Exporting Collusion under Capacity Constraints: an Anti-Competitive Effect of Market Integration

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Exporting Collusion under Capacity Constraints: an Anti-Competitive Effect of Market Integration*

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Abstract

The paper examines the effects of interconnecting two (network) markets that previously were totally separated. In each market different capacity-constrained firms operate. Firms collude whenever it is rational for them to do so.

We identify the maximum sustainable price in each of the two separate markets, as a function of the number of firms in the market, and of the vector of capacities.

Interconnecting the two markets may bring about greater competition, but greater ability to collude as well. We establish conditions on the number of firms and on capacity constraints such that interconnection fosters collusion and decreases total welfare. In this case, the interconnection of two markets exports collusion, rather than exporting competition.

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1 Introduction

Market integration has been increasingly recognized as a source of welfare by economists as well as policy makers. The ongoing debate on interconnection in network industries stresses its benefits, in particular in terms of cost reduction - through exploitation of economies of scale - and of greater competition[1]. Our paper questions the validity of this conventional view, and finds conditions under which openness and interconnection harm competition, and generate a decrease in welfare.

Our results hinge on the fact that better interconnection - both through an increase of physical possibility of trading and/or an improvement of the compatibility between systems - may bring about greater competition, but greater collusion as well. This may happen when the productive capacity of competing firms is limited. In this case integration entails two countervailing effects. The first one is a pro-competitive effect, due to the fact that in the interconnected market a higher number of firms compete relative to each individual market; this effect has been very often emphasized in the trade literature. However, we have a second, pro-collusive effect, because after integration while deviating remains an option with limited appeal - as the maximum output of each firm is bound by the capacity constraint - colluding may be more appealing as total demand is higher and in a collusive equlibrium every firm may be able to produce a higher output. We find that pro-collusive elements may prevail over pro-competitive forces, and, as a consequence, market interconnection may decrease welfare.

The paper can be linked to different streams of literature.

In the international trade literature, the positive effect of market integration on competition is well known since the very beginning. The analysis of the same phenomenon with imperfect competition (see e.g. Markusen, 1981) has confirmed the pro-competitive effect of trade[2]. However no analysis of the effects of integration on collusion in the presence of capacity constraints has been carried out, and this is the goal of our paper.

The second stream of literature is the one on collusion and capacity con-

[1] Integration has been central in the European debate both in goods markets, where the Single European Act has tried to eliminate remaining barriers to trade, as well as in public utility sectors, where in particular telecommunications and energy markets have been tackled by several Directives. More recently, the Lisbon declaration points out how increasing the capacity of transporting electricity among EU member states represents a priority goal and a key to increasing competition and system security. Something similar holds in the transport sector, where building a system of Trans-European Transport Networks (TEN-T) is considered, among other things, "a key element for the creation of the Internal Market" both with reference to the goods transported through the system and to the competition among railway companies. The key words are interconnection (which refers to the elimination of bottlenecks, the physical constraints to the capacity of networks) and interoperability (the compatibility among networks). Quite clearly, increasing the physical capacity of passing from one network to the other is not of much use if the two networks are incompatible.

[2] Notice that the possibility that trade reduces welfare in one of the countries involved is well known in the literature (see e.g. a standard textbook such as Krugman and Obstfeld, 2004). This might happen for instance because of a demand effect which may raise a price. However, our main point is not that integration may reduce welfare, but that it might make competition less intense in the first place.

traints (in a *single* market). Brock and Scheinkman (1985) point out the role of aggregate capacity in determining the threat after a deviation. When aggregate capacity is sufficiently low, and no firm is essential in producing the competitive outcome, Bertrand equilibrium involves positive profit, as documented by Kreps and Scheinkman (1983). In such situations, the threat posed by deviating from the collusive equilibrium pattern becomes less effective, making collusion harder to achieve. For this reason, Brock and Scheinkman find that, for a fixed capacity per firm, changes in the number of firms have a non-monotone effect on the best enforceable cartel price.

Compte, Jenny, and Rey (2002), examine the impact of asymmetric capacity constraints on the sustainability of collusion, showing that asymmetry may hinder collusion, thus contributing to increase welfare. A similar result was obtained by Penard (1997). The relevance of capacity constraints in collusion is confirmed by Fabra (2006), who builds on Haltiwanger and Harrington (1991), to show that when capacity constraints are very tight collusion may be easier in periods of low demand.

The paper is organised as follows. The next section lays down a very simple example which illustrates the point. Section 3 illustrates the basic model and derives equilibrium prices with separated and integrated markets. Section 4 contains the result in general form, while the final section contains some concluding remarks.

2 A very simple example

We first start with an example. Consider two separate countries, each with the same linear demand function $Q = a - P$. All firms have zero marginal cost and can produce up to capacity $k = a$. Firms operate with an infinite time horizon and discount future profits at a factor $\delta \in (\frac{2}{3}, \frac{3}{4})$.

In the first country, a single firm operates, and it produces the monopoly output, $\frac{a}{2}$.

In the second country, there are two identical firms. These firms may form a cartel, and, by assumption, select the "best" (in the sense, the aggregate profit-maximizing) equilibrium pair (price and quantitiy) in a supergame supported by a Bertrand-Nash reversion trigger strategy.

The sustainability of the cartel in the second country requires the following individual rationality (IR) constraint to hold for each of the two firms:

$$\frac{p^* q_i(p^*)}{1-\delta} \geq kp^* \Longrightarrow \frac{q_i(p^*)}{1-\delta} \geq k = a \tag{1}$$

$$q_i \geq (1-\delta)\,k = (1-\delta)\,a \tag{2}$$

The IR constraint when firms are capacity constrained requires the profit from a small ($\varepsilon \to 0$) deviation from the cartel price (producing at full capacity, k)[3] to be smaller than the profit from remaining in the cartel and producing

[3] Notice that as there are two firms with capacity a, the deviating firms will face a credible threat of zero price from the following period onwards.

q_i. It differs from the IR constraint in a standard collusive supergame, in that capacity constraints in this case bind the deviation output, thereby limiting the deviation profit (at a level of kp^*). This determines an easing of collusion.

As $\delta \in (\frac{2}{3}, \frac{3}{4})$, the minimum *aggregate* sustainable output, $(1-\delta)\, 2a$ is higher than the monopoly output $\frac{a}{2}$ and lower than the competitive output a.[4] When firms produce this output level, market price is $p^* = a - (1-\delta)\, 3a = a\,(3\delta - 2)$ (below monopoly price for $\delta \in (\frac{2}{3}, \frac{3}{4})$). This price is the maximum one which firms can support in the supergame equilibrium; hence, this represents the aggregate profit maximizing equilibrium, on which firms coordinate.

Suppose now that, in order to strengthen competition, the two countries decide to remove all barriers separating their two markets, and create an integrated market. The new aggregate demand function is thus: $Q = 2\,(a - P)$. The three firms face an infinte horizon and collude whenever rational. The rationality constraint for the sustainability of the three-firms cartel is again given by (2):

$$q_i \geq (1-\delta)\, k = (1-\delta)\, a$$

The minimum aggregate sustainable output *in the integrated market* is then $(1-\delta)\, 3a$, which is lower than the monopoly output a given $\delta \in (\frac{2}{3}, \frac{3}{4})$. Therefore, in the interconnected market the monopoly output, and hence the monopoly price $p^{mon} = \frac{a}{2}$, can be sustained.[5]

The creation of an integrated market - far from bringing about more competition - has "exported" the monopoly outcome from the first market into the second one. Loosely speaking, the reason is that from the viewpoint of the country where two firms operate, the increase in market size due to integration is more important than the increase in total capacity due to the third firm, so that a higher price can now be sustained. More precisely, while the deviation output remains bounded because of capacity constraints, and does not depend much on the increase in market size, the collusion output does increase with market size. Thus collusion becomes more appealing.

How general is this result? Is it pathological, or should it raise a genuine concern in markets - such as electricity generation or railway transport - where capacity constraints are often binding in the equilibrium? We will show in the next sections conditions under which this result may be obtained, in order to try to understand how the interplay of market size, number of firms and capacity levels can determine such an outcome.

3 The model

A good is produced in two countries, labelled A and B. In country j a given number of firms[6] $N_j \geq 2$ operates (with $N_A + N_B = N$). The demand curve

[4] Notice that - as proved by Brock and Scheinkman (1985) - with capacity constraints the collusive price depends on capacity.

[5] It is easy to show that coordinating on a price higher than its monopoly level is not rational.

[6] Although in the example we have considered a market with one firm, here we prefer to avoid this extreme case, concentrating on cases where no firm is essential to cover demand.

for market $j = A, B$ at time t is[7] $Q_{j,t}(P_{j,t})$. The reservation prices in the two markets are identical; this is useful to avoid the possibility of multi-market price discrimination by a decision maker maximizing the combined profit in the two markets. If the good can be freely traded between the two markets (i.e., if they are perfectly interconnected), in each period the price is P_{ic} and total demand $Q_{ic} = Q_A + Q_B$ is $Q(P_{ic})$, and its inverse[8] is given by: $(Q_A + Q_B)^{-1}(P_{ic})$.

Firms are capacity constrained. All firms have the same capacity k[9]. Firm i produces output q_i at a constant marginal cost up to capacity and cannot produce beyond it.

$$C(q_i) = \begin{cases} cq_i \ if \ q_i \leq k \\ \infty \ if \ q_i > k \end{cases} \tag{3}$$

Competition takes place in prices over an infinite number of periods. If in any period rationing occurs, it follows the efficient rationing rule, proposed by Levitan and Shubik (1972). For ease of exposition, we assume throughout the paper that no firm is essential for producing the competitive output both in A and in B. That is,

$$(N_j - 1)k > Q_j(c) \tag{4}$$

This assumption, identified as the "non-essentiality condition", or NEC, ensures that no firm is essential for producing the competitive quantity. This is necessary for the Bertrand equilibrium price in the static game p^b to be set at $p^b = c$. Hence, under (4), Bertrand profit, and as a consequence the deviation profit, is null; this greatly simplifies computations (for a version of the paper when NEC assumption is relaxed, see Boffa, 2006).

We compare two different scenarios. In the first one, markets are separated, while in the second one A and B are interconnected into a single market, where price discrimination is ruled out by assumption. In each market (indices omitted), the flow of profit of each firm i starting at a given t_0 depends on a demand function $Q_t(p_t)$, on a constant marginal cost, normalized to be zero for all firms, on the vector of prices charged in all future periods, $p_i = [p_{i,t_0}, p_{i,t_0+1}, ..., p_{i,\infty}]$.

Firms adopt a standard Bertrand - Nash reversion trigger strategy. For each t, $p_{i,t} = p^c$ (where the superscript c stands for collusion) if for all firms $p^i_{t-1} = p^c$, where $i = 1, ..., N_j$ in the j market, and $i = 1, ..., N$ in the interconnected market. Otherwise, i.e. if $p_{i,t-1} < p^c$ for some i , $p_{i,t} = p^b$, which obviously represents a credible punishment.

3.1 Equilibrium analysis: separated markets

Let us now characterize equilibria in a oligopoly supergame when firms are capacity constrained. Capacity constraints k may limit the profit achievable by

As we will see later, and as the example above shows, this assumption does not affect our result.

[7] We will usually omit the time index t to keep the notation less cumbersome.

[8] The demand functions are decreasing and concave, and they satisfy the conditions that make consumer surplus an adequate welfare measure.

[9] This is a semplifying assumption adopted for ease of exposition. The main result of the paper obtains even dispensing of that assumption (see Boffa, 2006).

each firm in the collusive agreement, but especially they make deviation less attractive, as a firm cannot serve the whole market. Hence, they widen the set of discount factors for which a cartel is sustainable.

Moreover, unlike the case of collusion with unlimited capacity, when firms are small the feasibility of collusion does depend on the collusive price firms coordinate on. Hence, under capacity constraints, it may well happen that collusion at the monopoly price is not feasible, while a cartel coordinating at a lower price $p^b < p^c < p^{mon}$ is. To see this, consider that for p^c to be an equilibrium price, the following has to hold:

$$\frac{q_i^c\left(p^c - c\right)}{1-\delta} \geq \left(p_i^* - c\right)\left(\min k, q\left(p^*\right)\right) \tag{5}$$

Suppose that $p^c \leq p^{mon}$ and that and the collusive price is such that $k < \sum_i q_i^c(p^c)$. In this case, the optimal deviation output[10] will be $q_i = k$, and (5) can be written as

$$\frac{q_i^c\left(p^c\right)}{1-\delta} \geq k \tag{6}$$

This condition depends on the collusive price, and in particular it holds more easily when p^c is low and thus q_i^c is large. Let us study the features of equilibrium prices in greater depth.

Analogously to the standard unconstrained case, it remains true that, as long as firms have an aggregate capacity sufficient to supply the monopoly quantity, the collusive price cannot exceed monopoly price. Given that we maintain assumption (4), we prove the statement only for such set of values of k.

Proposition 1 *Under the NEC condition, $p^c > p^{mon}$ is never an aggregate profit maximizing equilibrium.*

Proof. We first prove that if $p^c = p' > p^{mon}$ is sustainable, then also $p^c = p^{mon}$ is sustainable.

$$\frac{q^c\left(p' - c\right)}{1-\delta} \geq \left(p^* - c\right)\left(\min k, q\left(p^*\right)\right) \tag{7}$$

Notice that we must have $p^* \geq p^{mon}$. Suppose not, i.e. assume $p^* < p^{mon}$. Then, i would profit from deviating to $p^* = p^{mon}$. From the deviation profit expression: $\pi_i^{dev} = \left(p^* - c\right)\min\left(k, q\left(p^*\right)\right)$. If $k \geq q^{mon}$, then $\pi_i^{dev} = \left(p^{mon} - c\right) q^{mon}$; if $q\left(p'\right) < k < q^{mon}$, then $\pi_i^{dev} = \left(p\left(k\right) - c\right) k$, and ; if $k \leq q\left(p'\right)$, then $\pi_i^{dev} = p\prime k$.

In the first two cases, replacing p' with p^{mon} increases the collusive profit more than it increases the deviation profit; in the third case, it increases the collusive profit as much as the deviation profit. In all three cases, if $p^c = p' > p^{mon}$ is sustainable, then also $p^c = p^{mon}$ is sustainable

[10] Notice that in this case we will have rationing, with k_i units sold at $p^c - \epsilon$ and others sold at p^c. This argument, which focusses on the incentive of firm i, does not depend on the rationing rule.

When both $p' > p^{mon}$ and p^{mon} are sustainable, then p^{mon} maximizes aggregate collusive profit.

Q.E.D. ■

We can now characterize the equilibrium price in the oligopoly supergame in market j, denoted as p_j^{SG}. This is illustrated in the following:

Proposition 2 *Under (4), the aggregate profit maximizing equilibrium price of the supergame is:*

$$p_j^{SG} = \begin{cases} p^{mon} & if \quad N_j \leq \frac{\max\left(\frac{Q_j^{mon}}{k},1\right)}{(1-\delta)} \\ p\left(N_j k\left(1-\delta\right)\right) \in \left(c, p^{mon}\right) & if \quad \frac{\max\left(\frac{Q_j^{mon}}{k},1\right)}{(1-\delta)} \leq N_j \leq \frac{\max\left(\frac{Q_j^{b}}{k},1\right)}{(1-\delta)k} \\ c & if \quad N_j \geq \frac{\max\left(\frac{Q_j^{b}}{k},1\right)}{(1-\delta)k} \end{cases} \tag{8}$$

The proof is provided in the appendix.

Some comments are in order. Starting from the bottom of (8), as usual a very high number of firms (relative to the discount factor) leads to a supergame equilibrium which is a mere repetition of static Bertrand outcomes.

As the number of competitors decreases, output decreases and equilibrium price increases until the monopoly level is reached. Firms will find it easier to sustain a *monopolistic* cartel when the following holds:

- the number of firms is sufficiently small, when capacity constraints do not matter, in that each individual firm is able to supply the monopoly output (as in the standard case of collusion);
- aggregate capacity is sufficiently low, when capacity constraints do not allow any individual firm to supply the monopolistic output.

Moreover, collusion arises at an *intermediate price* (between monopoly and competition) if and only if the three following conditions hold simultaneously:

- firms are relatively numerous (so that, had they unlimited capacity, they would not be able to sustain a cartel);
- capacity constraints are such that each individual firm cannot produce the competitive outcome - this condition is represented by $k < Q_j\left(p_j^b\right)$, which holds in (8), when $p^{mon} > p^{SG} > p^b$; [11]
- aggregate capacity is above discounted monopoly, but below the discounted competition level (otherwise, they would find it rational to produce the Bertrand output).

[11] If this condition did not hold, we would revert back to the standard case of no capacity constraints.

4 Integration and welfare reduction

Having discussed the equilibrium in an isolated market, we now turn to consider the effects of integrating the two markets. Our goal consists in showing that interconnection may, for certain values of the parameters, reduce welfare.

We begin by displaying the outcome of the dynamic game when the two markets are integrated. In this case, we only have one price, p_{ic}.

Under our usual assumption that condition (4) holds in both markets[12], the collusive price in the supergame played by N firms in the interconnected market is the following:[13]

$$p_{ic}^{SG} = \begin{cases} p^{mon} & if \;\; N \leq \frac{\max\left(\frac{(Q_A+Q_B)(p_{ic}^{mon})}{k},1\right)}{(1-\delta)} \\ p\left(Nk\left(1-\delta\right)\right) & if \; \frac{\max\left(\frac{(Q_A+Q_B)(p_{ic}^{mon})}{k},1\right)}{(1-\delta)} < N \leq \frac{\max\left(\frac{(Q_A+Q_B)\left(p_{ic}^{b}\right)}{k},1\right)}{(1-\delta)k} \\ c & if \; N > \frac{\max\left(\frac{(Q_A+Q_B)\left(p_{ic}^{b}\right)}{k},1\right)}{(1-\delta)} \end{cases} \tag{9}$$

As for the relationship between integrated (collusive) price and the (collusive) prices in the separated markets, we can establish the following result.

Proposition 3 *If the NEC condition (4) holds, $p_{ic}^{SG} \leq \max\left(p_A^{SG}, p_B^{SG}\right)$, i.e., the price in the interconnected market has to be lower or equal to the highest of the prices in the two nodes.*

The proof is reported in the appendix.

The proposition shows that we cannot have a price increase in both countries. However, this does not exclude the event that the price increases in one country, while remaining constant in the other one. We explore this occurrence in the next section.

Total surplus in market j is TS_j, the sum of consumer surplus CS_j and aggregate profit Π_j. Hence, total surplus is:

$$TS_A = \int_{v=p_j}^{p^{res}} Q_j\left(\nu\right)d\nu - cQ_j\left(P_j\right)$$

where p^{res} denotes the reservation price, and analogously in the B market. In the interconnected market,

$$TS_{ic} = \int_{v=p_{ic}}^{p^{res}} \left(Q_A+Q_B\right)\left(\nu\right)d\nu - c\left(Q_A+Q_B\right)P_{ic}$$

Interconnection lowers total welfare if and only if:

$$TS_A + TS_B > TS_{ic}$$

[12] So that in each market the only Bertrand-Nash equilibrium outcome has $p = c$.

[13] The proof of this statement would be a trivial replica of the proof of Proposition 2 and is thus omitted.

Let us now investigate under what conditions this may happen.

Remark 4 *As long as $p_A \neq p_B$, a sufficient condition for $TS_{ic} < TS_A + TS_B$ is that $p_{ic} \geq \max(p_B, p_A)$*

This is very intuitive, in that under this condition welfare is not increased in *either* market. Obviously, given Proposition 3, the only relevant case is the one where $p_{ic} = \max(p_B, p_A)$. However, could such a price be the outcome of integration?

In what follows, we provide sufficient conditions under which interconnection increases the price in one market, and does not decrease it in the other one. Export of collusion results from the interplay between collusive output and aggregate capacity. If the relationship were linear, collusive output in the integrated market would simply equal the sum of the collusive outputs in the non-integrated markets, and the price would be an average. However, the non-linearity broadens the set of possible outcomes, and makes it possible that price in the interconnected market equals the highest of the two prices.

Exporting collusion The ability to collude mainly depends on **two** counterveiling factors. First, it depends on the number of firms, which increases with interconnection. This makes collusion harder in the interconnected market, (pro-competitive effect), and tends to raise welfare.

Second, it depends on the relationship between aggregate capacity and the size of the market both with separation and with integration. Aggregate capacity determines the minimum output that can be sustained in the collusive agreement, when the capacity constraint is not allowing any single firm to produce by itself the monopoly output (possibly anti-competitive effect).

The reason why this happens may be grasped through the example provided in Section 2. Intuitively, interconnection is being exported from the market with the smallest number of firms to the integrated market. The following Proposition displays a set of sufficient conditions under which collusion is exported, hence welfare is reduced after the interconnection.

Proposition 5 *Suppose $p_A^c = p_A^{mon}$ and $p_B^c < p_B^{mon}$. A sufficient condition for interconnection to reduce overall welfare is :*

$$N \in \left(\frac{Q_A(c) + Q_B(c) + k}{k}; \frac{\max\left(\frac{(Q_A+Q_B)(p_{ic}^{mon})}{k}, 1\right)}{(1-\delta)} \right) \tag{10}$$

and there are always parameters configurations such that this interval is not empty.

Proof. For $p_A^c = p_A^{mon}$ we must have $\frac{Q(c)+k}{k} \leq N_A \leq \frac{\max\left(\frac{Q_A(p_A^{mon})}{k}, 1\right)}{(1-\delta)}$, while for p_B^c to be lower than monopoly price p_B^{mon} we must have $N_B >$

$\frac{\max\left(\frac{Q_B(p_B^{mon})}{k},1\right)}{(1-\delta)}$. If (10) is met, then $p_{ic}^c = p_{ic}^{mon}$, which by the previous Remark implies that interconnection has reduced welfare. The only thing to prove is that the set of parameters for which these prices are equilibrium prices is non-empty.

Assume $k < \min\left(Q_A^{mon}, Q_B^{mon}\right)$. It has to be $\frac{Q(c)+k}{k} \leq N_A \leq \frac{Q_A(p_A^{mon})}{k(1-\delta)}$ and $\frac{Q_B(p_B^{mon})}{k(1-\delta)} < N_B < \frac{Q_B\left(p_B^b\right)}{k(1-\delta)}$. For there to be a set of values for which the (10) holds true, one needs

$$\frac{Q\left(c\right)+k}{k} \leq \frac{Q_A^{mon}}{k\left(1-\delta\right)}$$

which becomes

$$k \leq \frac{Q_A^{mon}}{\left(1-\delta\right)} - Q\left(c\right)$$

which certainly holds for $p_A^c = p_A^{mon}$ to be true.

Q.E.D. ■

The implication of this result is that we always have a non empty set of parameters, such that if two markets are interconnected, firms may end up coordinating on the highest of the two previous prices. In this way, the high price country exports (very effective) collusion into the country where collusion was relatively less damaging.

To provide the intuition for this result, notice that the outcome of the game depends on the relationship between aggregate capacity and market size[14]. In this environment, there may exist situations in which the two isolated markets sustain different outcomes. In market A the number of firms is smaller, so that monopoly pricing emerges. Notice that it may be the case that a small increase in the number of firms operating in market A does not affect this outcome: in other words, even with (little) extra capacity, monopoly would prevail.

Market B has a larger number of firm, with too much available capacity to be able to sustain collusion at monopoly price. After integration, we may think of firms operating in the market B to split into two groups. One serves customers located in market B, and this group is composed by exactly the number of firms that allows the monopolistic outcome to prevail in this market. The other group serves customers in market A, thus providing this market with extra capacity, but not enough to thwart the emergence of the monopolistic outcome in the market A. We can view interconnection as a way to shift capacity from one group of customers to the other in order to "better" collude.

Obviously, the set of parameters which leads to this result may or may not be very large, but there always exist a set of values which makes this result possible.

[14] Notice that, given our assumption on symmetric capacity, heterogeneity in aggregate capacity is generated by changes in the number of firms.

5 Conclusions

While most of the established literature claims that market inteconnection leads to greater competition, our results suggests that it may instead foster collusion, leading to an overall welfare reduction.

Limits on capacity increase the collusive potential of a market, as, in a repeated game, they may bound the deviation profit. This happens precisely when the aggregate output produced in the cartel could not be produced by a single individual firm, since it exceeds its capacity. In such a situation, the collusive quantity is a (non-linear) function of aggregate capacity. When aggregate capacity is below a certain threshold, whose value depends on the demand function, then the cartel may be run as a monopoly; for values of aggregate capacity above the threshold, the collusive price decreases as aggregate capacity increases, until the price, for a sufficiently high level of aggregate capacity, equals the competitive one. From that level of aggregate capacity on, collusion is not feasible, and the prevailing price is the competitive one.

More rigorously, outcome in the supergame results from the interplay between collusive output, market demand, and aggregate capacity. If the relation were linear, collusive output in the integrated market would simply equal the sum of collusive output in the two disintegrated markets, and the price would be an average. However, the non-linearity broadens the set of possible outcomes; namely, it might occur that the price in the interconnected market simply equals the price in the highest of the two separate markets.

Although most of the analysis is carried out under the assumption of symmetric capacites, it is easy to see that nothing substantial would change, if we relaxed such an assumption introducing asymmetry among firms. The paper has focused on capacity constraints, and not on increasing cost functions for expositional simplicity. However, as increasing cost functions possess most of the qualitative properties of capacity constraints, most of the results hold even in the case of continuously increasing cost functions.

Moreover, notice that - as we were interested in stressing the general point - we have only provided sufficient conditions for welfare reduction (due to a diffusion of collusion after market integration). The fact that there is always a set of parameters which may satisfy such conditions is a striking feature of our result. One possible extension should take into account that our paper considers two extreme situations, total separation versus full integration, neglecting the intermediate scenario of partial integration, in which the maximum flow of goods from one node to the other is limited, yet positive. In that case, it could be possible to examine the interplay of productive capacity constraints and transmission capacity constraint which may lead to a similar result.

The findings may be regarded as quite surprising, since, in most of the ongoing policy debates, it is often taken for granted that the interconnection of different nodes - for example in the electricity or in the railways sectors - has beneficial competitive effects. The paper, on the contrary, calls for a case-by-case analysis of the competitive effects of integration. In particular, an evaluation of the market microstructures in the two relevant nodes may be necessary in order to evaluate the welfare impact of the interconnection.

References

[1] Boffa, F. (2006), Essays on Optimal Capacity and Optimal Regulation of Interconnection Infrastructures, Unpublished Ph.D. Thesis, Northwestern University

[2] Brock, W. and J. Scheinkman (1985), Price Setting Supergames with Capacity Constraints, *Review of Economic Studies*, 52, p.371-82.

[3] Compte, O., F. Jenny, and P. Rey (2002), Capacity Constraints, Mergers and Collusion, *European Economic Review*, 46, p.1-29.

[4] Fabra, N. (2006), Collusion with Capacity Constraints over the Business Cycle, *International Journal of Industrial Organization*, 24, p.69-81.

[5] Haltiwanger, J. and J. Harrington (1991), The Impact of Cyclical Demand Movements on Collusive Behavior, *Rand Journal of Economics*, 22, p.89-106.

[6] Kreps, D. and J. Scheinkman (1983), Quantity Precommitment and Bertrand Competition Yield Cournot Outcomes, *Bell Journal of Economics*, 14, p.326-337

[7] Krugman, P. and M. Obstfeld (2004), *International Economics: Theory and Policy*, Pearson-Addison-Wesley, London.

[8] Levitan, R. and M. Shubik (1972), Price Duopoly and Capacity Constraints, *International Economic Review*, 13, p.111-22.

[9] Markusen, J. (1981), Trade and the Gains from Trade with Imperfect Competition, *Journal of International Economics*, 11, p.531-51.

[10] Penard, T. (1997), Choix de Capacités et Comportement Stratégique: une Approche par la Théorie des Jeux Répetés, *Annales d'Economie et de Statistique*, 46, p.203-24.

6 Appendix

Proof of Proposition 2 A collusive agreement in market j is sustainable if and only if $\frac{q_{i,j}^c (p^c - c)}{(1-\delta)} \geq (p^c - c) \min(k, Q_n^c)$, i.e.

$$q_{i,j}^c \geq (1-\delta) \min(k, N_j q_i^c)$$

Assume first

$$\min(k, N_j q_i^c) = k \tag{11}$$

i.e., no firm has sufficient capacity to produce the whole collusive equilibrium output. Under this assumption, a collusive agreement requires

$$q_{i,j}^c \geq (1-\delta) k$$

and the aggregate profit maximizing equilibrium price is then:

$$p_j^{SG} \; if \; k < Q^c = \begin{cases} p_j^{mon} \; if \;\; (1-\delta) N_j k \leq Q_j^{mon} \; and \; k \leq Q_j^{mon} \\ p_j \left((1-\delta) N_j k \; \right) \; if \; Q_j^{mon} \leq (1-\delta) N_j k \leq Q_j^b \; and \; k \leq (1-\delta) N_j k \\ p_j^b = c \; if \; Q_j^b \leq (1-\delta) N_j k \; and \; k \leq (1-\delta) N_j k \end{cases} \tag{12}$$

Assume now

$$\min \left(k, N_j q_i^c\right) = N_j q_i^c \tag{13}$$

i.e, each individual firm has sufficient capacity to produce the entire collusive equilibrium outcome. In such case, we revert back to the standard IR constraint for collusion when firms have unlimited capacity, which entails:

$$p_j^{SG} \; if \;\; k \geq Q^c = \begin{cases} p_j^{mon} \geq p_j^c \geq p_j^b \; if \;\; \delta \geq \frac{N_j - 1}{N_j} \; and \; k \geq Q_j^c \\ p_j^b = c \; if \;\; \delta \leq \frac{N_j - 1}{N_j} \; and \; k \geq Q_j^b \end{cases} \tag{14}$$

Combining (12) and (14), one obtains the aggregate profit maximizing equilibrium of the supergame.We start by conditions under which a cartel coordinating on monopoly price can be sustained:

$$p_j^{SG} = p_j^{mon} \; if \;\; i \; OR \; ii \; OR \; iii \; holds : \begin{cases} i. \; N_j \leq \frac{1}{(1-\delta)} \; and \; k \leq Q_j^{mon} \; or \\ ii. \; N_j \leq \frac{Q_j^{mon}}{(1-\delta)k} \; and \; N_j \geq \frac{1}{(1-\delta)} \; or \\ iii. \; N_j \leq \frac{1}{(1-\delta)} \; and \; k \geq Q_j^{mon} \end{cases} \tag{15}$$

This may be rewritten as:

$$\begin{aligned} p_j^{SG} \;\; &= \;\; p_j^{mon} \; if \;\; i \; OR \; ii \; holds : \begin{cases} i. \; N_j \leq \frac{1}{(1-\delta)} \; or \\ ii. \; \frac{1}{(1-\delta)} \leq N_j \leq \frac{Q_j^{mon}}{(1-\delta)k} \end{cases} \\ p_j^{SG} \;\; &= \;\; p_j^{mon} \; if \;\;\; N_j \leq \frac{\max\left(\frac{Q_j^{mon}}{k}, 1\right)}{(1-\delta)} \end{aligned}$$

Now, by combining (12) and (14), we examine conditions under which an intermediate price between monopoly and competition emerges as the aggregate profit maximizing supergame equilibrium:

$$p_j^{SG} = p_j \left((1-\delta) N_j k \; \right) \;\; if \;\;\; \frac{Q_j^{mon}}{(1-\delta) k} \leq N_j \leq \frac{Q_j^b}{(1-\delta) k} \; and \; N_j \geq \frac{1}{(1-\delta)} \tag{16}$$

This may be rewritten as:

$$p_j^{SG} = p_j \left((1-\delta) N_j k \; \right) \;\; if \;\; \frac{\max\left(1, \frac{Q_j^{mon}}{k}\right)}{(1-\delta)} \leq N_j \leq \frac{\max\left(1, \frac{Q_j^b}{k}\right)}{(1-\delta) k}^{15} \tag{17}$$

[15] Notice that the collusion at an intermediate price with $\delta \geq \frac{N_j - 1}{N_j}$ and $k \geq Q_j^c$, in spite of being an equilibrium, is never part of an aggregate profit maximizing equilibrium. Indeed, when $\delta \geq \frac{N_j - 1}{N_j}$ and $k \geq Q_j^c$ firms can sustain a cartel at a monopoly price, and this maximizes their profit.

Finally, again by combining (12) and (14), we check under what conditions collusion cannot be sustained, and competitive price is prevailing:

$$p_j^{SG} = c \; if \; i. \; OR \; ii. \; holds : \begin{cases} i. \; \frac{Q_j^b}{k(1-\delta)} \leq N_j \; and \; \frac{1}{(1-\delta)} \leq N_j \; or \\ ii. \; N_j \geq \frac{1}{(1-\delta)} \; and \; \frac{1}{(1-\delta)} \geq N_j \end{cases} \tag{18}$$

Rewriting (18), we obtain:

$$p_j^{SG} = c \; if \; N_j \geq \frac{\max\left(\frac{Q_j^b}{k}, 1\right)}{(1-\delta)}$$

Q.E.D.

Proof of Proposition 3 Suppose not, i.e. that $p_{ic}^{SG} > \max\left(p_A^{SG}, p_B^{SG}\right)$. For that to be true, $p_{ic}^{SG} > p^b$, hence either $p_{ic}^{SG} = p_{ic}^{mon}$ or $p_{ic}^{mon} > p_{ic}^{SG} > p_{ic}^b$. Assume first $p_{ic}^{SG} = p_{ic}^{mon}$. Then, it has to be that $p_A^{SG}, p_B^{SG} < p_{ic}^{mon} = p_A^{mon} = p_B^{mon}$[16].

$p_A^{SG}, p_B^{SG} < p_{ic}^{mon} = p_A^{mon} = p_B^{mon}$requires:

$$N_j > \frac{\max\left(\frac{Q_j^{mon}}{k}, 1\right)}{(1-\delta)}, \; j = A, B \tag{19}$$

while $p_{ic}^{SG} = p_{ic}^{mon}$ requires

$$N \leq \frac{\max\left(\frac{(Q_A+Q_B)(p_{ic}^{mon})}{k}, 1\right)}{(1-\delta)} \tag{20}$$

By (19), it follows that $N = N_A + N_B > \frac{\max\left(\frac{Q_A^{mon}}{k}, 1\right)}{(1-\delta)} + \frac{\max\left(\frac{Q_B^{mon}}{k}, 1\right)}{(1-\delta)} \geq \frac{\max\left(\frac{(Q_A+Q_B)(p_{ic}^{mon})}{k}, 1\right)}{(1-\delta)}$, since $(Q_A + Q_B)\left(p_{ic}^{mon}\right) = Q_A^{mon} + Q_B^{mon}$, given the assumption on common reservation price across the two separate markets. Hence, $N > \frac{\max\left(\frac{(Q_A+Q_B)(p_{ic}^{mon})}{k}, 1\right)}{(1-\delta)}$, in contradiction with (20).

Assume now $p_{ic}^{mon} > p_{ic}^{SG} > p_{ic}^b$. The requirement that $p_{ic}^{SG} > \max\left(p_A^{SG}, p_B^{SG}\right)$ entails $p_{ic}^{SG} > \left(p_A^{SG}, p_B^{SG}\right)$.

$p_{ic}^{mon} > p_{ic}^{SG} > p_{ic}^b$ requires

$$p_{ic}^{SG} = p\left(Nk\left(1-\delta\right)\right) \; if \; \frac{\max\left(\frac{(Q_A+Q_B)(p_{ic}^{mon})}{k}, 1\right)}{(1-\delta)} < N \leq \frac{\max\left(\frac{(Q_A+Q_B)\left(p_{ic}^b\right)}{k}, 1\right)}{(1-\delta)\,k}$$

[16] Notice that, given our assumption on equal reservation prices in markets A and B (and as a consequence in the interconnected market), $p_A^{mon} = p_B^{mon} = p_{ic}^{mon}$

while $p_{ic}^{SG} > \left(p_A^{SG}, p_B^{SG}\right)$ requires

$$p_A^{SG} = \begin{cases} p\left(N_A k\left(1-\delta\right)\right) \ if \ \frac{\max\left(\frac{\left(Q_A^{mon}\right)}{k},1\right)}{(1-\delta)} \leq N_A \leq \frac{\max\left(\frac{\left(Q_A^{b}\right)}{k},1\right)}{(1-\delta)} \\ p_A^b \ if \ N_A \geq \frac{\max\left(\frac{\left(Q_A^{b}\right)}{k},1\right)}{(1-\delta)} \end{cases}$$

$$p_B^{SG} = \begin{cases} p\left(N_B k\left(1-\delta\right)\right) \ if \ \frac{\max\left(\frac{\left(Q_B^{mon}\right)}{k},1\right)}{(1-\delta)} \leq N_B \leq \frac{\max\left(\frac{\left(Q_B^{b}\right)}{k},1\right)}{(1-\delta)} \\ p_B^b \ if \ N_B \geq \frac{\max\left(\frac{\left(Q_B^{b}\right)}{k},1\right)}{(1-\delta)} \end{cases}$$

Assuming $\frac{\max\left(\frac{\left(Q_A^{mon}\right)}{k},1\right)}{(1-\delta)} \leq N_A \leq \frac{\max\left(\frac{\left(Q_A^{b}\right)}{k},1\right)}{(1-\delta)}$ and $\frac{\max\left(\frac{\left(Q_B^{mon}\right)}{k},1\right)}{(1-\delta)} \leq N_B \leq \frac{\max\left(\frac{\left(Q_B^{b}\right)}{k},1\right)}{(1-\delta)}$, then

$$q_{ic}^{SG} = \left(N_A + N_B\right) k\left(1-\delta\right) = q_A^{SG} + q_B^{SG} = N_A k\left(1-\delta\right) + N_B k\left(1-\delta\right)$$

Hence, if $p_A^{SG} = p_B^{SG}$, then $p_{ic}^{SG} = p_A^{SG} = p_B^{SG}$; if $p_A^{SG} \neq p_B^{SG}$, then p_{ic}^{SG} is at an intermediate level between p_A^{SG} and p_B^{SG}, so $p_{ic}^{SG} \leq \max\left\{p_A^{SG}; p_B^{SG}\right\}$. This is a contradiction with $p_{ic}^{SG} > \max\left\{p_A^{SG}; p_B^{SG}\right\}$. Assuming the supergame equilibrium entails the competitive outcome in one of the markets (say, without loss of generality, market A), then $N_A \geq \frac{\max\left(\frac{\left(Q_A^{b}\right)}{k},1\right)}{(1-\delta)}$, then

$$q_{ic}^{SG} = \left(N_A + N_B\right) k\left(1-\delta\right) \leq N_B k\left(1-\delta\right) + Q_A^b$$

In this case, one of the separate market (say, without loss of generality, A) has $p_A^{SG} = p_A^b = c$. Since $p_{ic}^{SG} > p_A^b$, then it has to be that $p_{ic}^{SG} < p_B^{SG}$. This is a contradiction with $p_{ic}^{SG} > \max\left\{p_A^{SG}; p_B^{SG}\right\}$. Q.E.D