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Welfare effects of vertical integration in energy distribution

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Abstract

This paper analyzes the welfare effects of vertical integration of networks and trade in energy markets. Vertical integration reduces the effect of double marginalization, thus increasing welfare. On the other hand, vertical integration hinders equal competition, rendering the vertically integrated supplier a competitive advantage. We find that the net effect of vertical integration is beneficial to welfare if firms are symmetric, but the effect is ambiguous in the probably more relevant situation where the non-network firm has a cost advantage.

Key words: energy, vertical integration, networks, market power
JEL-codes: D43, L13, L22, L94, L95, Q41

1. Introduction

The electricity and natural gas industries in the European Union are subject to an ongoing process of market reform, aimed at reaching a single European markets for each commodity by 2007. An important feature of both industries is that they are network industries, networks form an essential facility for the delivery of electricity and natural gas to the consumer. Traditionally, European energy companies are vertically integrated firms, meaning they both sell and transport energy (and often also produce it). In its directives, the European Commission mentions the demand of separate accounts and uniform fees for access to the network, but does not mention whether vertical integration should or should not be prohibited.

This paper analyzes the short term welfare effects of the vertical integration of energy trade and the supply of network services.[1] There are two main effects of vertical integration. First of all, as Prosperetti (2000) points out, network owners who are vertically integrated with the incumbent producer have little incentive to strive for competitive markets. They are inclined to use network access as a mean to discourage entry or hinder competition. Borenstein *et al.* (2000) use similar arguments, stating that it may be profitable to induce congestion and become a monopolist on residual demand.

On the other hand, vertical integration in markets where market power exists prevents double marginalization, as Tirole (1988) has shown. Double marginalization arises when firms at different places in a supply chain (e,g. a trader and a transporter) both have market power. They will both use their market power to receive a positive margin on their product. Tirole shows that if these firms would be vertically integrated, the total (single) margin would be lower than the sum of margins in the disintegrated case.

The remainder of this paper is organized along the lines of these two main effects described above. The next section describes the base model that we use to analyze the effects. Sections 3 and 4 describe the effects of vertical integration on the access fee and double marginalization respectively. We combine the results in section 5 and derive the effects on Welfare from it. The final section discusses the implications of our results.

[1] Note that we ignore the generation and extraction of electricity and natural gas respectively. Further note that we only discuss short-term effects. Long-term welfare effects may differ because of dynamic effects, such as investment in new capacity.

2. The base model

This section sets out the base model used for the analysis. Our model describes a market where energy retailers buy energy (this may be either natural gas or electricity) and sell it to end-users.[2] We assume that retailers engage in price competition with two part tariffs. The model is based on telecommunication market models, as described by Laffont *et al.*, 1998 and De Bijl, 2000. These models tend to be more useful than the traditional energy markets models, since their focus is primarily on network related competition strategies. The model is essentially a duopoly model, but it can be expanded to a larger number of players.

We start with a simple framework. Consider a representative consumer, purchasing energy from firm i. His net utility consists of the utility gained from being connected to the network and from consuming the energy minus the out of pocket costs. Being connected to firm i's network facilitates energy use, and is therefore connected to positive fixed utility, u_i^0. Furthermore, firm i may or may not have a certain reputation for certainty of delivery, careful billing, also yielding positive utility (r_i). We define utility to be measured in monetary units, in order to be able to extract out of pocket expenses. These expenses consist of standing charge m_i and the unit price of energy (p_i) times the amount consumed (x_i).

$$v_i = u_i^0 + r_i + u_i[x_i] - p_i x_i - m_i \tag{1}$$

In equation (1), $u_i[x_i]$ represents a strictly concave (i.e. $\partial u_i / \partial x_i > 0$ and $\partial^2 u_i / \partial x_i^2 < 0$) utility function of consuming x_i units of energy.

$$u_i = a x_i - \tfrac{1}{2} b x_i^2 \tag{2}$$

We will leave provider choice aside for now and turn to demand first. Given the choice for provider i, the representative consumer's individual demand is based on utility maximization. Maximum utility is reached at the point where price equals marginal costs, which yields the following demand equation.

$$x_i = \frac{a - p_i}{b} \tag{3}$$

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[2] A model describing the wholesale market would not differ essentially from our model however.

Our next step is to model provider choice. Note that this is a discrete choice, any consumer chooses one provider. We assume consumers to switch between providers based on the net utility they offer. The representative consumer will switch from firm i to firm j if $v_i < v_j$. Obviously, this would imply that even the smallest difference in net utility would lead to the extreme outcome where one firm has a marketshare of one, leaving the other firm without customers. In real life, we don't see this kind of developments, for instance because of differences in preferences, brand loyalty, unawareness of alternatives, transaction costs and so on. Following De Bijl (2000), we model this by introducing switching costs, *z*. The representative consumer will now switch from provider i to provider j if $v_i < v_j - z$.

We assume that z is distributed uniformly on the interval [0, Z $s_{i,\, t-1}$], where Z is a positive constant and $s_{i,\, t-1}$ is the lagged market share of firm i. From this inequality and the uniform distribution of z, it follows that the market share of firm i equals:[3,4]

$$s_i = s_{i,t-1} + \frac{v_i - v_j}{Z} \tag{4}$$

From this equation, we can see that Z, the upper bound of the switching costs, is a measure for the price sensitivity of consumers and therefore a measure of the volatility of market shares. When we combine equations (1) through (4) and define the number of consumers as n, we derive total demand for firm i:

$$X_i = ns_i x_i = n\left(s_{i,t-1} + \frac{u_i^0 - u_j^0 + m_j - m_i + \frac{(a-p_i)^2 - (a-p_j)^2}{2b}}{Z} \right)\frac{a-p_i}{b} \tag{5}$$

In the remainder of our analysis we will assume that *n*=1 for notational simplicity. Note that all variables are now in per capita terms.[5]

[3] Note that we define market share as the share of customers connected to a firm rather then the share of sales.

[4] This can be generalized to a larger number of players by stating $s_i = s_{i,t-1} + \sum_j \frac{v_i - v_j}{Z}$

[5] Or per household, if we define the consumer base in terms of households.

On the cost side of the model, we divide between purchase costs (*pc*) and transport costs (*tc*). Purchase costs consist of the wholesale price of energy plus possible transaction costs that go with the purchase of energy (e.g. search costs, negotiation costs and so on). Following Laffont *et al.* (1998), we distinguish between fixed transport costs, connection-dependent transport costs and traffic-dependent transport costs. Ignoring all fixed (purchase and transport) costs for simplicity, we define connection-dependent transport costs as a fixed amount, $f_i>0$, per customer, which contains costs for billing and servicing. For now, we assume that traffic-dependent transport costs equal the exogenous access fee paid to the network owner, τ:

$$C_i = s_i(f_i + (pc_i + \tau)x_i) \qquad (6)$$

From the demand and cost equations above, we can deduct the profit function for each firm:

$$\pi_i = s_i(m_i - f_i + (p_i - pc_i - \tau)x_i) \qquad (7)$$

We finish our description of the base model by introducing welfare into the model. We define welfare as the sum of industry profits and consumer surplus. Industry profits can be found by simply adding up the profits of all firms in the industry:

$$\Pi = \sum_i \pi_i = \sum_i s_i(m_i - f_i + (p_i - pc_i - \tau)x_i) \qquad (8)$$

Consumer surplus equals the net utility of all consumers minus switching costs. As we have defined the number of consumers as 1, the net utility of all consumers equals the net utility of the representative consumer, which can be found by adding up equation (1) over all firms. Total switching costs equal the number of switchers times the average switching costs. From equation (4), we find that the number of switchers from firm j to firm i equals $(v_i - v_j)/Z$.
Since we assumed switching costs to be distributed uniformly, the rule of half applies to the average switching costs of switchers. Combining these elements, we find the following equation for consumer surplus:

$$CS = \sum_i s_i v_i - \frac{\left(v_i - v_j\right)^2}{2Z} \tag{9}$$

Now, following our definition, we add up equations (8) and (9) to find total welfare.

$$W = \sum_i s_i (u_i^0 + r_i + ax_i - \tfrac{1}{2} bx_i^2 - f_i - (pc_i + \tau) x_i) - \frac{\left(v_i - v_j\right)^2}{2Z} \tag{10}$$

Solution for the duopoly case

Now that we have completed the base model, we solve it for the duopoly case. Numerical simulation shows that per unit prices equal marginal (production and transport) costs, whereas consumer surplus is pruned away through the standing charge. This finding is consistent with the findings of other models with two part tariffs.[6] The finding that per unit prices are cost-based, simplifies the solution for the optimal standing charge. We can now state that $p_i = pc_i + \tau$ and maximize profits with respect to the standing charge only. We start by multiplying all terms in the first order condition (FOC) for both firms by Z, and then add up both equations, using the condition that market shares should add up to one. We then find a simple relationship between the standing charges and fixed costs of both firms:

$$m_1 = -m_2 + f_1 + f_2 + Z \tag{11}$$

Although we derived equation (11) in order to find the relationship between the standing charges of both firms, the relation also gives us information on industry profits. Since per unit prices are at marginal cost levels, both firms only receive profit from the difference between standing charge and fixed costs. As equation (11) shows, the difference between the sum of standing charges and the sum of fixed costs equals the upper bound of the switching costs (i.e. $Z = (m_1 + m_2) - (f_1 + f_2)$). From this finding, we can conclude that *Z* is not only a measure of market share volatility, it also resembles the upper bound of industry profits. We substitute equation (11) into the FOC of firm 2 and simplify the equation to find the solution for m_2:

[6] See, for instance, Schmalensee (1981). Furthermore, note that Cournot competition in x would yield the same outcome, as Harrison and Kline (2001) suggest. This can be checked by inverting equation (3) and then solve the model.

$$m_2 = \frac{2f_2 + f_1 + r_2 - r_1 + u_2^0 - u_1^0 + \frac{(a - pc_2 - \tau)^2 - (a - pc_1 - \tau)^2}{2b} + Z(1 + s_{2.t-1})}{3} \tag{12}$$

Since the model is symmetric, we derive a similar solution for the standing charge of firm 1. We can simplify our finding by assuming total symmetry between firms, such that $m^*=m_1=m_2$. This requires that all cost and utility terms are equal between firms, as well as equal market shares (i.e. $s_1=s_2=1/2$). We now find that:

$$m^* = f^* + \tfrac{1}{2}Z \tag{12*}$$

The interpretation of equation (12*) follows that of equation (11) closely. The standing charge of the total symmetry case equals fixed costs plus half the value of Z. When we compare equation (12) to equation (12*), we can further analyze the standing charge.

There are several reasons why a firm may have a higher standing charge than its competitor. First of all, if a firm has a higher initial market share, the firm is likely to capture a larger part of industry profits, since customers do not switch immediately. Second, if a firm has higher fixed costs, it will partly pass on the difference to its customers. If customers value the connection with a firm or the reputation of that firm higher, this will be translated partly into the standing charge, which is a third reason for standing charge differences. Finally, if a firm has lower per unit costs, the utility surplus from consumption is higher, leaving room for more cream skimming through the standing charge.

3. The effect of vertical integration on access pricing

In this section we will determine the effect of vertical integration on the access fee. First, we analyze the behavior of an independent profit maximizing network firm, to learn more about the situation where there is no vertical integration of trade and transport. Then we adjust the model by combining the network firm with one of the retailers, thus creating a vertically integrated company.

The demand for network services can be derived directly from the demand for energy products. Since all energy has to be transported before it can be delivered, demand for transport equals total demand for energy:

$$x_0 = \sum_i s_i x_i = \sum_i s_i \frac{a - p_i}{b} \tag{13}$$

Since per unit prices are cost based, p_i in equation (13) can be substituted by $pc_i + \tau$. Defining transport costs per unit as tc_0 and ignoring fixed transport costs, we can write the profit function of the network firm as:

$$\pi_0 = (\tau - tc_0)x_0 = (\tau - tc_0)\sum_i s_i \frac{a - (\tau + pc_i)}{b} \tag{14}$$

Maximization of profits yields the first order condition for profit maximization. We solve this equation for the access fee in the appendix, finding:

$$\tau = \frac{tc_0}{2} + (a - pc_2) \Big/ 2\left(1 + \frac{(pc_2 - pc_1)^2}{3Zb}\right) - \frac{\left(b\left(Z\left(1 + s_{1,t-1}\right) + (f_2 - f_1) - (r_2 - r_1 + u_2^0 - u_1^0)\right) - \frac{pc_2{}^2 - pc_1{}^2 - 2a(pc_2 - pc_1)}{2}\right)(pc_1 - pc_2)}{2\left(3Zb + (pc_2 - pc_1)^2\right)} \tag{15}$$

This solution may look rather complicated, but it can be easily interpreted by assuming symmetry in costs. This assumption allows us to substitute $pc^* = pc_1 = pc_2$ into the equation and the obvious monopoly outcome is revealed.

$$\tau^* = \frac{a - pc^* + tc_0}{2} \tag{15*}$$

We can interpret the terms in equation (15) by comparing the equation to the simplified version in (15*). The first term, half the marginal transport costs, is the same in both equations. The second term is comparable and reflects standard monopolistic cream skimming. Half the surplus is skimmed in the symmetric case, whereas this portion is smaller in the non-symmetric case. This reflects the limitation to prune away the full half of the surplus of the firm with the largest surplus. The final term in equation (15) reflects the influence of both firms' marketshares on the weighing of surpluses. The net effect depends on all the factors in the equation. It is however obvious that

$$\frac{a-pc_i+tc_0}{2} \le \tau \le \frac{a-pc_j+tc_0}{2}$$

should hold for all $pc_i \ge pc_j$.

Our next step is to adjust the base model in such a way that it reflects a situation where trade and transport are vertically integrated. Let us suppose firm 1 is the vertically integrated network firm. We adjust firm 1's profit equation by adding the income from the access charge to it, to find a combination of equations (7) and (14)

$$\pi_1 = s_1(m_1 - f_1 + (p_1 - pc_1 - \tau)x_1) + (\tau - tc_0)(s_1x_1 + s_2x_2) \tag{16}$$

We can simplify this equation in the following manner

$$\pi_1 = s_1(m_1 - f_1 + (p_1 - pc_1 - tc_0)x_1) + (\tau - tc_0)s_2x_2 \tag{16'}$$

This small simplification reveals a quite important insight. Equation (16') shows that firm 1's costs are not affected by the access fee, but by transport costs only. The reason for this is of course that firm 1 collects exactly the access fee it pays, no matter how high (or low) the access fee is. As we have seen earlier, the per unit price equals the sum of the purchase price and transport costs, so $p_1 - pc_1 - tc_0 = 0$. As we show in the appendix, we may solve this model into the following semi-solution:[7]

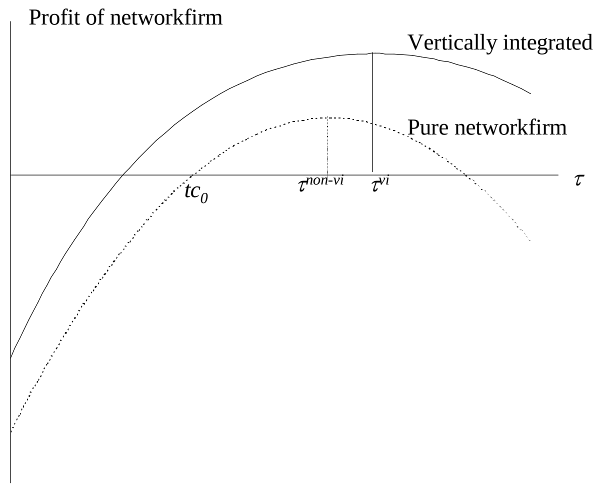
$$\tau = \frac{a-pc_2+tc_0}{2} + \frac{bZ}{2}\frac{s_1}{s_2}\frac{\partial s_1}{\partial \tau} \tag{17}$$

which is obviously larger than τ*, unless firm 1 is unable to make a profit from the standing charge. In that case, s_1 goes to zero, firm 1 specializes in network services and is no longer vertically integrated. Obviously, as firm 1 becomes a pure network firm, the access fee equals the access fee without vertical integration.

[7] The equation reflects a semi-solution, since it contains terms that depend on τ. For now, it is sufficient to know that these terms are positive.

The difference between equations (15*) and (17) may also be represented graphically. Figure 1 shows that the maximum profit of a vertically integrated network firm is reached at a higher level for the access fee than the optimal access charge of a pure network firm. The solid line represents the profit of a vertically integrated firm as a function of the access fee, whereas the dotted curve graphs this function for a pure network firm. The level of profits for the vertically integrated firm is higher for all levels of τ, since this firm also makes a profit out of sales.

Figure 1 *Optimal access fees for vertically integrated firm and pure network firm*



The suggestion in figure 1 holds if we assume that both firms have equal cost levels. If we relax this assumption, we can no longer use equation (15*), but we have to switch to equation (15). Let us demonstrate the case of non-symmetric costs by assuming that firm 2 has a cost advantage over firm 1, i.e. $pc_2 < pc_1$.[8] Numerical evaluations of equation (15) show that the effect on the profit maximizing access fee is small and ambiguous in the case without vertical integration.[9] For the vertically integrated firm, cost differences do change the profit maximizing access fee. If the other (non-network) firm has lower (higher) costs, the profit maximizing access fee will be higher (lower).

[8] Fixed cost advantages ($f_2 < f_1$) or utility advantages ($u_2^0 > u_1^0, r_2 > r_1$) yield similar results, as well as an advantage in initial marketshares ($s_{2,\,t-1} > s_{1,t-1}$).
[9] The sign of the effect depends on the anticipated market shares. If the lower cost firm has the higher anticipated market share, the access fee is lower than in the symmetric case and vice versa.

4. Double marginalization

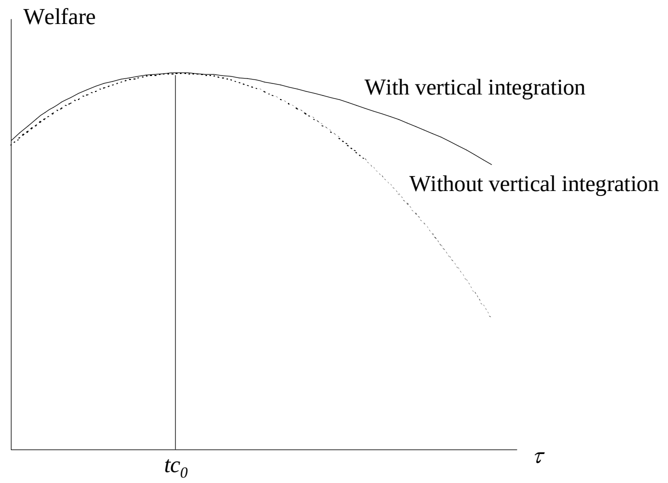
As we have seen earlier, the per unit price equals marginal costs of purchase plus marginal costs of transportation. If there is no vertical integration, $p_i = pc_i + \tau$ must hold for all firms. For the vertically integrated firm however, marginal costs of transportation are tc_0 instead of τ. This is comparable to the finding described above where vertically integrated firms refrain from double marginalization. Table 1 lists the per unit prices for different regimes by supplier.

Table 1 *Per unit prices for different regimes by supplier*

	Vertical integration	no vertical integration
p_1	pc_1+tc_0	$pc_1+\tau^{non\text{-}vi}$
p_2	$pc_2+\tau^{vi}$	$pc_2+\tau^{non\text{-}vi}$

The outcomes in table 1 suggest that, at any given level of τ, the average price is lower in the vertically integrated market, compared to the average price in the market without vertical integration, since τ should be larger than tc_0 in order to have positive profits for network services. It can be shown that, for symmetrical firms, this effect leads to a higher welfare for the vertically integrated market, as figure 2 shows.

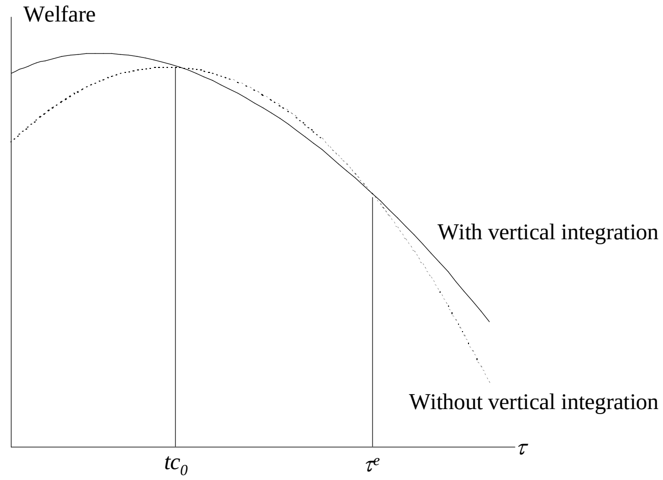
Figure 2 *Welfare level versus access fee for different regimes when firms are symmetric*



From the figure, it shows that at the welfare maximizing level of $\tau=tc_0$, there is no difference between regimes. However, as the access fee becomes higher, welfare declines faster in the market without vertical integration than in the market where a vertically integrated firm is active, because customers of the latter are not subject to double marginalization. The difference becomes larger at higher levels of τ, because the rising transport cost difference in the VI-case drives customers towards the vertically integrated firm.

The effect of the transport cost difference on market shares brings us to another point. If firms are totally symmetric, as we assumed in figure 2, this effect is beneficial to welfare. If on the other hand the vertically integrated firm has a higher cost level than its competitor, this effect implies a shift from a low cost supplier to a high cost supplier. This effect runs counter to the effect of double marginalization as described above. Figure 3 gives a graphical representation of this situation.

Figure 3 *Welfare level versus access fee for different regimes when the vertically integrated firm has higher costs*



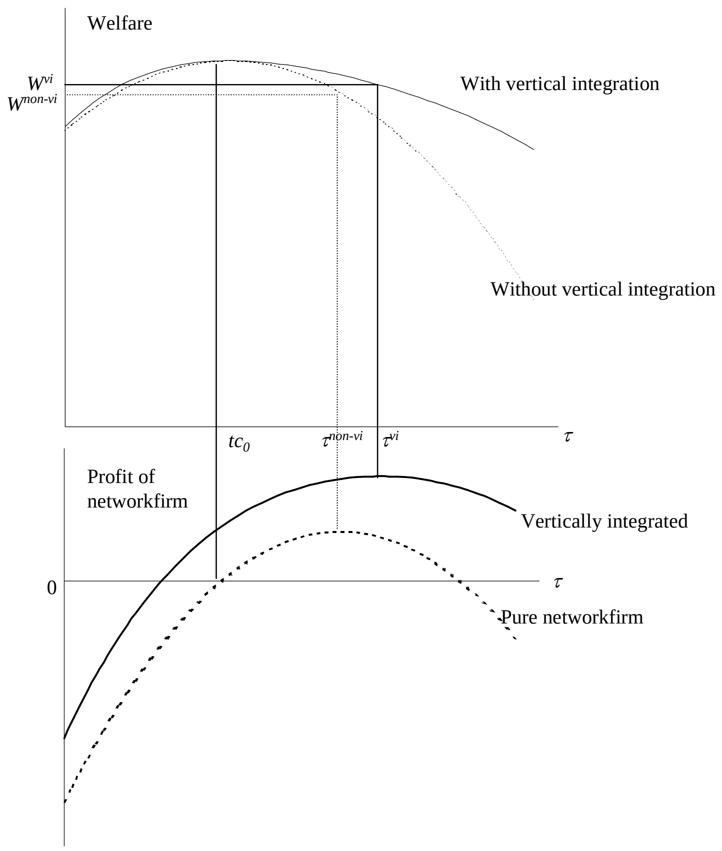
Like in figure 2, there is no difference between regimes at the welfare maximizing level of $\tau = tc_0$. In the case of figure 3, a rise of difference in transport costs ($\tau - tc_0$) incurs a shift of customers away from the low cost supplier, thus raising average costs of consumption. At the same time, consumers are shifted away from a supply chain with double marginalization. Both effects net out at the access fee value of τ^e.

5. The influence of vertical integration on welfare

In the previous sections we have established two main differences between markets that are vertically integrated and markets that are not. First, the vertically integrated network firm has an incentive to raise the access fee above the profit maximizing level of a pure network firm. The second difference is that the customers of the vertically integrated firm are not subject to double marginalization, whereas customers of other companies are. In this section, we will combine both differences and establish the effect of these combined differences on welfare.

Let us first turn to the case where firms are totally symmetric. To analyze the difference between the two types of markets, we combine figures 1 and 2 to deduct the welfare level that goes with the profit maximizing access fee. Figure 4 below shows the combination, linking the graphs through the profit maximizing access fee.

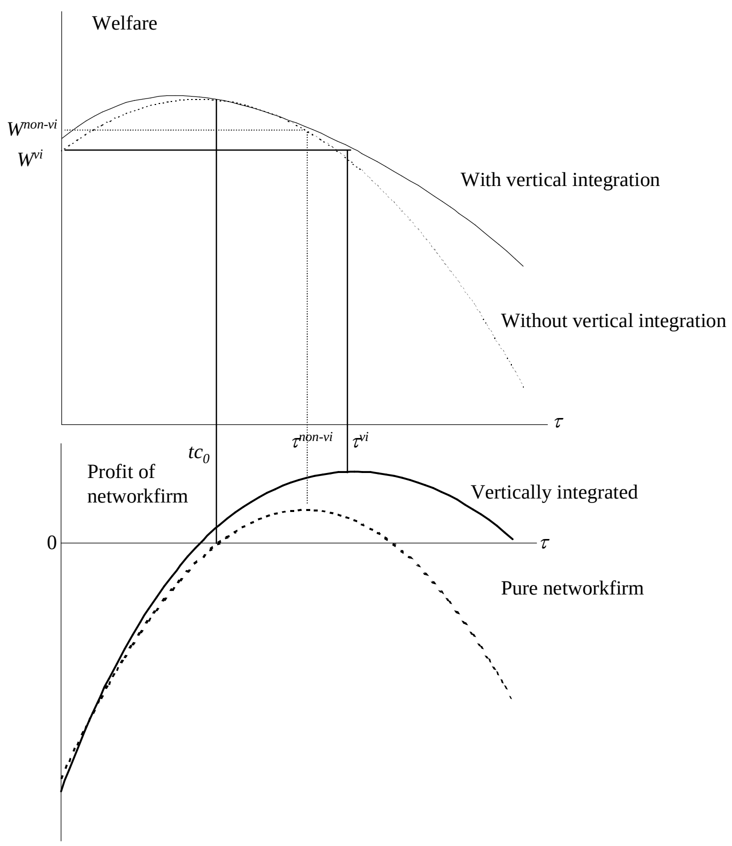
Figure 4 *Welfare level of regimes with symmetric firms*



The figure above suggests that welfare levels are higher if the market is vertically integrated. This finding is indeed true if both firms are fully symmetric, as we show in the appendix. If the assumption of symmetry is relaxed, the outcome becomes ambiguous. Again we analyze the non-symmetric case by assuming there are cost-differences. In footnote 8 we already mentioned that similar results are found for all types of cost differences, as well as for differences in utility.

As we showed earlier, vertical integration undermines the level playing field. Transport costs are lower for the vertically integrated firm than for the trader, rendering a competitive advantage to the vertically integrated network firm. As long as this firm is the low cost firm, this advantage enhances the positive effect on welfare we found for the symmetric case. If on the other hand the pure trader has a cost advantage, this is no longer the case. Figure 5 graphically illustrates how vertical integration may lower welfare despite the absence of double marginalization for the customers of the vertically integrated firm.

Figure 5 *Welfare level of regimes if the trader has a cost advantage*



It is illuminating to compare figure 5 to figure 4. As we can see, the welfare level of the vertically integrated market is still above that of the market without vertical integration for all levels of τ. Furthermore, for both regimes the profit maximizing access fee is comparable to the level found in figure 4. The main difference is the pace at which the welfare functions diverge. This pace is lower in the non-symmetric case, because the competitive advantage of the vertically integrated firm is counterbalanced by the cost advantage of the pure trader.

The outcome in figure 5 suggests that, if the cost advantage of the pure trader firm is sufficiently large, the effect of vertical integration on welfare is negative. In that case the unlevel playing field diverts consumers to the ‘wrong’ (i.e. more expensive producers) to such an extent that the advantage of the absence of double marginalization is surpassed. Therefore, we may conclude that vertical integration is beneficial to welfare in the short run in the case of symmetric firms and if the vertically integrated firm has a cost advantage, whereas it may be detrimental to short-term welfare if the pure trader has a cost advantage.

6. Discussion

In this section, we will focus on two subjects. First, we will briefly discuss our results in the context of a liberalizing energy market. Subsequently, we focus on promising points of interest for future research.

As we have seen in the previous section, the short-term effect of vertical integration on welfare is ambiguous and depends on which firm has a cost (or other) advantage. This finding may be matched to a general idea on how market openings lead to efficiency gains. The basis idea is that efficient firms enter into markets because they see possibilities of generating a profit in that market. As these efficient firms gain market share, the market gets more efficient on average and efficiency gains are realized. Possibly, the increase in competition may also urge the incumbent firm(s) to increase their efficiency, thus creating even more efficiency gains.

Based on the line of reasoning above, one would expect entrants to be more efficient (i.e. have a cost advantage) than incumbents. At the same time, a vertically integrated company is (almost by definition) an incumbent. This implies that vertical integration is likely to be detrimental to welfare in the case of a market that is opening up, as are energy markets nowadays. Furthermore, the competitive advantage of the vertically integrated incumbent may slow down or even deter entry, leading tom slower (if any) liberalization of energy markets. From this point of view, vertical integration does not seem to be the optimal market configuration for a market in transition. For the UK Monopolies and Mergers Commission (MMC) this type of argument was an important reason to vertically separate British Gas.

The analysis in this paper provides us with important insights in the effects of vertical integration on welfare. Further research may be pointed at a further understanding of the mechanisms behind this effect. This requires that we go beyond graphical and numerical illustrations and find the exact point where the effects of double marginalization and the excess access fee cancel out.

Apart from taking a mathematical step, as suggested above, we may also aim further research to introducing new aspects to the model. One of those aspects may be the regulator, who may try to limit certain prices in order to achieve maximal welfare. Another aspect that may be introduced into the model consists of several types of dynamics, such as endogenous entry and entry deterrence, long-term objectives of firms and network capacity planning. In relation to the latter, attention should also be devoted to strategic behavior with respect to congestion.

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Appendix

Profit maximizing access fee of an independent network firm

We start by deriving total demand. Total demand is defined as:

$$x_0 = s_1 \frac{a-(\tau + pc_1)}{b} + s_2 \frac{a-(\tau + pc_2)}{b} \tag{A1}$$

This may be reshuffled to isolate cost differences:

$$x_0 = \frac{a-\tau - pc_2}{b} - s_1 \frac{(pc_1 - pc_2)}{b} \tag{A2}$$

Next, we substitute the equation for firm 1's marketshare:

$$x_0 = \frac{a-\tau - pc_2}{b} - \left(\frac{2s_{1,t-1} + s_{2,t-1}}{3} + \frac{(f_2 - f_1) - (r_2 - r_1 + u_2^0 - u_1^0) - \frac{(a - pc_2 - \tau)^2 - (a - pc_1 - \tau)^2}{2b}}{3Z} \right) \frac{pc_1 - pc_2}{b} \tag{A3}$$

We rewrite to isolate τ:

$$x_0 = \tau\left(-\frac{1}{b} - \frac{(pc_2 - pc_1)^2}{3Zb^2}\right) + \frac{a - pc_2}{b}$$
$$-\left(\frac{2s_{1,t-1} + s_{2,t-1}}{3} + \frac{(f_2 - f_1) - (r_2 - r_1 + u_2^0 - u_1^0) - \dfrac{pc_2{}^2 - pc_1{}^2 - 2a(pc_2 - pc_1)}{2b}}{3Z}\right)\frac{pc_1 - pc_2}{b} \quad \text{(A4)}$$

Now we turn to the profits of the network firm:

$$\pi_0 = (\tau - tc_0)x_0 \quad \text{(A5)}$$

Maximization of profits yields the first order condition:

$$\frac{\partial \pi_0}{\partial \tau} = x_0 + (\tau - tc_0)\frac{\partial x_0}{\partial \tau} = 0 \quad \text{(A6)}$$

We derive the first derivative of demand and substitute this result and the definition of x_0 into (A6):

$$\frac{\partial \pi_0}{\partial \tau} = \tau\left(-\frac{1}{b} - \frac{(pc_2 - pc_1)^2}{3Zb^2}\right) + \frac{a - pc_2}{b}$$
$$-\left(\frac{2s_{1,t-1} + s_{2,t-1}}{3} + \frac{(f_2 - f_1) - (r_2 - r_1 + u_2^0 - u_1^0) - \dfrac{pc_2{}^2 - pc_1{}^2 - 2a(pc_2 - pc_1)}{2b}}{3Z}\right)\frac{pc_1 - pc_2}{b} \quad \text{(A7)}$$
$$+\left(\tau - tc_0\right)\left(-\frac{1}{b} - \frac{(pc_2 - pc_1)^2}{3Zb^2}\right) = 0$$

Again, we regroup terms in order to isolate the access fee:

$$\frac{\partial \pi_0}{\partial \tau} = 2\tau\left(-\frac{1}{b} - \frac{(pc_2 - pc_1)^2}{3Zb^2}\right) + \frac{a - pc_2}{b} - tc_0\left(-\frac{1}{b} - \frac{(pc_2 - pc_1)^2}{3Zb^2}\right)$$
$$-\left(\frac{2s_{1,t-1} + s_{2,t-1}}{3} + \frac{(f_2 - f_1) - (r_2 - r_1 + u_2^0 - u_1^0) - \dfrac{pc_2{}^2 - pc_1{}^2 - 2a(pc_2 - pc_1)}{2b}}{3Z}\right)\frac{pc_1 - pc_2}{b} = 0 \quad \text{(A8)}$$

Now we solve for τ, and simplify:

$$\tau = \frac{tc_0}{2} + (a - pc_2) \Big/ 2\left(1 + \frac{(pc_2 - pc_1)^2}{3Zb}\right)$$

$$- \frac{\left(b\left(Z(1+s_{1,t-1}) + (f_2 - f_1) - (r_2 - r_1 + u_2^0 - u_1^0)\right) - \frac{pc_2{}^2 - pc_1{}^2 - 2a(pc_2 - pc_1)}{2}\right)(pc_1 - pc_2)}{2\left(3Zb + (pc_2 - pc_1)^2\right)} \quad \text{(A9)}$$

Profit maximizing access fee of a vertically integrated network firm

Consider the profit function of the vertically integrated firm, as we defined in equation (16') of the main text:

$$\pi_1 = s_1(m_1 - f_1) + (\tau - tc_0)s_2 \frac{a - pc_2 - \tau}{b} \quad \text{(A10)}$$

Profit maximization yields two FOC's:

$$\frac{\partial \pi_1}{\partial \tau} = \frac{\partial s_1}{\partial \tau}(m_1 - f_1) - s_2 \frac{\tau - tc_0}{b} + \frac{\partial s_2}{\partial \tau}(\tau - tc_0)\frac{a - pc_2 - \tau}{b} + s_2 \frac{a - pc_2 - \tau}{b} = 0 \quad \text{(A11)}$$

$$\frac{\partial \pi_1}{\partial m_1} = s_1 + \frac{\partial s_1}{\partial m_1}(m_1 - f_1) + \frac{\partial s_2}{\partial m_1}(\tau - tc_0)\frac{a - pc_2 - \tau}{b} = 0 \quad \text{(A12)}$$

We rewrite (A11) to:

$$\tau = \frac{a - pc_2 + tc_0}{2} + \frac{b}{2s_2}\left(\frac{\partial s_1}{\partial \tau}(m_1 - f_1) + \frac{\partial s_2}{\partial \tau}(\tau - tc_0)\frac{a - pc_2 - \tau}{b}\right) \quad \text{(A13)}$$

Since $\frac{\partial s_2}{\partial \tau} = -\frac{\partial s_1}{\partial \tau}$, we may rewrite:

$$\tau = \frac{a - pc_2 + tc_0}{2} + \frac{b}{2s_2}\frac{\partial s_1}{\partial \tau}\left((m_1 - f_1) - (\tau - tc_0)\frac{a - pc_2 - \tau}{b}\right) \quad \text{(A14)}$$

Now we use the second foc (A12). We may use that $\frac{\partial s_2}{\partial m_1} = -\frac{\partial s_1}{\partial m_1} = \frac{1}{Z}$ to rewrite:

$$(f_1 - m_1) + (\tau - tc_0)\frac{a - pc_2 - \tau}{b} = -s_1 \Big/ \frac{\partial s_2}{\partial m_1} = -s_1 Z \quad \text{(A15)}$$

When we substitute (A15) into (A14), we find the semi-solution for τ, similar to equation (17) in the main text:

$$\tau = \frac{a - pc_2 + tc_0}{2} + \frac{bZ}{2}\frac{s_1}{s_2}\frac{\partial s_1}{\partial \tau} \qquad \text{(A16)}$$

Welfare levels if firms are fully symmetric

We make the simplifying assumption that there is no switching (e.g. infinite switching costs). In the symmetric case, half of the consumers pays no margin over transport costs, whereas the other half pays a higher margin than they would have in a market without vertical integration. Since all other things are symmetric, vertical integration has a positive effect on welfare if:

$$\tau^{vi} - \tau^* < \tau^* - tc_0 \qquad \text{(A17)}$$

Let us first substitute τ^* into the right hand term:

$$\tau^* - tc_0 = \frac{a - pc^* + tc_0}{2} - tc_0 = \frac{a - pc^* - tc_0}{2} \qquad \text{(A18)}$$

Substitution of $\frac{\partial s_1}{\partial \tau} = \frac{a - pc_2 - \tau}{bZ}$ into (A16) yields:

$$\tau^{vi} = \frac{a - pc_2 + tc_0}{2} + \frac{s_1}{s_2}\frac{a - pc_2 - \tau}{2} \qquad \text{(A19)}$$

Since we have assumed no switching and symmetry, market shares are equal

$$\tau^{vi} = \frac{2a - 2pc_2 + tc_0 - \tau^{vi}}{2} \qquad \text{(A20)}$$

or:

$$\tau^{vi} = \frac{2a - 2pc_2 + tc_0}{3} \qquad \text{(A21)}$$

Now the left hand side of the inequality we started with, can be completed:

$$\tau^{vi} - \tau^* = \frac{2a - 2pc^* + tc_0}{3} - \frac{a - pc^* + tc_0}{2} = \frac{a - pc^* - tc_0}{6} \qquad \text{(A22)}$$

which is obviously smaller than the right hand side (A21), implying that vertical integration has a positive effect on welfare under these assumptions. Next, we relax the assumption of no switching. Consumers will switch from the pure trader to the vertically integrated firm if the margin on transport is greater than their switching costs. The welfare loss of their switching costs is at least counterbalanced by the welfare gain of the raise in consumption caused by the lower price the consumers pay.