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The effect of counter-trading on competition in electricity markets

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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 unlikely to be the case, and expect counter-trading 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).

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.[1]

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 Svenska 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. It was chosen as the regulatory framework to deal with congestion in the Netherlands.

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

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

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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).[2] 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 counter-trading (less entry compared to nodal pricing) into account, would only strengthen our result that any competitive benefits of counter-trading 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 zone) 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 the 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.

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] This paper focuses on the competitive effect of entry, assuming that one firm is already present in the market. Petropoulos and Willems (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.

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,[3] 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.[4]

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 (Bjørndal et al., 2003; Hakvoort et al., 2009).

Under such a system, it is plausible that uniform prices may lead to suboptimal dispatching of power plants.[5] Green (2007) shows

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

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

[5] 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.

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 behavior 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 (cf. Stoft, 1997).

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.

Supporters of the zonal approach have argued that by using the zones (and neglecting the physical constraints in the spot market), firms face more competitors, and markets become more competitive. On the other hand, if prices are different at every node, so must be markets, and therefore, using nodal pricing will enhance the options of dominant firms to increase its profits. It therefore follows that aggregation of several nodes into larger zones creates competition across a wider area and reduces the market power of the monopolist (see for instance, Oren et al., 1995 for this line of argument). Hence, nodal pricing (or geographically splitting of regions) should be pursued only when there is enough competition at each node or in each new zone.[6] However, Harvey and Hogan (2000) and Hogan (1999) argue that this conclusion is incorrect as it ignores poorer incentives for investment, socializes the higher costs by taxing consumers and requires payments to generators to reduce supply when inter-zonal congestion occurs. Those payments may lead to strategic behavior. Moreover, firms realize that in the balancing market, where physical constraints cannot be neglected, they face less competition and are able to charge prices above the competitive level. The profit in the balancing market represents an opportunity cost when they bid in the spot market. As a result, firms will also bid less competitive in the spot market. Hence, using a zonal approach does not necessarily improve competition.

The fact that firms might behave strategically in the wholesale market in combination with reserve/ancillary markets, has been well documented. In order to address such forms of localized market power, regulators often rely on special forms of regulation. In California, reliability must-run (RMR) contracts were imposed on generation plants with a high risk of market power abuse. However, Wolak and Bushnell (1999) show that even those RMR contracts did not solve all market power abuses. The presence of the RMR market made it more profitable for the firms to behave non-competitively in the spot and ancillary markets. By withholding capacity in the spot market (and the ancillary market) and submitting higher priced bids, firms can increase the spot market price (and the price for ancillary services). At the same time,this behavior will increase the likelihood of being able to sell in the RMR market and puts positive pressure on the RMR contract prices.[7]

In our paper 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 plants have an increased opportunity to be called upon in the counter-trading market. As a result those generators will increase their bids 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.[8]

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.

There are several papers modeling the possibility of strategic behavior under nodal pricing. 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. Gilbert et al. (2004) and Joskow and Tirole (2000) discuss how different mechanisms for allocating transmission capacity (such as physical transmission rights, and nodal pricing with financial transmission rights) affect market power in the wholesale market sector.[9]

There are however few papers modeling market power under counter-trading. One exception is Hers et al. (2009) who develop numerical simulation models of the European electricity market to compare different types of congestion management schemes. They find that the benefits of introducing re-dispatch 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, and (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.

[6] Note that the discussion in the Netherlands focused on how zonal pricing could improve competition not by creating larger markets, but by new entry.

[7] Another example of strategic behavior is given in Ofgem (2009). When NETA was extended to Scotland via the BETTA arrangements in 2005, concerns over possible market abuse arising from constraints between England/Wales and Scotland have been raised on several occasions. Ofgem launched a formal investigation into the behavior of ScottishPower and Scottish & Southern Energy in April 2008, and found that the two companies may have withheld generation plant from the spot market while using the same plant to supply balancing power at excessive prices.

[8] See for instance, Küpper and Willems (2010) 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.

[9] Numerical simulation models can also be used to model market power in the electricity market. See for instance Boucher and Smeers (2001), Hobbs et al. (2004) and Wei and Smeers (1999). Ventosa et al. (2005) discuss different modeling techniques, and Neuhoff et al. (2005) compare different numerical Cournot models.

Bjørndal et al. (2003) on the other hand, study the strategic behavior of the network operators in systems that combine market splitting and counter-trading. They show that it is indeed possible for network operators 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.

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 Fig. 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 capacities of the incumbent and the entrant (if it enters) are equal to k_I and k_E, respectively, 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 of the incumbent is given by $C > c_I$. There is no capacity constraint on production in the import constrained area. Consumers, who 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^*.

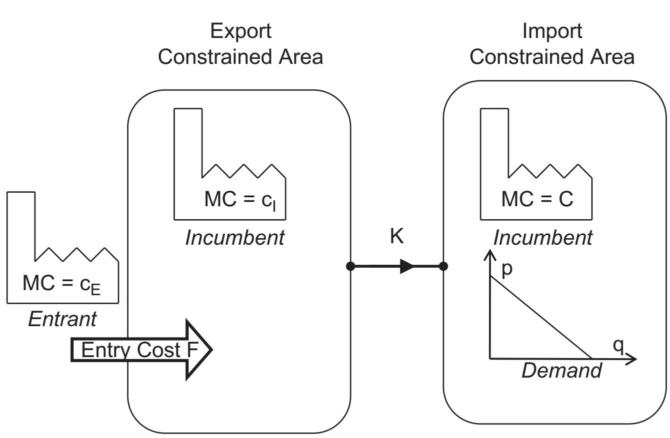

Fig. 1. Stylized representation of the market.

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.

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 $p^* = c_I$. Fig. 2A 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.[10]

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.*

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 Fig. 2B. The incumbent will not produce and receive a compensation of $(p - c_E)K$ for being unable

[10] Note that it has to hold that $(p^* - c_E)K > F$ for the entrant to enter the market.

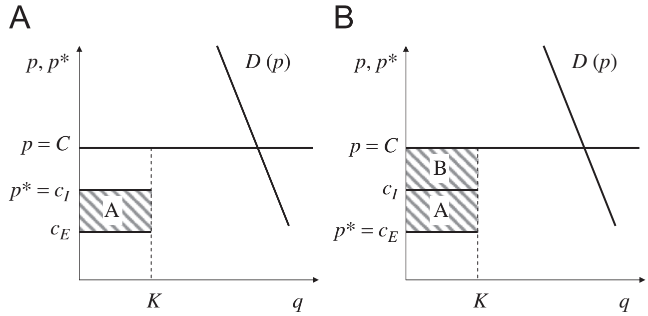

Fig. 2. Perfect competition with congestion. (A) Nodal pricing and (B) Counter trading.

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.[11]

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 paid for (socialized) by a charge to energy users, and hence, create welfare reductions in the form of a deadweight loss.[12]

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 in the export constrained area to $p^* = c_I$ (see Fig. 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 Fig. 3A 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 deadweight loss will decrease. This is indicated with deadweight gain (DWG) in Fig. 3A. The social benefit of entry is equal to $(c_I-c_E)K+DWG-F$.

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

[12] Given the low short-term demand elasticity, those welfare losses are expected to be small in the short-run, but can become larger in the long-run (see Lijesen, 2007).

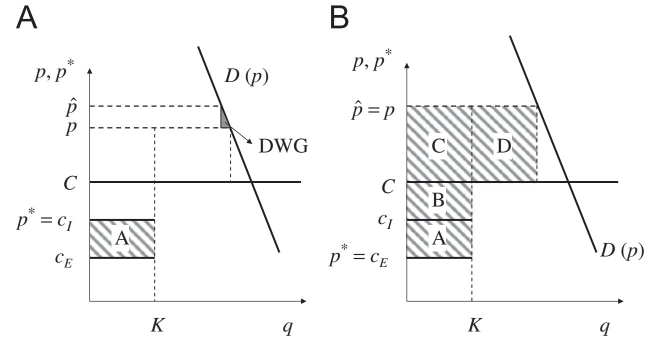

Fig. 3. Oligopolistic competition with congestion. (A) Nodal pricing and (B) Counter trading.

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.

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 Fig. 3B.[13] 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.

Hence, given that the incumbent's behavior does not change, the post-entry price level p is the same as the pre-entry price $\hat{p}$. Fig. 3B 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 is 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, if the costs of counter-trading are socialized, this might lead to a 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

[13] Here, we assume that the firms coordinate on the equilibrium that is Pareto dominant (see Appendix I).

costs is equal to

$$(c_I - c_E)K - F - DWL \quad (1)$$

(or: area A minus the fixed entry cost and the deadweight 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 (see Proposition 5), and counter-trading implies an additional deadweight 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 deadweight 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?

Fig. 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.

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

$$(p - c_E)k_E - F \quad (2)$$

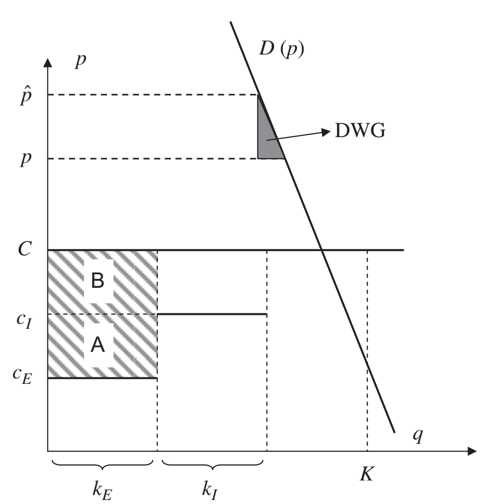

Fig. 4. Oligopolistic competition without congestion.

The social value of entry is given by the reduction in production costs (area $A+B$ in Fig. 4) and the deadweight gain (DWG in Fig. 4) minus the fixed cost of entry F,[14] or:

$$DWG + (C - c_E)k_E - F \quad (3)$$

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.

Proposition 8. *In a n-firm oligopolistic market with linear demand and without congestion, subsidizing entry will only be socially efficient if the entrant obtains a market share of*

$$1 - \frac{1}{(n+1)^2 + 1}$$

Proof: See Appendix III.

For instance, for a market with two oligopolistic firms ($n=2$), additional entry in the export constrained area should cover at least 90% of total market demand in order to increase total surplus. The intuition for this result is simple: The private incentives of the entrant to enter the market are proportional to the size of entry, while the pro-competitive effect is only a second order effect. Hence, for small entrants the pro-competitive effect is always smaller than the private incentives to enter.

This does not imply that small entry should necessarily reduce overall welfare: If the investment cost of the entrant is low, then entry will improve welfare. However, this entrant does not need to be subsidized to enter the market, as it is already profitable without subsidy.

Proposition 8 is only valid for linear demand. However, if entry is sufficiently small, then any demand function can be approximated by a linear one, and entry should never be subsidized. We cannot derive conditions for general demand functions, but Appendix III shows that the results hold also for a large range of parameters under constant elasticity demand functions. 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.[15] Even if there would be a positive welfare effect during uncongested hours, this has to be weighed 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

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

[15] Due to the introduction of counter-trading, some firms will enter the market that otherwise would not have entered. Those firms have a relatively high investment cost, and are less likely to improve overall welfare.

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 defacto 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 deadweight 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 suggest that regulators and governments should seriously consider the introduction of a nodal (or zonal) pricing model (cf. Sweden) as an alternative to a counter-trading model (cf. the Netherlands).

Furthermore, 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 has the lowest bids 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. If a tie occurs (they both submit an equal bid), we assume that the more efficient entrant will produce. We will now derive the best response correspondence for the incumbent and the entrant in a bidding 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 also bid $B_I = c_I$, the entrant will produce, and the incumbent receives the compensation $p-c_I$. For $B_E > c_I$, the incumbent's best response correspondence is to undercut the entrant by bidding $B_I < B_E$, in doing so deterring entrance, 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 also bid $B_E=c_E$, as the more efficient firm will produce, and receive $p-c_E$. 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 $c_E\leq B_E\leq c_I$ 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 $p^*=c_E$.

Appendix II. Profit maximization of the oligopolistic incumbent

This appendix derives the regional prices under counter-trading 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

$$\max_{Q,q_I,p} p(Q+q_I)-CQ-c_Iq_I$$

subject to

$$p=p(Q+q_I),\quad q_I\leq K \tag{4}$$

Here, Q is the amount produced by the incumbent in the import constrained area (after counter-trading has taken place), 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 in the import constrained area $S^F(p)$, and the production of the incumbent in the import constrained area 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

$$p'(Q+k)(Q+k)+p(Q+k)=C \tag{5}$$

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

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

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

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 of the incumbent 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 beproducing. 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 thecounter-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 counter-trading market until the equation is satisfied.[16]

The program of the incumbent then simplifies to

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

subject to

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

Substituting the constraints we find the following optimization problem:

$$\max_Q p(Q+K)Q-CQ+(p(Q+K)-c_E)K$$

In the day-ahead market, the monopolist will set $Q^{DA^*}=K$ in the export constrained area, as this will maximize the counter-trading payments it receives. The monopolist is indifferent about the quantity it sets in the import constrained area given perfect arbitrage. Hence, Q^{DA} is not uniquely determined.

Maximizing profits using the first order conditions now gives

$$p'(Q+K)Q+p(Q+K)+p'(Q+K)K=C \tag{6}$$

When comparing the two first order conditions (6) and (5), 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.

Summarizing, the entrant and the incumbent both submit bids in the day-ahead market to produce K units in the export constrained area. The incumbent also submits bids in the import constrained area. It could for instance submit a bid to produce $Q-K$. During counter-trading, the incumbent will receive payments to reduce production with K units in the export constrained area, and be paid the price p to increase production with K units in the import constrained area.

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

[16] 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.

Appendix III. Necessary condition for welfare improving subsidies

A necessary and sufficient condition for entry subsidies to be welfare improving is that private incentives alone 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 first derive when it is optimal to subsidize entrants, if demand is linear. For non-linear demand, we are unable to derive general conditions, as those will typically depend on the precise shape of the demand function over a whole range of prices. However, for small entry levels, the demand can be approximated by a linear function, and the results for linear demand are generally valid for small levels of entry. Such a linear approximation is not valid if a single entrant captures a large fraction of the market. In the last part of this appendix, we therefore report numerical simulation results for constant elasticity demand functions and show for which types of entry subsidies would be optimal. The results for linear demand functions seem to carry over to other classes of demand functions.

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

$$F \leq (p_A - c_E)k_E$$

where p_A is the price after, c_E is the marginal cost, k_E is the production, and F is the fixed cost of the entrant.

From a society viewpoint the entrant should invest as long as

$$F \leq \frac{\Delta p^2 |D'|}{2} + (C - c_E)k_E \quad (7)$$

where F is the fixed entry cost of the entrant and Δp the difference between the price before (p_B) and after entry (p_A). 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). In order to calculate the competitive effect, we assume that the demand function is linear.

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:

$$p_B - C = \frac{D(p_B)}{n|D'|} \quad (8)$$

$$p_A - C = \frac{D(p_A) - k_E}{n|D'|} \quad (9)$$

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[17]

$$\Delta p = p_B - p_A = \frac{k_E}{(n+1)|D'|} \quad (10)$$

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 $|D'|$). Subsidizing entry is justified if the private incentives to invest are smaller than the social incentives

$$\frac{\Delta p^2 |D'|}{2} \geq (p_A - C)k_E \quad (11)$$

Replacing Δp and $p_A - C$ with the expressions (9) and (10), we find that subsidizing entry can only be socially optimal if the size of the entrant is sufficiently large:

$$\frac{k_E}{D(p_A)} \geq \frac{(n+1)^2}{(n+1)^2 + 1} \quad (12)$$

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 the entrant takes up at least 90% of total electricity demand in the post-entry regime. 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 entrants with high investment costs may enter the market too often.This does not mean that small levels of entry will always reduce welfare. Entrants with a low investment cost will improve overall welfare by entering the market, but they do not require a subsidy to do so.

Note that Eq. (12) is valid only for linear demand functions. However, if entry is small, we can take a linear approximation of the demand function, and it will therefore never be optimal to subsidize a (very) small entrant. The intuition for this is that the competitive effect (LHS of Eq. (11)) is a second order effect as it depends on Δp^2, while the private benefit (RHS of Eq. (11)) is a first order effect depending on k_E.

For non-linear demand, we cannot derive general conditions for when subsidizing entry is socially optimal or not. We therefore illustrate our results with numerical simulations, assuming constant elasticity demand functions ($D(p) = \alpha p^{\nu}$ with $\nu < 0$), for different levels of market concentration and pre-merger competitiveness. Fig. 5 shows the market share a single competitive entrant should at least obtain for entry subsidies to be socially optimal. The horizontal axis measures the degree of market power before entry as the price–cost ratio.[18] The figure shows that for large ranges of market conditions, subsidizing entry is not optimal. Subsidizing entry is more likely to improve social

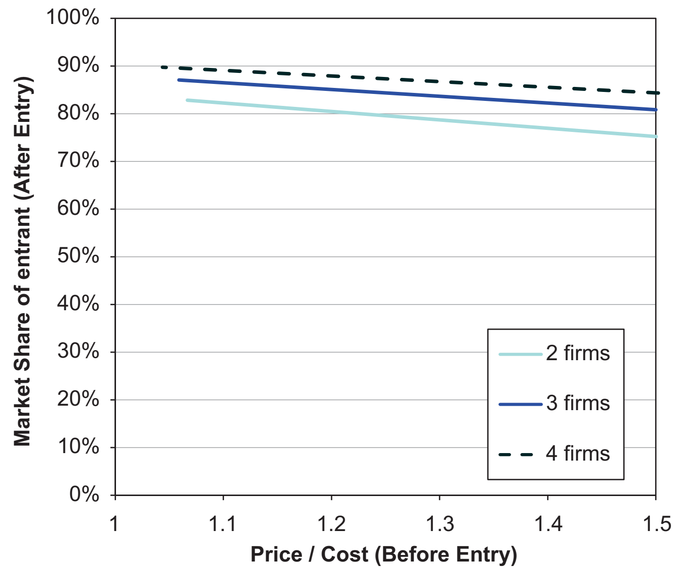

Fig. 5. When is it socially optimal to subsidize entry?

[17] We thank a referee for highlighting a mistake in an earlier derivation of this equation.

[18] We calibrated the demand elasticities to the pre-entry price–cost margins, and then compared the private incentives of entry with the social optimum.

welfare, if the pre-merger market is less competitive, i.e. fewer firms are active, and the pre-merger price–cost margin is larger.

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