for entry and exit of power plants, and hence, causes over-entry in export constrained areas and under-entry in import constrained areas. In a non-competitive (oligopolistic) market, entry will improve the competitiveness of the market, and will increase total social surplus. Since under counter-trading entrants in the export constraint area receive an implicit subsidy, there will be more entry, the level of competition in the market might increase, and the price-cost margin will reduce. When the Dutch Ministry of Economic Affairs proposed to introduce counter-trading it argued that this positive competitive effect of new entry would outweigh the potential negative inefficiency effects (MinEZ, 2008a, 2008b).

We study whether this competitive entry effect makes counter-trading more efficient than market splitting (*i.e.* nodal pricing)[3]. To achieve this goal, we build a stylized electricity market model that endogenizes the entry decision in the export constrained area, and derive the welfare effect of additional entry caused by counter-trading. All along we assume that there is no effect on entry in the import constrained area. Taking this potential negative effect on competition of countertrading (compared to nodal pricing) into account, would only strengthen our result that any competitive benefits of countertrading are outweighed by the loss in efficiency.

We consider an electricity market with two regions which are connected with a congested transmission line. An incumbent firm is active in both regions, demand is present in one region (the import constrained region) and the entrant, if it incurs an entry cost, can invest in the other region (the export constrained zone). If it invests, the entrant, which is assumed to be more efficient than the incumbent, will displace production of the incumbent in the export constrained zone.

Under nodal pricing and perfect competition, entry into the electricity market is efficient as the entrant's private benefit of entry is equal to the social benefit of entry. Counter-trading, on the other hand, implies an implicit subsidy to entrants in the export constrained area (and potentially a tax in the import constrained area) whenever the market is congested. Entrants will therefore overinvest in the export constrained region and underinvest in the import constrained area. Hence, in a competitive market, counter-trading reduces total surplus as locational investment incentives are distorted.

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[3] This paper focuses on the competitive effect of entry, assuming that one firm is already present in the market. Dijk *et al*. (2009) study the dynamic effect of entry in a multi-period setting with sequential entry by strategic firms. They consider both the first-mover advantage of entry and the option value of waiting.

If firms have market power, additional entry in the export constrained area might have a positive effect on total surplus by improving the competitiveness of the sector. We test whether it outweighs the aforementioned reduction in total surplus. In the framework of our model we find the following results:

First, we study the effect of entry when the transmission line is congested. With nodal pricing, entry in the export constrained zone will lower the price in the import constrained zone. When the entrant invests, the incumbent's imports are displaced by the entrant's, the inframarginal rents of the incumbent decrease, and its incentives to raise prices are mitigated. Although the investment incentives of the entrant are larger with counter trading, the pro-competitive effect does not exist, because the incumbent receives a compensation for its displaced capacity in the export constrained area. Hence nodal pricing has a larger pro-competitive effect and is better from a social viewpoint.

Second, we show that during the hours without congestion, additional entry will make the market more competitive, but, also find that the competitive effect does not outweigh the additional investment cost that the entrant incurs and that subsidizing entry is socially not optimal.

Combining the results for congested and non-congested hours, it is evident that nodal pricing is socially preferred to counter-trading.

The remainder of the paper is organized as follows. Section 2 reviews the literature on nodal spot pricing and counter-trading. In section 3, the stylized electricity market model is introduced. Section 4 analyzes the welfare effects of counter-trading and nodal spot pricing on both the perfectly competitive and the oligopolistic electricity market. Section 5 concludes.

2 Literature Review

The concept of nodal spot pricing on electricity markets originates from the work of Schweppe *et al*. (1988). In the short run, nodal spot pricing ensures that regional prices reflect physical constraints (i.e. congestion on the transmission lines), and hence, scarcity on the transmission network. Therefore, nodal spot prices ensure optimal usage of the transmission network in the short run (Hogan, 1992).

The Pennsylvania-New Jersey-Maryland (PJM) Interconnection introduced nodal pricing in April, 1998. The PJM market encompasses the movement of wholesale electricity in 13 US states (some partially) and the District of Columbia. This market has a spot market coordinated by an independent system operator (ISO). The ISO gathers both the bilateral schedules and the voluntary bids of the market participants, and determines the associated locational marginal cost prices (while accounting for security-constrained dispatch of the power flows). When the transmission system is constrained, the spot prices can differ substantially across locations. The transmission charge for bilateral transactions is given by the difference in the locational prices between origin and destination. An accompanying system of fixed transmission rights (FTR) provides financial hedges between locations (Hogan, 1998).

In Western Europe, full nodal congestion pricing is not used. Prices are imposed to be uniform within a country[4], and price differences between zones reflect, more or less, cross-border congestion. In order to deal with congestion within a country, counter-trading is used. This market based approach allocates scarce transmission capacity among the different market players. Under counter-trading, firms are paid for not producing in the export constrained area. Also in the Nordic countries, such a system is used. Zonal prices reflect inter-zonal constraints, and counter-trading is implemented when the network operator is faced with intra-zonal congested paths (Bjørndal *et al.*, 2003).

A standard counter-trading scheme works (approximately) as follows:

First, based on the supply and demand schedule bids of the market participants on the spot market, the market is cleared while ignoring any grid limitations. Second, the network operators check where generation on the grid has to be reduced or increased, so that congestion can be relieved. Third, these increases and decreases in generation are determined using a separate balancing market. Generators offer transmission adjustment bids on this market. Fourth, the system operator selects the least expensive bids for increases and decreases in generation and pays the respective generators. Hence, some generators are constrained off and compensated with the equilibrium price of the market for generation reductions, whereas others are constrained on and receive the equilibrium price for generation increases.[5]

It is clear that this mechanism induces costs for the system operator, since he has to buy and resell energy according to the adjustment bids of the generators. On the Nordic market, these counter trading costs are financed through the fixed charges of the network tariff, *i.e.*, the costs are socialized (Hakvoort *et al*., 2009, Bjørndal *et al*., 2003).

[4] There are some exceptions. For instance, Italy and Norway have price zones which are considerably smaller than the whole country.

[5] As a referee correctly pointed out, in some markets generators are paid according the pay-as-bid rule and not the market price when they are constrained-off.

Under such a system, it is plausible that uniform prices may lead to suboptimal dispatching of power plants.[6] Green (2007) shows that, in a competitive market, the negative welfare effects of prices which do not reflect transmission constraints may reduce welfare with a few percentage points. However, taking into account the long-term effects on investment decisions and the occurrence of strategic behaviour may increase the negative effects of uniform prices and counter-trading. The combination of zonal prices and counter-trading has been criticized by several authors.

Ehrenmann and Smeers (2005) show that it is impossible to define transmission capacity on cross-border transmission lines uniquely. Using a simple six-node model in which only two lines have limited capacities, they show that zones can be constructed in different ways. The number of possible zones becomes substantial in the meshed part of the continental submarket of Europe where many line capacities may be binding. Hence, the authors argue that choosing 'good' zones may be a difficult and important problem. Furthermore, freezing of zones is not a solution, because the characteristics of 'good' partitioning may change over time.

Bjørndal (2000) and Bjørndal and Jörnsten (2001) study how an electricity network can be optimally divided in a limited set of price zones. They show that an optimal definition of zones requires the solution of a complex integer optimization problem. They argue that contrary to the belief that the zonal approach is easier to put into practice, implementing zonal pricing is more complex than implementing nodal spot pricing.

While there are several papers exploring the possibility of strategic behavior under nodal pricing – for instance, Borenstein *et al*. (2000) find that under nodal pricing limited transmission capacity can give a firm the incentive to restrict its output in order to congest transmission into its area of dominance – little attention is given to this topic under counter-trading. Following a similar line of reasoning as Borenstein *et al*. (2000), we argue that counter-trading leads to strategic bidding by generators. The idea is that firms in the export constrained area will have an incentive to bid a very low price in the energy market to be sure that congestion will be created, and hence, receive a payment for not producing under a counter-trading scheme. This method of strategic bidding may reduce market efficiency. Also in the import constrained region, firms might adjust their bids strategically. The intuition is that the firms in the import constrained area will understand that, due to internal congestion, their production capacity becomes more valuable in the importing region as their production

[6] As noted by one of the referees, counter-trading can lead to an optimal short-run dispatch, if all consumers and generators are able to participate in the counter trading market. In practice, however, (small) consumers are often unable to participate.

plants have an increased opportunity to be called upon in the counter-trading market. As a result those generators will increase their bids also in the spot market. The reason is that the opportunity cost of their production plants has increased. Moreover, these effects might be aggravated if firms strategically create congestion by withholding capacity in the import constrained area, and scheduling more capacity in the export constrained area[7].

The overall price effect of strategic bids under counter-trading is undetermined. Some firms are bidding lower (in the export constrained area), and other firms are bidding higher (in the import constrained area). Therefore, it may be that the total supply function does not change fundamentally, and hence, prices on the market could remain fairly constant.

Bjørndal *et al*. (2003) argue that the simultaneous use of market splitting and counter-trading might also give rise to strategic behaviour by network operators. They show that it is indeed possible to replace a real intra-zonal constraint by a fake constraint on an inter-zonal line. The incentive for the network operator is that he does not have to pay for the costs of counter-trading this way. The incentive to move the constraint under such a system exists also for the market participants. They are faced with decreased transmission tariffs when counter-trading costs are eliminated, and might also be able to change the zonal prices when a real intra-zonal constraint is replaced by a fake constraint on an inter-zonal line.

The consensus in the literature is that counter-trading is less efficient than nodal spot pricing. Although there are some important strategic considerations, the most prominent reason for this is the argument that locational price signals are distorted under counter-trading.

Most papers neglect the dynamic effects of counter-trading on entry decisions. One exception is Hers *et al.* (2009) who develop numerical simulation models of the European electricity market comparing different types of congestion management schemes. They find that the benefits of introducing redispatch outweigh the costs of the status quo situation in which no firms would be allowed to enter the market. The study differs from our study in three important aspects: (1) The entry decisions of the entrants are taken as given. (2) The standard nodal pricing model is not considered as a scenario, instead different variants of the counter trading model are compared. (3) The strategic incentives of generators are taken into account by studying the profitability of sensible but ad-hoc deviations of the competitive benchmark. We have a much simpler set-up, but try to provide more in depth intuition for the strategic and entry effects.

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[7] See for instance Küpper and Willems (2007) for a discussion on how a monopolist, on a market characterized by market splitting, might create congestion when it has production capacity on both ends of a possibly congested line.

3 Model

This section presents a stylized model of an electricity market with congestion. We consider an electricity market with one small export constrained area and one large import constrained area that are connected by a transmission line with a capacity for K units of electricity. See Figure 1. The import constrained area can be thought of as a densely populated area with a large demand level but relatively few opportunities for new investments. There is no demand in the export constrained area, but there is ample space for new investments. Examples for this set-up could be the Norwegian electricity market or the England and Wales market. In both cases, there is cheap generation capacity in the north, but the main load area is in the south.

An incumbent player is active in both areas of the market, while an entrant player can only enter in the export constrained area. Consumers are only present in the import constrained area. In the export constrained area, the marginal production costs of the incumbent and the entrant are c_I and c_E, respectively, with $c_E < c_I$. Hence, we assume that the entrant has a cost advantage compared to the incumbent. This assumption makes it more likely that entry is beneficial for society, as it will reduce overall production costs, and therefore, makes it more likely that counter-trading will socially outperform nodal pricing.

In the export constrained area, the installed generation capacity of the incumbent and the entrant (if it enters), is equal to k_I and k_E, with $k_I, k_E = k$. The fixed cost of entry is given by F. In the import constrained area, the constant marginal production cost for the incumbent is given by $C > c_I$. There is no capacity constraint on production in the import constrained area. Consumers, which are only present in the import constrained area, are price takers and pay a price p for their electricity. Furthermore, we assume that demand is always larger than $2k$ for the relevant price range that we consider. The price in the export constrained area will be denoted by p^*.

Unless stated otherwise, we assume that the transmission line is congested, and that only one of the firms can produce in the export constrained area ($K = k$). If there is congestion, the entrant will replace k units of the production of the incumbent in the export constrained area. If there is no regional congestion ($K > 2k$), then the entrant will, as it is more efficient, replace k units of the production of the incumbent in the import constrained area.

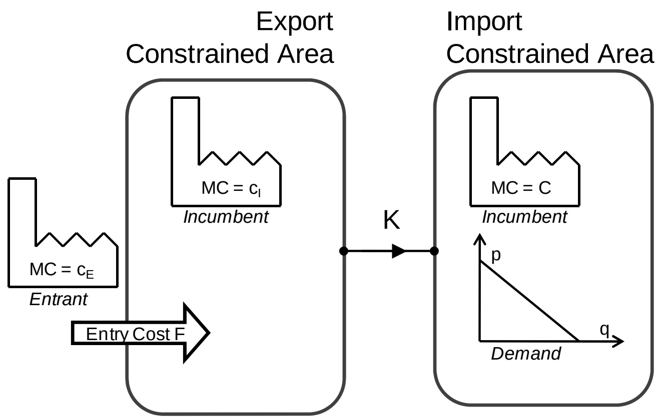

Figure 1. Stylized representation of the market

4 Analysis

The analysis consists of three steps. We first show that under perfect competition, entry is efficient under nodal pricing, but inefficient with counter-trading. In the second step, we test whether the competitive effect of additional entry might offset the negative effects of inefficient entry for an oligopolistic market. We show that the entrant does not bring about a pro-competitive effect under counter-trading, as the incumbent is compensated for any loss of market power. Hence, nodal pricing outperforms counter-trading here. In the last step, we assume that the line is non-congested during some hours of the day, and test whether the pro-competitive effect during those hours, outweighs the negative efficiency effects. We find that, even during the hours that there is no congestion, the competitive effect of additional entry is insufficient to justify the introduction of counter-trading.

4.1 Perfect competition

This section shows that, under perfect competition, entry is efficient with nodal pricing, but inefficient with counter-trading. In particular, we show that, under counter-trading, the private incentives to enter are larger than the social ones.

First, we assume that nodal spot pricing is used to manage congestion. Since the entrant is more efficient, he will replace the production of the incumbent in the export constrained area and supply K units of electricity to the import constrained area. Furthermore, as there is competition in the export constrained area to sell energy through the transmission line, the “nodal” price p^* in the export constrained area will be equal to the incumbent’s cost $p^* = c_I$. Figure 2.A shows that the private benefit of entry (the profit the entrant makes in the spot market minus the entry costs $(p^* - c_E)K - F$) is equal to the benefit to society (a reduction in marginal production costs minus the entry costs: $(c_I - c_E)K - F$).

Both are equal to the size of area *A* minus the fixed entry cost. Hence, the entrant has the right incentives to enter the market.

Proposition 1: In a perfectly competitive market, using nodal pricing to manage congestion, the private benefit of entry is equal to the benefit to society.

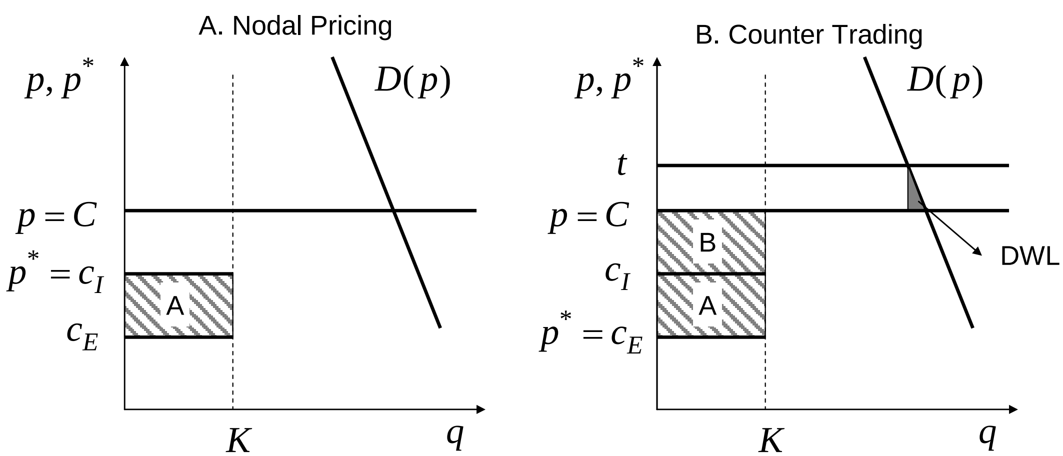

Figure 2. Perfect competition with congestion

We will now compare nodal pricing with counter-trading. In this framework, the incumbent and the entrant in the export constrained area will place "cost bids to produce". The firm with the lowest cost bid will produce, and the other firm will be compensated for not being able to supply.

Proposition 2: It is a Pareto dominant Nash equilibrium for the entrant to bid its marginal cost, and for the incumbent to bid slightly above.

The proof of proposition 2 is derived in appendix I. The result of this equilibrium is presented in Figure 2.B. The incumbent will not produce and receive a compensation of $(p - c_E)K$ for being unable to supply *K* units of electricity to the market. The entrant simply earns its margin on production and receives $(p - c_E)K - F$. This is the private value of entry. In the figure, this is equal to the area *A* + *B* minus the fixed cost of entry *F*.[8]

[8] Again, as long as $(p - c_E)K > F$, the entrant will find it optimal to enter the market.

Proposition 3: In a perfectly competitive market with counter-trading the private benefit of entry is larger than the benefit to society.

The social value of entry is equal to the cost savings of having K units produced more efficiently by the entrant minus the investment costs: $(c_E - c_I)K - F$, i.e. area *A* minus the fixed entry cost. Hence, the private benefit of entry is larger than the benefit to society, and there is over-entry under counter-trading.

Furthermore, the costs of counter-trading, *i.e.* the subsidy to the incumbent (area *A* + *B*), and the additional subsidy to the entrant (area *B*) come at a cost for society. Often those costs are socialized, which creates further welfare losses. Energy users will pay a higher final energy price t, the consumer surplus will decrease, and an additional dead-weight loss is created (See Figure 2.B).

Summarizing, we show that in a perfectly competitive market, nodal pricing outperforms counter-trading as the latter gives the wrong signals for entry (and exit) of power plants. Counter-trading comes with an additional inefficiency if the costs of counter-trading are socialized. In the following section, we study whether the competitive entry effect makes counter-trading more efficient than nodal spot pricing when the market has an oligopolistic nature.

4.2 Market Power

This section compares the efficiency of nodal pricing and counter-trading when the market is oligopolistic, *i.e.* there is a positive price cost margin $p > C$ in the import constrained area.

Assume that nodal pricing is used as a method to solve congestion. Again, competition in the export constrained area will drive down the market price to $p^* = c_I$ See Figure 3. Given that the entrant is more efficient, he will replace the production of the incumbent in the export constrained area and supply K units of electricity to the import constrained area. The profit of the entrant is equal the profit in the spot market minus the investment cost: $(c_I - c_E)K - F$ (Area *A* in Figure 3.A minus the fixed cost). The incumbent loses market share (its own imports are displaced by the entrant's), and therefore will behave more competitively. Hence, the price drops from the pre-entry price $\hat{p}$ to the post-entry price p, and the dead weight loss will decrease. This is indicated with DWG (Deadweight Gain) in Figure 3.A. The social benefit of entry is equal to $(c_I - c_E)K + DWG - F$.

Proposition 4: In an oligopolistic market with nodal pricing, the private benefit of entry in the export constrained region is smaller than the benefit to society. Subsidizing entry might be optimal.

Note that the entrant does not benefit from the fact that the incumbent has market power in the import constrained area (and the high price p) due to congestion. However, entry reduces the market share of the incumbent, and reduces its incentives to set high prices.

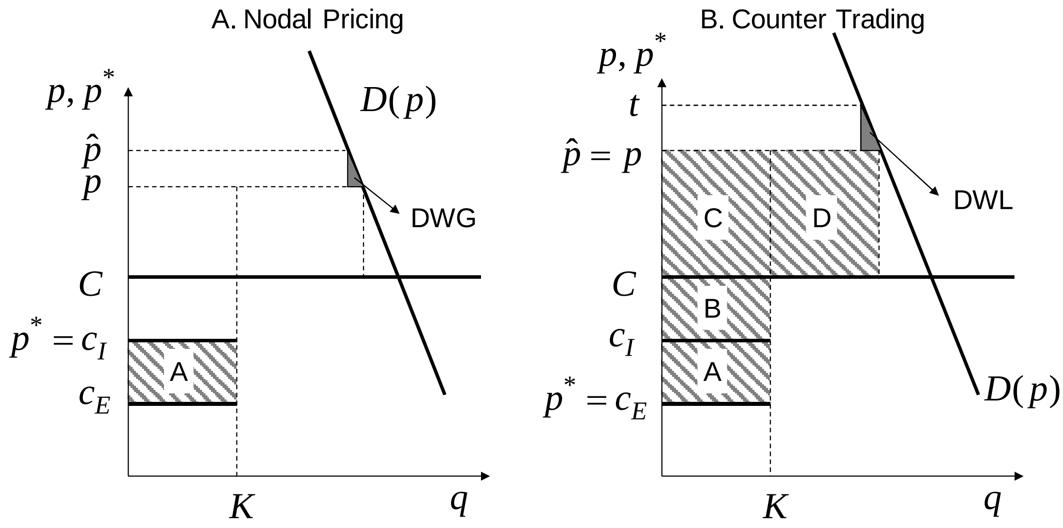

Figure 3. Oligopolistic competition with congestion

Now consider the case in which the incumbent will be compensated for losing its market share to the more efficient entrant by the means of counter-trading. For this case, we first examine the effect of entry on the price in the import constrained area under counter-trading.

Proposition 5: The profit maximizing incumbent in the import constrained area will not change its behavior on the spot market post-entry under counter-trading.

A formal proof of proposition 5 is derived in appendix II. The intuition for this result is that the incumbent is being compensated for losing market share, and therefore will not change its strategic behavior after entry. The incumbent's profit before entry is given by the area *B* + *C* + *D* in Figure 3.B. The profit after entry is equal to the area (*A* + *B* + *C* + *D).* It consists of two parts: profit for not producing in the export constrained area (equal to *A* + *B* + *C*) and a profit for producing in the import constrained area (area *D*). The incumbent will set the price p as to maximize its overall surplus. This price is the same under both regimes.

Hence, given that the incumbent's behavior does not change, the post-entry price level p is the same as the pre-entry price $\hat{p}$. Figure 3.B presents the market equilibrium and the welfare effect of entry by the more efficient entrant. Since the entrant is more efficient, he will supply the K units of electricity to the import constrained area. The private benefit of the entrant is given by area $A + B + C$ minus the fixed costs of entry, or $(p - c_E)K - F$. The private benefit of the incumbent is given by the compensation it receives from the counter-trading scheme and equal to $(p - c_E)K$. Furthermore, note that the competitive pressure does not reduce the deadweight loss as prices do not change ($p = \hat{p}$). However, the socialization of counter-trading costs (energy users pay final energy price t) would increase the deadweight loss.

Proposition 6: In an oligopolistic market with counter-trading the private benefit of entry is larger than the benefit to society.

Hence, the result is over-investment. While the private benefit of the entrant is given by $(p - c_E)K - F$, (the area $A + B + C$ minus the fixed entry cost), the benefit to society of having K units of electricity produced more efficiently after incurring the entry costs is equal to

$$(c_I - c_E)K - F - \text{DWL} \tag{1}$$

(or: area A minus the fixed entry cost and the dead weight loss).

Proposition 7: For every realization of the investment cost F of the entrant, nodal pricing is at least as good as counter-trading.

First, assume that the entrant enters in a regime with nodal pricing. Then it will for sure enter in a counter-trading regime. Welfare will be higher under nodal pricing, as the competitive effect only occurs under nodal pricing, and counter-trading implies an additional dead weight loss.

Second, assume that the entrant does not enter with nodal pricing. This implies that the cost advantage of the entrant does not outweigh the investment costs. If in that case the entrant would enter under counter-trading, total welfare will be lower, as not only total costs will increase ($F > (c_I - c_E)K$), but also an additional dead weight loss is created.

Summarizing, in an oligopolistic market, there will be over-entry when counter-trading is implemented. When the market is congested, there is no pro-competitive effect, but counter-trading introduces extra costs, namely the cost of entry and the cost of socializing the compensation payments. Nodal pricing always outperforms counter-trading.

4.3 Competitive effects during non-congested hours

Suppose that congestion is not permanent, but that for some fraction of the time the transmission line is uncongested. Hence, the entrant receives an implicit subsidy during the hours that there is congestion, which increases entry, and additionally, this subsidy creates a pro-competitive effect during the hours that there is no congestion. Will counter-trading in this situation be more efficient than nodal pricing?

Figure 4 shows the market equilibrium, and the welfare effect of entry, assuming that the transmission line has a sufficiently large capacity to accommodate both the entrant and the incumbent firm.

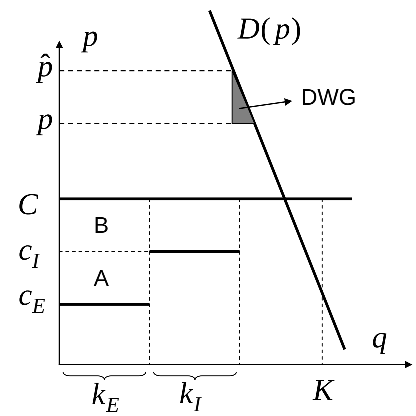

Figure 4. Oligopolistic competition without congestion

Due to entry, the market becomes more competitive, less efficient firms lose market share (k_E is now produced by the entrant instead of the incumbent in the import constrained zone), and price drops from $\hat{p}$ to p. Since the entrant is more efficient and does not face any congestion when exporting, it is able to produce k_E, and will make a profit

$$(p - c_E)k_E - F \,. \tag{2}$$

The social value of entry is given by the reduction in production costs (area A + B in Figure 4) and the deadweight gain (DWG in Figure 4) minus the fixed cost of entry F,[9] or:

$$DWG + (C - c_E)k_E - F \tag{3}$$

Whether the entrant has the right incentives to enter the market is derived in Appendix III for a simple Cournot model with n incumbent firms.

[9] As long as $(p_A - c_E)k_E > F$, the entrant will find it optimal to enter the market.

Proposition 8: In an oligopolistic market without congestion, entrants generally enter too often. Only if entrants can capture a very large market share will entry benefit society.

In appendix we show that only if the production capacity of the entrant k_E covers a large fraction of total market demand $D(p)$, entry will increase total surplus, or:

$$k_E \geq \frac{2n}{2n+1} D(p) \tag{4}$$

For instance, for a market with four oligopolistic firms ($n=4$), additional entry in the export constrained area should cover at least 89% of total market demand in order to increase total surplus. Hence, small entrants under counter-trading will have the wrong long term signals for entry and will enter the market too often. Therefore, we argue that it is very unlikely that the additional entry due to counter-trading will have a positive effect on total surplus during the hours that the line is not congested. Even if there would be a positive welfare effect during uncongested hours, this has to be weighted against the cost of socializing the implicit subsidy.

Proposition 9: Nodal pricing will always outperform counter-trading if the size of the entrant is small.

First, assume that the entrant does not enter under nodal pricing, but enters under counter-trading. Welfare will then be lower under counter-trading than under nodal pricing. The reason for this is that the private benefit for the firm under nodal pricing is an upper limit for welfare under counter-trading.

Second, assume that the entrant enters under nodal pricing. It will therefore also enter under counter-trading. Also in this case welfare will be lower under counter-trading for the same reasons as before: the competitive effect is larger under nodal pricing and recovering the subsidies creates an additional deadweight loss under counter-trading.

4.4 Robustness of the results

We have shown that additional entry in the export constrained area by the introduction of counter-trading is unlikely to improve total surplus. This result was derived assuming that: (1) the introduction of counter-trading would have no effect on entry in the import constraint area, (2) entrants in the export constraint area would behave competitively, and (3) the entrant had a lower marginal cost than the incumbent. This section shows that when those assumptions are relaxed our main results are likely to be reinforced.

First, since locational signals for entry are distorted due to the implicit subsidy created by counter-trading, it may reduce entry in regions where firms do not receive an implicit subsidy. Additional entry in the export constrained area (due to the implicit subsidy) will delay investments in the import constrained area. Those delays might have a significant welfare costs as those investments would have had a competitive effect not only during the hours where there is no congestion, but also at times when there is congestion.

Second, in practice, entrants often sign long-term contracts with the incumbent firms. By signing those contracts, small entrants, such as combined heat and power plants, become de-facto part of incumbent firms. Hence, the competitive effect of entry will disappear, and counter-trading will only have a negative effect on the overall welfare level.

Third, if the entrant has higher marginal costs than the incumbent, then the entrant might displace production of a more efficient, but less competitive incumbent. This would make it less likely for subsidizing entry to be socially optimal.

5 Conclusion

This paper compares two mechanisms to manage congestion in the electricity market: nodal pricing and counter-trading. Nodal pricing gives efficient long term price signals to firms with respect to their investment location, as prices reflect the scarcity of network resources. Compared with nodal pricing, counter-trading implies an implicit subsidy to firms in the export constrained area whenever there is congestion, and an implicit tax on firms in the import constrained area. Counter-trading therefore distorts the long term investment signals. If no other market imperfections are present, then the regional misallocation of investments will reduce overall welfare.

In this paper we test whether nodal pricing still outperforms counter-trading when there is market power in the generation market. A possible rational for this is the following: With nodal prices, firms in export constrained areas pay a higher price for accessing the network than in import constrained areas. This price implicitly forms an entry barrier in export constrained areas. By introducing counter-trading this entry barrier is lowered, and more firms will enter in the export constrained area, making the market more competitive.

With our model, we show that this will not increase overall welfare: The positive competitive effects of more entry in the export constrained area do not outweigh the investment cost of the new firms. There are three reasons why this is the case:

1. With counter trading, the incumbent firm is compensated for the displacement of its imports by the entrant's. Setting a higher price in the import constrained zone increases the size of the compensation it receives. Therefore, the incentives of the incumbent do not

change with entry, and it charges the same price before and after entry. There is no competitive effect of counter trading.

2. If there is no congestion, entry has a positive effect on market power, but subsidizing entry is socially not optimal. The reason for this is that there is already too much entry without a subsidy, because the entrant wants to steal the rents of the incumbent, but rent stealing itself does not improve welfare.
3. Counter-trading requires that additional funds are collected from network users. This creates a dead weight loss for society.

Summarizing: Counter-trading is an inefficient tool to manage congestion, and an ineffective instrument to promote competition in the electricity market. It subsidizes entry at locations where it is least needed, *i.e.* at those parts of the network with a generation surplus.

We therefore would suggest that regulators and governments seriously consider the introduction of a nodal (or zonal) pricing model (*cf.* Sweden) as an alternative of a counter-trading model (*cf.* the Netherlands).

When promoting 'green energy' investments in generation, governments might be tempted to interfere with the congestion management scheme and give additional benefits to "green electrons" on the network. We are convinced, that replacing nodal pricing with counter trading as a way to subsidize green energy is inefficient. Counter-trading acts as an implicit subsidy both to the entrant and the incumbent. Offering a subsidy only to the green producers would reduce the overall costs for reaching the goal of subsidizing green energy. Counter-trading implies a subsidy to green energy in the *export constrained* areas but not for green energy in the *import constrained area*, while the producers in the import constrained area are more likely to improve competition, and more likely to be able to bring their green energy to final consumers. Counter trading is therefore not likely to induce green energy producers to invest in the right location, and arguably not the most efficient strategy to bring about a more sustainable society.

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Appendix

I. Nash equilibria of counter-trading bids

Under counter-trading, the incumbent and the entrant in the export constrained area will place “cost bids” indicating their willingness to produce. We denote the bids of the entrant and the incumbent by B_E and B_I, respectively. The firm that bids the lowest variable cost will be allowed to export K units of electricity to the import constrained area. The other firm will receive a compensation for not being able to supply equal to $(p-B)K$, with B

equal to its bid, and p the price in the import constrained area. We will now derive the best response correspondence for the incumbent and the entrant in a game .

For $B_E < c_I$, the incumbent's best response correspondence is to bid slightly above the entrant: $B_I = B_E + \varepsilon$, with ε very small, since in this case he receives a compensation of $p - (B_E + \varepsilon) > p - c_I$ for every unit of electricity produced by the entrant. For $B_E > c_I$, the incumbent's best response correspondence is to undercut the entrant by bidding $B_I < B_E$, thereby undercutting the entrant and receiving $p - c_I$ for every unit produced.

For $B_I < c_E$, the entrant's best response correspondence is to bid just above the incumbent, $B_E = B_I + \varepsilon$, since it will then receive a compensation of $p - (B_I + \varepsilon) > p - c_E$. For $B_I > c_E$, the entrant's best response correspondence is to bid $B_E < B_I$, thereby undercutting the incumbent and receiving $p - c_E$ for every unit produced.

Hence, any pair of bids (B_E, B_I) for which $c_E \le B_E \le c_I$ and $B_I = B_E + \varepsilon$ is a Nash equilibrium in this framework. In this case, the incumbent receives a compensation of $(p - (B_E + \varepsilon))K$ for not being able to supply the K units of electricity to the market. The entrant will make a production profit of $(p - c_E)K$ in equilibrium. For receiving this profit the entrant paid an entry cost F .

There is a large set of possible Nash equilibria. In the remainder of the paper we assume that the firms coordinate on the equilibrium that is Pareto dominant, i.e. $(B_E = c_E, B_I = c_E + \varepsilon)$. The price in the export constrained zone is then given by $p^* = c_E$.

II. Profit maximization of the oligopolistic incumbent

This appendix derives the regional prices under countertrading before and after entry occurred, and shows that the incentives for the incumbent do not change. We consider an incumbent monopoly, active in both the import and export constrained area, a fringe generator with supply function $S^F(P)$ in the import constrained area, and an inelastic level of demand in the import constrained area. We introduce the fringe generator here, as this firm is more likely than consumers to react to prices on short notice, and to arbitrage between the day-ahead-market and the counter trading market. The profit maximization problem of the incumbent, before entry occurs is:

$$\begin{aligned}&\max_{Q,q_I,p} p \cdot (Q + q_I) - C \cdot Q - c_I \cdot q_I \\ &\text{subject to:} \qquad\qquad (5)\\ &p = p(Q + q_I) \quad q_I \le K\end{aligned}$$

Here, Q is the demand the incumbent faces in the import constrained area, while q_I denotes the supply of the incumbent in the export constrained area. The inverse demand function $P(\bullet)$ represents the residual demand function the incumbent faces in the import constrained area. The price is determined by setting total (inelastic) demand Q^D equal to the sum of imports K, the (elastic) supply by a fringe firm $S^F(p)$ and the production of the monopolist Q:

$$S^F(P) + K + Q = Q^D$$

This can be rewritten as:

$$p = p(Q+K) = S_F^{-1}(Q^D - Q - K)$$

Maximizing profits using the first order conditions gives

$$p'(Q+k)(Q+k) + p(Q+k) = C \quad (6)$$

where we assume that the line is sufficiently small, so that it is congested $q_I = k$.

Now consider the profit maximization problem of the incumbent when entry occurs. This is slightly more complex as we have to take into account both the day ahead market and the balancing market. The incumbent's profit is the revenue in the day ahead market, plus the revenue from selling extra power in the import constrained area, minus the revenue it loses for being constrained-off in the export constrained area, minus production costs.

$$\pi = p^{DA} \cdot (Q^{DA} + Q^{*DA}) + p \cdot (Q - Q^{DA}) - p^* \cdot Q^{*DA} - C \cdot Q$$

where p^{DA} is the day ahead price, p the price in the import constrained area after counter trading, and P^* the price in the export constrained area. Q^{DA} and Q^{*DA} are the quantities sold in the day ahead market in the import constrained and the export constrained areas respectively and Q is the final production level in the import constrained area.

In the *import constrained area*, the price is determined by the inverse demand function

$$p = p(Q+K) = S_F^{-1}(Q^D - Q - K)$$

In the *export constrained area,* only the (competitive) entrant will be producing. The price in the export constrained area is

$$p^* = c_E$$

The *price in the day ahead market* p^{DA} is determined by an arbitrage condition. Fringe producers will only sell in the day-ahead market, if they receive the same price in the day ahead market, as in the counter-trading market. Therefore:

$$p^{DA} = p$$

If this would not be the case, then the fringe producers would reduce their supply in the day-ahead market, and increase their net sales in the countertrading market until the equation is satisfied.[10]

The program of the incumbent then simplifies to

$$\max_{\substack{p^{DA},p^{*},p \\ Q^{DA},Q^{DA*},Q}} \quad \pi = p \cdot Q - C \cdot Q + (p^{DA} - p) \cdot Q^{DA} + (p^{DA} - p^{*}) \cdot Q^{DA*}$$

subject to:

$$p^{*} = c_E, \qquad p = p(Q+K) \qquad p^{DA} = p$$

$$Q^{DA*} \le K$$

Substituting the constraints we find the following optimization problem:

$$\max_{Q} p(Q+K) \cdot Q - C \cdot Q + (p(Q+K) - c_E) \cdot K$$

Maximizing profits using the first order conditions now gives

$$p'(Q+K)Q + p(Q+K) + p'(Q+K)K = C \qquad (7)$$

When comparing the two first order conditions (7) and (6), we find that they are identical. Hence, the incumbent in the import constrained area will not change its behavior on the spot market post-entry. Therefore, the post-entry price level remains the same in our model.

We derived this model for a monopoly case. A similar result can be derived for oligopoly models. As counter-trading refunds firms for lost market share, they will not become more competitive after entry.

III. Necessary condition for welfare improving subsidies

A necessary condition for subsidizing entry to be welfare improving is that private incentives will lead to under-investments. This happens if the private incentives (of the entrant) to enter are smaller than the social incentives. In this appendix, we show when this is the case.

The entrant will enter the market as long as its short term profit outweighs the investment costs:

$$F \le (p_B - c_E - \Delta p) k_E,$$

where Δp is the difference between the price before (p_B) and after entry (p_A), c_E is the marginal cost, k_E is the production, and F is the fixed cost of the entrant.

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[10] Note that the entrant does not have an incentive to arbitrage between the day ahead market price P^{DA} and the price in the counter trading market P^{*}, as it would only reduce its profit.

From a society viewpoint the entrant should invest as long as

$$F \leq \frac{\Delta p^2 \left|D'(p)\right|}{2} + (C - c_E)k_E \tag{8}$$

where F is the fixed entry cost of the entrant, the second term represents the size of the reduction in deadweight loss (competitive effect), and the third term is the increase in producer surplus (efficiency gain).

We assume that there are n symmetric incumbent Cournot firms in the import constrained area that have similar marginal costs C, and that the entrant is competitive and always produces at maximal capacity k_E. The price cost margins before and after entry are then given by the following first order conditions:

$$p_B - C = \frac{D(p)}{n\left|D'(p)\right|} \tag{9}$$

$$p_A - C = \frac{D(p) - k_E}{n\left|D'(p)\right|} \tag{10}$$

In the post entry condition, k_E is subtracted from the total level of demand to obtain the residual demand for the incumbent firm(s) in the import constrained area. Subtracting both equations we find the price effect of entry

$$\Delta p = p_B - p_A = \frac{k_E}{n\left|D'(p)\right|} \tag{11}$$

The price effect is proportional to the size of investments by the entrant, is smaller when the market has more firms (n), and if demand is more elastic (large $\left|D'(p)\right|$).
Subsidizing entry is justified if the private incentives to invest are smaller than the social incentives

$$\frac{\Delta p^2 \left|D'(p)\right|}{2} \geq (p_B - C - \Delta p)k_E \tag{12}$$

Replacing Δp and $p_B - C$ with the expressions (10) and (11), we find that subsidizing entry can only be socially optimal if the size of the entrant is sufficiently large:

$$k_E \geq \frac{2n}{2n+1} D(p) \tag{13}$$

If the size of the entrant is sufficiently large, it is optimal to subsidize its entry. The critical minimal size depends on the number of incumbent firms present in the market, and the size of market demand. For instance, if there are two firms active in the import constrained area, the entry decision of the entrant will only be optimal if upon entry it will take over at least four fifth of total electricity demand. If the total level of entry is less than this critical value, it is not optimal to subsidize entry, as it will lower overall welfare. Note that if we assume that the entrant would have a higher marginal cost than the incumbent firm, then it is even less likely that entry is going to be welfare improving.

Hence, in our stylized model, small entrants will have the wrong long term signals for entry and will enter the market too often. Only if entrants are very large, will entry be optimal.