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ABSTRACT

Economic Integration and Investment Incentives in Regulated Industries

The paper studies the impact of market integration on investment incentives in non-competitive industries. It distinguishes between investment in transportation and production cost-reducing technologies. Each domestic firm is controlled by a national regulator in a common market made of two countries. When public funds are costly, and production costs in the two countries are not very different, business stealing effect decreases welfare in both countries. Welfare increases in both countries when the difference in production costs is large enough. Market integration tends to increase the level of sustainable investment in cost-reducing technology compared to autarky. This is in contrast with the systematic underinvestment problem arising for transportation facilities. Free-riding reduces the incentives to invest in these public-good components, while business-stealing reduces the capacity for financing new investment.

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1 Introduction

The integration of market economies progresses unevenly across industries. In regulated markets, due to increasing returns to scale and the incumbency advantage, the main players of integrated markets are the top performers of the former national monopolies. For instance, in the European electricity market, economic liberalization has generated a wave of mergers and acquisitions so that two thirds of the European market is in the hands of eight large companies (Jamasp and Pollitt, 2005).¹ In theory, public intervention should mitigate the consequences of firms' market power and ensure that the efficiency gains generated by the reforms are passed along to consumers and taxpayers. However, market imperfections are harder to handle in an integrated market than in a closed economy because integration implies a loss of control for the national regulators. Economic integration removes barriers to trade so that the relevant market is regional, while regulation still acts nationally. In the absence of a legitimate supranational authority to regulate prices, production quantities or investment, competition among countries for the sector rents yields inefficiencies. The present paper addresses the problems posed by infrastructure investment in liberalized regulated markets. It first analyzes the welfare implications of an imperfect integration of regulated industries. It next studies how coordination problems between independent regulators affect supranational investments, such as interconnection facilities or infrastructures for the common market. Examples from the electricity sector illustrate the analysis.

World electricity demand is projected to double by year 2030. The total cumulative investment in power generation, transmission and distribution necessary to meet this rise in demand is estimated to be \$ 11.3 trillion (see International Electricity Agency, 2006). This amount covers investment in fast-growing developing countries, such as India and China. It also covers investments in OECD countries where ageing facilities need to be replaced and new facilities need to be built. Finally, it covers investments necessary to relieve the acute power penury experienced by some of the world's poorest nations, especially in Sub-Saharan Africa. The problem of how to finance the amount of capital

¹Moreover, among the EU-15, the top three European generation firms have 60% of the market in ten different countries (European Commission 2007, Energy Sector Enquiry). <http://ec.europa.eu/comm/competition/sectors/energy/inquiry/index.html>

required for these various investments is daunting. The deregulation and liberalization waves that swept throughout the world in the 1980s and the 1990s have eroded governments' ability to tax industry rents and to subsidize infrastructure deployment. In the logic of the reform, the private sector was to be the substitute provider of investment capital previously committed by public/regulated industry. However, in developing countries, private investment flows dried up after the collapse of Enron and the Asian financial crisis. In advanced economies, liberalized electricity markets that have not been accompanied by regulated capacity markets do not generate enough revenues to support investment in new generating capacity (see Joskow, 2006). Power capacity reserve margins are hence falling in all OECD countries, a signal of under investment.

In this context market integration may allow a better use of existing resources and infrastructures. Without cross-border trade, countries are obliged to rely on much more expensive sources of generation in order to respond to a growing demand. Cost complementarities constitute the engine of integration in the EU electricity market, in the Greater Mekong Subregion (GMS), in North, Central and South American electricity regional markets² and in Africa.³ Market integration may also allow the realization of projects that are not achievable by an isolated country. For instance less than a third of hydropower potential is currently exploited (mostly in advanced economies), because major hydroelectric-generation facilities are generally oversized for a single country. For West Africa, Sparrow et al. (2002) estimate between 5 and 20% the potential cost reduction associated with market integration (the estimation refers to the cost of expansion of the thermal and hydroelectric capacities).

Despite the potential benefits of market integration, sovereign countries focus on domestic welfare and tend to favor policy of energy independence. Most countries rely on public/mixed firms and regulation, to achieve these goals. Former national monopolies are generally under direct government control, while new entrants are not. In OECD countries, asymmetric regulation is hence the norm in electricity and telecommunication

²Central American nations, Guatemala, Nicaragua, El Salvador, Honduras, Panama, Costa Rica, have established a common regulatory body, the Regional Commission of Electricity Interconnection (CRIE).

³In Africa there are several power pool: South African power pool (SAPP), West African power pool (WAPP), Central African Power Pool (CAPP), East African Power Pool (EAPP) and interconnection initiatives in North Africa with ties to the Middle East.

markets (see Flacher and Jennequin, 2008).⁴

The paper shows that market integration has complex welfare implications in non-competitive industries controlled by national regulators. To be more specific, when the cost difference between two national champions is small, competition for market share is fierce. Prices decrease in both countries so that transfers rise. By eroding the rent extracted from the regulated sector, competition reduces the possibility of performing taxation via regulation. This is the case when the negative business-stealing effect outweighs the efficiency gains: welfare decreases in both regions following integration. By contrast, market integration is welfare-enhancing when the cost difference is large between the two regions. First, if the foreign firm is significantly less efficient than the national firm, the benefits from increased export profit (due to the possibility of serving also foreign demand) increase total welfare in the exporting country. Second, if the foreign firm is significantly more efficient than the national firm, the inefficient country can benefit from the reduction in price caused by competition, which enhances consumer welfare in the importing country. Even when the efficiency gains from integration are large enough so that both countries win from integration, opposition might still subsist internally. Indeed, market integration has redistributive effects. For instance, given small levels of opportunity cost for public funds, prices converge at some "average" of the closed-economy prices. Consumers in the formerly low-price region are thus worse off after integration.

The paper next studies investment incentives depending on the nature of the investment. Compared to autarky, market integration is shown to improve the incentives to invest in cost-reducing technology. First, when one country is much more efficient than the other, a case where integration is particularly appealing, the level of sustainable investment increases with market liberalization. Moreover, the incentives to invest in obsolete technology decrease, and the incentives to invest in efficient technology in-

⁴In Europe, the Commission promotes the formation of an integrated market. However, in markets that are not competitive, the European Union allows national regulators to control operators with significant market power. Governments and national regulators retain jurisdiction over specific choices, while respecting the overall framework designed by the Commission. United States and Canadian regulators impose asymmetric interconnection obligations on incumbent firms, which are also required to unbundle and share network components. For instance, during the California deregulation experiment (significantly revised after the crisis of 2001), a ceiling was imposed on the retail price that incumbent suppliers charged for electricity.

crease. Supranational competition, by stimulating investment in more efficient generation sources, hence reduces some of the inefficiencies arising in closed economies. Nevertheless, the global level of investment remains suboptimal because the country endowed with the low-cost technology does not fully internalize the foreign country consumers' surplus (i.e., it only internalizes sales). Second, when the two countries' technologies are not sufficiently differentiated, in the open economy the firms have to fight for their market shares. They might overinvest compared to the optimal solution.

By contrast, there is systematic under-investment in infrastructures that provide a public good, such as interconnection or transportation facilities. Free-riding behavior reduces the incentives to invest, and business stealing reduces the capacity of financing new investment, especially in the importing country. The problem is sometimes so severe that global investment decreases, compared to autarky. That is, when the two firms are not sufficiently differentiated in terms of productivity, the maximal level of investment in public-good facilities is not only suboptimal, but it is also *smaller* than under a closed economy. Business-stealing worsens the gap between the optimal investment level and the equilibrium one. Even when market enlargement increases the incentives to invest, which occurs when the two countries have significantly different productivity, the investment level remains suboptimal. The underinvestment problem has important policy implication. For instance, several programs supported by the World Bank in Bangladesh, Pakistan and Sri-Lanka have failed because of this problem. The Bank supported lending to generators through the Energy Fund, in the spirit of Public Private Partnerships. Investment in generation was made and the production of kilowatts rose. However, due to poor transmission and distribution infrastructures, the plants were kept well-below efficient production levels. On the one hand, power consumption stagnated because power was largely stuck at production sites. On the other hand, public subsidies to the industry rose because generation investment had been committed under take-or-pay Power Purchase Agreements (see Manibog and Wegner, 2003). In the end both consumers and taxpayers were worse off.

1.1 Relationship with the literature

Starting with the seminal paper of Brander and Spencer (1983), the literature on the interaction between regulation and market integration considers the strategic effect of trade subsidization policies.⁵ Subsidies have a rent-shifting effect that makes the domestic firm more aggressive in the common market. The increase in the national profits compensates for the value of subsidies. The strategic reaction of the rival government creates a prisoner's dilemma, with the consequence that countries stand to benefit from jointly reducing the subsidies. Brainard and Martimort (1996, 1997) show that the losses associated with the prisoner's dilemma can be mitigated in the case of asymmetric information, because competition reduces the agency costs of regulation. Combes, Caillaud, and Jullien (1997) add domestic production and national consumers to the analysis. In the absence of a budget constraint for the government, they show that market integration is always welfare-improving and subsidization desirable.⁶ By contrast, when public funds are costly, Collie (2000) shows that subsidization policies can lead to welfare losses, offering a theoretical argument for their prohibition.

Since it focuses on investment issues, the present paper also relates to the work of Haaland and Kind (2008), which looks at R&D subsidies for national firms competing in a third market. Haaland and Kind (2008) concentrate on the strategic motive for subsidies: governments could pay excessive subsidies in order to strengthen the position of the national firm in the common market. In a similar framework, Leahy and Neary (Forthcoming) find that subsidies could end up being too low, rather than excessive, if investment has positive spillovers (i.e. investment also increases the profits of the rival), and particularly if the social planner takes consumer welfare into account. Both papers follow the classical trade-policy approach in the sense that they concentrate on the strategic effect of unit subsidies when public funds are not costly. By contrast, the present paper analyzes the interaction between regulatory and investment policies in open economies. As in Leahy and Neary (Forthcoming), we distinguish between different types of investments with different impacts on a competitor's costs and profits (i.e., transporta-

⁵For more details about the strategic trade policy literature, see Brander (1997).

⁶As Neary (1994) shows, when public funds are costly and lump sum transfers not allowed, the optimal unit subsidy can be negative (i.e. an export tax), even in the case of quantity competition.

tion/interconnection infrastructures and generation technologies). The investments have to be financed either by consumers or by taxpayers. To find the right balance between the two, we take into account the opportunity cost of public funds. Taxation by regulation hence emerges when public funds are costly. The optimal regulated price is a Ramsey tariff. Unregulated competition can have the adverse effect of undermining the tax base (Armstrong and Sappington, 2005).⁷ Market integration erodes the possibility of conducting taxation via regulation because regulators do not control foreign firms. They can tax and subsidize domestic firms more easily, especially in case of public or mixed ownership.

Thus, the relevant setting is that of incomplete or asymmetric regulation: national regulators control only domestic firms. The literature includes Caillaud (1990), who studies a regulated market in which a dominant incumbent is exposed to competition from an unregulated, competitive fringe, operating under asymmetric information and cost correlation. He shows that competition has a positive effect on overall efficiency and helps to reduce the rent of the regulated firm. In Caillaud (1990), the competitive fringe prices at marginal cost. Biglaiser and Ma (1995) extend the analysis to the case where a dominant regulated firm is exposed to competition from a single strategic competitor. Allowing for horizontal and vertical differentiation, they find that competition helps to extract the information rent of the regulated firm, but allocative inefficiency arises in equilibrium. Both papers focus on new entry into a closed economy. More recently, Calzolari and Scarpa (Forthcoming) have studied (in a model with costless transfers) the optimal regulation of a firm that is a monopoly at home but competes abroad with a foreign firm. Since market integration is a process of reciprocal market opening, Biancini (2008) has extended the analysis to the case where the unregulated entrant is the incumbent of the foreign market, showing that differences in production technologies can be an engine of integration.

The present paper also considers the possibility of the national leader being challenged in its formerly protected national market and simultaneously trying to expand its activity

⁷As a consequence, taxation by regulation has to be replaced by other fiscal policies (e.g. targeted subsidies to the industry). These other policies do not come without a cost. Gasmi, Laffont, and Sharkey (1999, 2000) show that in considering the example of telecommunications cross subsidies remains a powerful tool for financing universal service under competition in developing countries.

in the foreign market. Integration is represented by a removal of barriers to trade, which leads to price convergence, while regulation is asymmetric (i.e., it remains national as in liberalized electricity markets). We show that integration has asymmetric effects on countries. For instance welfare can decrease in one country, while it increases in the other one. In general, the country with a more efficient technology (lower production costs) gains more from integration. This result is reminiscent of a result obtained by Ganuza and Hauk (2004) in the context of procurement. They study integration (i.e., the institution of a common legislation regulating procurement auctions) in the presence of corrupted bureaucrats. In their model, countries differ in the level of corruption and of productive efficiency. They show that integration generally reduces corruption and increases global welfare. However, if countries have the same productive efficiency, the less corrupted country could be a loser of the integration process. This negative effect on the less corrupted country can be offset by a difference in efficiency, increasing the set of parameters for which a union is possible.⁸

2 A model of market integration with regulated firms

We consider two symmetrical countries, identified by $i = 1, 2$. The inverse demand in each country is given by:

$$p_i = d - Q_i \tag{1}$$

Where Q_i is the home demand in country $i = 1, 2$. Before market integration, there is a monopoly in each country. In a closed economy, Q_i corresponds thus to q_i , the quantity produced by the national monopoly, also identified by $i \in \{1, 2\}$. When markets are integrated, Q_i can be produced by both firms 1 and 2 (i.e. $Q_i = q_{ii} + q_{ji}$, $i \neq j$, where q_{ij} , is the quantity sold by firm i in country j). Total demand in the integrated market is given by:

$$p = d - \frac{Q}{2} \tag{2}$$

where $Q = Q_1 + Q_2$ is the total demand in the integrated market, which can be satisfied by firm 1 or 2 (i.e. $Q = q_1 + q_2$).

⁸This happens in Ganuza and Hauk (2004) if the less efficient countries is also more corrupted.

On the production side, firm $i = 1, 2$ incurs a fixed cost K , which measures the economies of scale in the industry. The fixed cost K is sunk so that it does not play a role in the optimal production choices. The firm also incurs a variable cost function given by:

$$c(\theta_i, q_i) = \theta_i q_i + \gamma \frac{q_i^2}{2}. \quad (3)$$

Contrary to Biancini (2008), who focused on constant marginal cost, the variable cost function includes a linear and a convex (quadratic) term. The firms' linear cost parameter θ_i represents a production cost. The quadratic term, which is weighted by the parameter γ , is interpreted as a transportation cost. Indeed the cost function (3) can be generated from an horizontal differentiation model in which Firm 1 is located at the left extremity and Firm 2 at the right extremity of the unit interval. The final price is uniform and firms have to cover the transportation cost.⁹ For example, in the case of electricity, θ_i can be interpreted as a generation cost, constant after some fixed investment, K , has been done, while γ is a measure of transportation costs (i.e., transport charges and losses). The transportation costs are increasing with the distance.

In what follow we assume that γ and θ_i are common knowledge. Since γ is a common value, the regulator can implement some yardstick competition to learn freely its value in case of asymmetric information. By contrast if the regulator does not observe the independent cost parameter θ_i , some rent has to be abandoned to the producer in order to extract this information. The cost parameter then is replaced by the virtual cost (i.e., production cost plus information rent). Our results are unchanged except for the inflated cost parameter.¹⁰ For the sake of simplicity we focus on the symmetric information case. Any distortions occurring at the equilibrium can thus be ascribed to a coordination failure between the national regulators.

⁹That is, each consumer, who are uniformly distributed over $[0, 1]$, consumes one unit of the good if their constant valuation for it is higher than the price. Transportation cost associated with a consumer located at $q \in [0, 1]$ is γq for firm 1 and $\gamma(1 - q)$ for firm 2. The variable production cost of firm i with market share equal to q_i can then be written $c(\theta_i, q_i) = \int_0^{q_i} (\theta_i + \gamma q) dq$, or equivalently $c_i(q_i) = \theta_i q_i + \gamma \frac{q_i^2}{2}$ ($i = 1, 2$).

¹⁰Market integration can reduce the distortion related to the information rent and thus the virtual cost, for instance through yardstick competition (e.g., Caillaud (1990)). However, Calzolari and Scarpa (Forthcoming) and Biancini (2008) show that this is not always the case. International competition sometime increases the distortion related to asymmetric information.

The profit of firm $i = 1, 2$ is

$$\Pi_i = P(Q)q_i - \theta_i q_i - \gamma \frac{q_i^2}{2} - K - t_i \quad (4)$$

where t_i is the tax it pays to the government (it is a subsidy if it is negative). The participation constraint of the regulated firm is:

$$\Pi_i \geq 0 \quad (5)$$

The regulator of country i has jurisdiction over the national monopoly i . She regulates the firm and is allowed to transfer funds from and to it. In particular she taxes operating profits when they are positive. For simplicity, one can think of public ownership. Indeed in the case of electricity public and mixed firms are still key players in most countries. For instance Electricité de France (EDF), which is one of the largest exporter of electricity in the world, is owned at 87.3% by the French government. In 2007 the firm has paid more than EUR 2.4 billion in dividend to the government. However the paper assumptions are also consistent with the imposition of taxes on the rents made by private firms. For instance the outcry concerning the windfall gains to shareholders in the privatization of the UK electricity sector helped Tony Blair's Labour party regain power. It also led to the imposition of a special tax on the profit of the shareholders (see Birdsall and Nellis, 2003).¹¹ In contrast the regulator of country i does not control the production, the investment nor the profit of firm j (i.e. she does not size the rents, nor subsidize the loss, of firm j). Rents extraction does not apply to foreign firms because they do not report their profits locally. For instance between 1996 and 2000, 71% of foreign-based firms operating in the U.S. paid no U.S. income taxes (United States General Accounting Office, 2004). The assumption that firm j production and investment decisions escape regulator i control is consistent with the situation of asymmetric regulation prevailing in liberalized network industries.

¹¹Taxation by regulation, which is a substitute for direct taxation, has always existed in countries where regulated firms were private (mainly the USA). For instance a federal excise tax on local and long distance telephony US services was created in 1898. It has been repealed occasionally and re-enacted ever since. The tax's opponents argue that it is regressive and distortive, while its proponents insist on the need for revenues. It is hard to get around this argument: at a tax rate of 3% tax collection reached USD 5.185 billions in fiscal year 1999 (reported in budget of the United States Government, fiscal year 2000).

Each utilitarian regulator maximizes the home welfare, given by the surplus of national consumers plus the profit of the national firm minus the opportunity cost of public transfers. The welfare in country i is $W_i = S(Q_i) - P(Q) Q_i + \Pi_i + (1 + \lambda)t_i$, where the consumer surplus function is $S(Q_i) = \int_0^{Q_i} p_i(Q)dQ = dQ_i - \frac{Q_i^2}{2}$. Substituting $t_i = P(Q)q_i - \theta_i q_i - \gamma \frac{q_i^2}{2} - K - \Pi_i$ from (4) in the function W_i it is easy to check that W_i is decreasing in Π_i when $\lambda \geq 0$. Since leaving rents to the monopoly is socially costly, the regulator always binds the participation constraint of the national firm (5): $\Pi_i = 0$. The utilitarian welfare function in country $i = 1, 2$ is

$$W_i = S(Q_i) - P(Q) Q_i + (1 + \lambda)P(Q)q_i - (1 + \lambda)(\theta_i q_i + \gamma \frac{q_i^2}{2} + K) \quad (6)$$

Term $\lambda \geq 0$ can be interpreted as the shadow price of the government budget constraint. It captures the idea that public funds are raised through distortive taxation. Abandoning a positive subsidy to a regulated firm creates distortions in other sectors. Conversely, when the transfer is positive (i.e. taxes on profits), it helps to reduce distortive taxation or to finance investment. The assumption of costly public funds is a way of capturing the general equilibrium effects of sectoral intervention. We assume that both countries have the same cost of public funds λ .¹² In what follows, it is convenient to express the results in function of $\frac{\lambda}{1+\lambda}$. Let

$$\Lambda = \frac{\lambda}{1 + \lambda}. \quad (7)$$

It is straightforward to check that Λ increases with λ so that $\Lambda \in [0, 1]$ when $\lambda \in [0, +\infty)$. We first briefly study the benchmark case of a closed economy.

2.1 Closed Economy

In a closed economy, marked C , each regulator maximizes expected national welfare (6) with respect to the quantity subject to the autarky production condition $Q_i = q_i$. Solving this problem the optimal autarky quantity is:

¹²Studying the case of asymmetric λ s is possible in a fully linear model (i.e., see Biancini (2008)). However considering asymmetric λ s in a more general framework is challenging because both the equilibrium quantities and the welfare function are non linear functions of λ . Nevertheless some local results can be drawn: increasing the cost of public funds of one country generally increases the negative impact of business stealing and thus decreases its gains from trade. Conversely, the country with a relatively lower λ benefits more from market integration, which generally increases its willingness to invest.

$$q_i^C = \frac{d - \theta_i}{1 + \gamma + \Lambda} \quad (8)$$

We deduce that the autarky price is $P(q_i^C) = \theta_i + (\Lambda + \gamma) \frac{d - \theta_i}{1 + \gamma + \Lambda}$. When $\Lambda = 0$, public funds are costless and the price is equal to the marginal cost $P(q_i^C) = \theta_i + \gamma q_i^C$. When $\Lambda > 0$, the price is raised above the marginal cost with a rule which is inversely proportional to the elasticity of demand (Ramsey pricing): $P(q_i^C) = \theta_i + \gamma q_i^C + \Lambda \frac{P(q_i^C)}{\varepsilon}$. The optimal pricing rule diverges from marginal cost pricing proportionally to the opportunity cost of public fund Λ because the revenue of the regulated firm allows to decrease the level of other transfers in the economy (and thus distortive taxation).

3 Market integration

When barriers to trade are removed, firms can serve consumers in both countries. We first consider the solution that would be chosen by a global welfare maximizing social planner. This theoretical benchmark describes a process of integration in which the two countries are fully integrated, even fiscally.

3.1 The Global Optimum

The supranational utilitarian social planner has no national preferences. He maximizes the sum of welfare function (6), marked $W = W_1 + W_2$,

$$W = S(Q_1) + S(Q_2) + \lambda P(Q)Q - (1 + \lambda)(\theta_1 q_1 + \gamma \frac{q_1^2}{2} + \theta_2 q_2 + \gamma \frac{q_2^2}{2} + 2K) \quad (9)$$

with respect to quantities (Q_1, Q_2, q_1, q_2) , under the constraint that consumption $Q = Q_1 + Q_2$ equals production $q_1 + q_2$. This problem can be solved sequentially. First of all, the optimal consumption sharing rule between the two countries (Q_1, Q_2) is computed for any level of production Q . This amounts to maximize $S(Q_1) + S(Q_2)$ under the constraint that $Q_1 + Q_2 = Q$. Since $S(Q_i) = dQ_i - \frac{Q_i^2}{2}$ we deduce easily the next result.

Lemma 1 *Whatever (q_1, q_2) chosen at the production stage, at the consumption stage it is optimal to set $Q_1 = Q_2 = \frac{q_1 + q_2}{2}$.*

By virtue of Lemma 1 the supranational utilitarian objective function (9) becomes

$$W = 2S(\frac{q_1 + q_2}{2}) + \lambda P(q_1 + q_2)(q_1 + q_2) - (1 + \lambda)(\theta_1 q_1 + \gamma \frac{q_1^2}{2} + \theta_2 q_2 + \gamma \frac{q_2^2}{2} + 2K) \quad (10)$$

Let $\theta_{\min} = \min\{\theta_1, \theta_2\}$ and $\Delta = \theta_2 - \theta_1$ be the difference in cost parameters between producer 2 and producer 1. It can be positive or negative. Optimizing (10) with respect to the quantities q_1 and q_2 yields the following result.

Proposition 1 *The socially optimal quantity is:*

$$Q^* = \begin{cases} \frac{2}{1+\Lambda+2\gamma}(d - \theta_{\min}) & \text{produced by a monopoly if } |\Delta| > \Delta^*(\theta_{\min}) = \frac{2\gamma(d-\theta_{\min})}{1+2\gamma+\Lambda} \\ \frac{2}{1+\Lambda+\gamma} \left(d - \frac{\theta_1+\theta_2}{2}\right) & \text{produced by a duopoly otherwise.} \end{cases} \quad (11)$$

The quantity produced by firm $i = 1, 2$ at the duopoly solution is:

$$q_i^* = \frac{Q^*}{2} + \frac{\theta_j - \theta_i}{2\gamma} \quad \text{if } |\Delta| \leq \Delta^*(\theta_{\min}) \quad (12)$$

Proof. See Appendix 1. ■

When the cost difference between the two firms is large (i.e., when $|\Delta| > \Delta^*(\theta_{\min})$) the less efficient producer is shut down and the most efficient firm is in a monopoly position. This implies that when there is no transportation cost (i.e., $\gamma = 0$), the first best contract always prescribes to shut down the less efficient firm.¹³ However the “shut down” result is upset with the introduction of transportation cost. When γ is positive both firms produce whenever $|\Delta| \leq \Delta^*(\theta_{\min})$. The market share of firm $i = 1, 2$ is: $\frac{q_i^*}{Q^*} = \frac{1}{2} + \frac{\theta_j - \theta_i}{2\gamma Q^*}$. The most efficient firm (i.e., the firm with the cost parameter θ_{\min}) has a larger market share than its competitor. However, the market share differences decreases with γ .

The supranational social planner exploits the gains from trade to maximize the sum of national welfare. The common market welfare, $W^* = W_1^* + W_2^*$, is thus higher than the sum of the two closed economy welfare, $W^C = W_1^C + W_2^C$. Focusing on the interior solution, which arises when $|\Delta| \leq \Delta^*(\theta_{\min})$, the total welfare in the case of perfect economic integration W^* is obtained by substituting (11) in (10). Similarly, W_i^C is computed replacing (8) in (6) for $i \in \{1, 2\}$. Rearranging terms, one can check that the welfare gains from integration is:

$$W^* - W^C = \frac{\Delta^2}{4\gamma} \frac{1 + \Lambda}{1 + \gamma(1 - \Lambda)} \geq 0 \quad (13)$$

¹³This corresponds to the linear case studied by Biancini (2008).

The welfare gain in (13) is an increasing function of the cost difference $|\Delta|$. The higher the difference in the production cost the higher are the gains related to the reallocation of production in the common market. However when γ is large, expanding the production of the most efficient firm becomes costly. The gains from trade decrease with the transportation cost γ .

The solution chosen by a global welfare maximizing social planner corresponds to perfect integration. In practice, such fusion of regulatory bodies and fiscal systems is rarely achieved. The German reunification is an exception. The East and West German economic systems have been unified under the same government. Consistent with the theory, many firms have been shut down in the East. The reallocation of production towards more efficient units has been sustained by transfers from the West. However, in most cases, economic integration excludes fiscal and political institutions, which remain decentralized at the country level. Sovereign governments and regulators do not share profits and tariff revenues among themselves; taxpayers enjoy taxation by regulation insofar as the rents come from their national firms. The next section studies the non-cooperative outcome of economic integration given asymmetric regulation.

3.2 The Non Cooperative Equilibrium

In the open economy, marked O , there is a single price. Since the demand functions are symmetric this implies that the level of consumption is the same in the two countries: $Q_i = \frac{1}{2}Q^O$, $i = 1, 2$. By contrast the cost functions are different, which implies different level of production in the two countries. National regulators simultaneously fix the quantity produced by the national firm through the regulatory contract, q_i^O , maximizing expected national welfare (6). The system of reaction functions of the regulators determine the non cooperative equilibrium of the model.

Proposition 2 *The quantity produced at the non cooperative equilibrium of the open economy is:*

$$Q^O = \begin{cases} \frac{4}{3+4\gamma+\Lambda} (d - \theta_{\min}) & \text{by a monopoly if } |\Delta| > \Delta^O(\theta_{\min}) = \frac{2(1+2\gamma)(d-\theta_{\min})}{3+4\gamma+\Lambda}; \\ \frac{4}{2(1+\gamma)+\Lambda} (d - \frac{\theta_1+\theta_2}{2}) & \text{by a duopoly otherwise.} \end{cases} \quad (14)$$

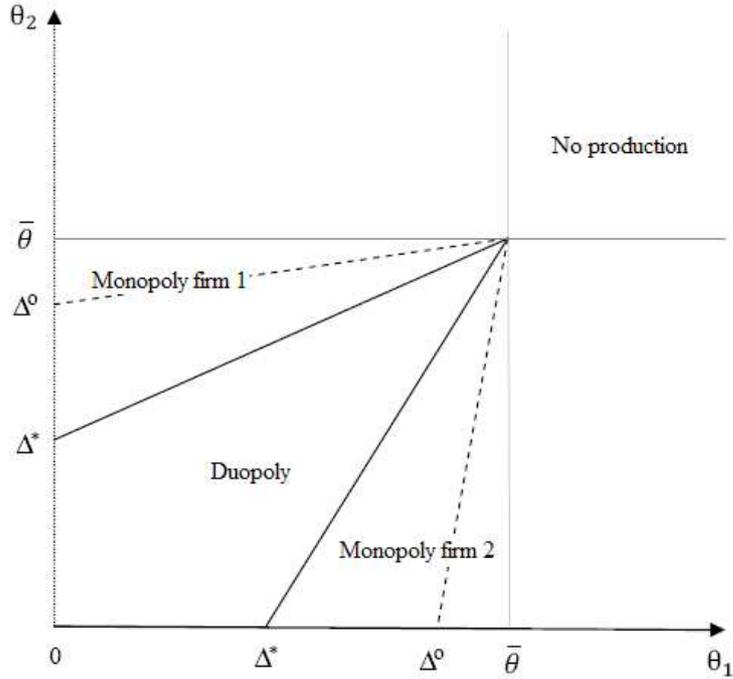
The quantity produced by firm $i = 1, 2$ at the duopoly solution is:

$$q_i^O = \frac{Q^O}{2} + \frac{\theta_j - \theta_i}{1 + 2\gamma} \quad \text{if } |\Delta| \leq \Delta^O(\theta_{\min}) \quad (15)$$

Proof. See Appendix 2. ■

When $|\Delta| > \Delta^O(\theta_{\min})$, the less efficient producer shuts down. The quantity in (14) is thus a function of the low cost parameter θ_{\min} . Comparing equations (14) and (11) the equilibrium solution implies the shut down of the less efficient firm *less often* than the socially optimal solution. That is, $\Delta^O(\theta_{\min}) \geq \Delta^*(\theta_{\min}) \forall \theta_{\min} \in [\underline{\theta}, \bar{\theta}]$. This result is illustrated Figure 2. The dotted lines represent the equilibrium shut down threshold of the less efficient firm in the integrated market with independent regulators. The solid lines represent the optimal threshold.¹⁴

Figure 1: Shut down threshold of the less efficient firm. Solid line: optimal threshold, Dotted line: non-cooperative equilibrium.



Comparing the quantities produced in the common market with the quantities produced in a closed economy, it is straightforward to check that Q^O defined equation (14)

¹⁴The figure is plotted for $d = 1$, $\lambda = 0.3$, $\gamma = 0.5$, $\theta_i \in [0, 1]$ with $\Delta^* = \Delta^*(0)$ and $\Delta^O = \Delta^O(0)$. The same shape is obtained for any support such as $\bar{\theta} - \underline{\theta} > \frac{2\gamma(d - \theta_{\min})}{1 + 2\gamma + \lambda}$.

is always larger than $Q^C = q_1^C + q_2^C$ defined equation (8). The fact that the total quantity increases under market integration does not necessarily imply a welfare improvement. Indeed when $|\Delta| \leq \Delta^*(\theta_{\min})$, it is easy to check that $Q^C = Q^*$ defined equation (11). We deduce that excessive production occurs in the common market. To be more specific let compare the production of firm $i = 1, 2$ in the common market with its production under closed economy. Substituting Q^O from equation (14) in equation (15) and comparing it with equation (8), yields:

$$q_i^O > q_i^C \quad \Leftrightarrow \quad \theta_j - \theta_i \geq -\frac{\Lambda(d - \theta_i)(1 + \gamma)}{(1 + \gamma + \Lambda)^2} \quad j \neq i \quad i = 1, 2 \quad (16)$$

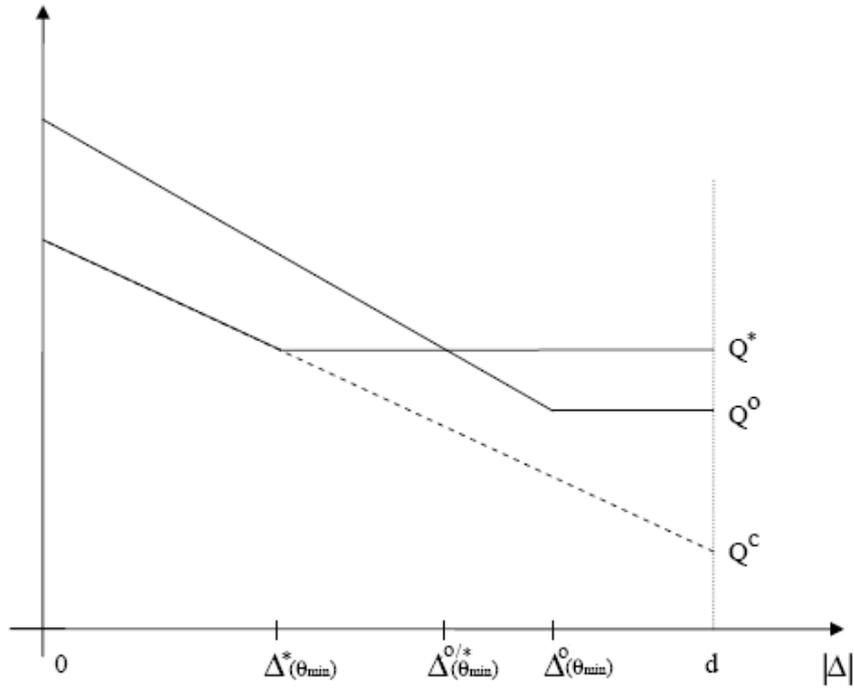
When $\Lambda = 0$, the quantity produced by the national firm is increased with respect to the quantity produced in a closed economy if and only if the foreign firm is less efficient (i.e., if $\theta_j - \theta_i > 0$). In this case, the foreign monopoly leaves some space to the more efficient competitor and consumers enjoy larger surplus. By contrast when $\Lambda > 0$ the regulator might choose to expand the national quantity with respect to the quantity produced in a closed economy even if the competitor is slightly more efficient. The reason is that competition decreases the net profits of the national firm without generating drastic increase in consumers surplus. In a closed economy, the regulator chooses a small quantity to enjoy high Ramsey margin. However, in the open economy, the Ramsey margin is eroded by competition and producing such a small quantity is no longer optimal. It only reduces the market share of the domestic firm. In his attempt to mitigate the business stealing effect the regulator increases the quantity of the domestic firm.

Comparing Q^O and Q^* hence yields

$$Q^O \geq Q^* \quad \Leftrightarrow \quad |\Delta| \leq \Delta^{O/*}(\theta_{\min}) = \frac{(2\gamma + \Lambda)(d - \theta_{\min})}{1 + 2\gamma + \Lambda}. \quad (17)$$

When $|\Delta|$ is smaller than $\Delta^{O/*}(\theta_{\min})$, the business stealing effect is strong. Regulators fight to maintain their market shares by boosting domestic production. Aggregate quantities are then larger in the common market than at the optimum. Symmetrically, when $|\Delta|$ is large the regulator of the most efficient country controls a large market share (the firm even becomes a monopolist in the common market when $|\Delta| > \Delta^O(\theta_{\min})$). The problem is that she does not internalize the welfare of foreign consumers. She chooses a suboptimal production level, $Q^O < Q^*$, whenever $|\Delta| > \Delta^{O/*}(\theta_{\min})$. Figure 2 illustrates

Figure 2: Total Quantities Q^* , Q^O and Q^C in function of $|\Delta|$



the results. It represents for a given θ_{\min} the quantity levels Q^* , Q^O and Q^C in function of $|\Delta| \in [0, d]$. The flat sections correspond to the shut down of the less efficient producer.

3.3 Welfare analysis of market integration

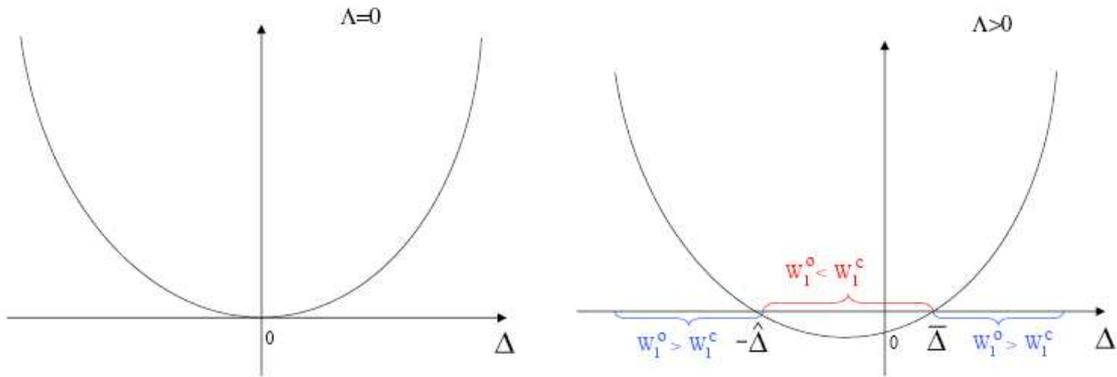
Replacing the optimal quantities in the welfare function, we compute the effect of market integration on welfare.

Proposition 3 *For $\Lambda = 0$, market integration increases welfare in both countries. For any Λ strictly positive, market integration increases welfare in both countries if and only if the difference in the marginal costs $|\Delta|$ is large enough.*

Proof. See Appendix 3. ■

Figure 3 illustrates Proposition 3. It shows the welfare gains of country 1 for $\Lambda = 0$ and $\Lambda > 0$ respectively. When $\Lambda = 0$, taxation by regulation is not an issue and an increase in $|\Delta|$ increases the welfare gains identically in the low cost and high cost country. The less efficient country enjoys lower price while the more efficient country enjoys higher profits. Business stealing creates no loss because it is compensated by an increase in consumer surplus in the country with a smaller market share. However, the equilibrium quantities (14) do not correspond with the optimal levels (11): not all gains from trade are exploited. When $\Lambda > 0$, the intercept, corresponding to $\Delta = 0$, is negative, which means that if $\theta_1 = \theta_2$ both countries lose from integration. To fight business stealing both countries increase their quantities. Price is decreased below the optimal monopoly Ramsey level and taxation by regulation decreases. Yet competition does not increase efficiency because the firms have the same cost. The net welfare impact is negative for both countries. The welfare-degradation result of integration established for linear costs (see for instance Biancini (2008)) is hence robust to the introduction of transportation costs (i.e., to $\gamma > 0$). For $\Delta \neq 0$ the welfare gains of the two countries are asymmetric. For the most efficient country the gains are strictly increasing. For the less efficient country they are U-shaped. The welfare gains are first decreasing and then increasing. For $|\Delta|$ big enough, the welfare gains are positive in both countries.

Figure 3: Welfare gains from integration, $W_1^O - W_1^C$



Remark that $\hat{\Delta} \geq \bar{\Delta}$. It is clear that for Δ belonging to the interval $[-\bar{\Delta}, \bar{\Delta}]$, market integration achieved by two independent jurisdictions is inefficient. Each country welfare

is decreased by integration.¹⁵ The region as a whole is better off with the co-existence of two closed economies. The negative welfare effect arises because of the market share rivalry between the two countries. It is thus related to the literature on trade and competition (starting from Brander and Spencer, 1983). In the case of trade policy sustained by export subsidies, the result arises because of a prisoner dilemma between governments. Both countries would be better off if trade subsidies were forbidden. Here, the result depends on the negative public finance effect of competition.

For value of $|\Delta| \in [\bar{\Delta}, \hat{\Delta}]$ the most efficient country wins while the less efficient country loses. If one region loses while the other one wins, there will be resistance to integration. By contrast welfare is increased in both countries for values of Δ smaller than $-\hat{\Delta}$ and larger than $\hat{\Delta}$. In other words, the theory predicts that integration will be easier when the costs difference between the national champions is large.

In addition to the global welfare impact, the creation of an integrated market with common price $P(Q^O)$ has redistributive effects. Indeed substituting Q^O from equation (14) in the inverse demand function yields the equilibrium price $P(Q^O) = \frac{d(\frac{\Lambda}{2} + \gamma) + \frac{\theta_1 + \theta_2}{2}}{1 + \gamma + \frac{\Lambda}{2}}$ if $|\Delta| \leq \Delta^O(\theta_{\min})$. Comparing this price with the price in the closed economy, $P(q_i^c) = \theta_i + (\Lambda + \gamma) \frac{d - \theta_i}{1 + \gamma + \Lambda}$, one can check that market integration induces a price reduction in country $i = 1, 2$ if and only if the costs difference is not too large. That is,

$$P(Q^O) \leq P(q_i^c) \quad \Leftrightarrow \quad \theta_j - \theta_i \leq \frac{\Lambda(d - \theta_i)}{1 + \gamma + \Lambda} \quad j \neq i \quad i = 1, 2 \quad (18)$$

Price convergence is usually considered positively, because it is a sign of effective market integration. However, for some countries it can imply that prices are higher after integration than in the closed economy. Indeed equation (18) shows that if $|\Delta| > \frac{\Lambda(d - \theta_{\min})}{1 + \gamma + \Lambda}$ then the price decreases in the less efficient region and *increases* in the more efficient one.¹⁶ Consumers of the relatively efficient region are then worse off after integration. This can be a source of social discontent and opposition towards market opening. For instance the integration of electricity markets is advanced between France and neighbor countries

¹⁵The negative effect of business stealing on welfare, is not related to the assumption of a limited competition (i.e., duopoly) in the integrated market. Increasing the number of unregulated competitors would only worsen this effect.

¹⁶For instance when $\Lambda = 0$ the price in the integrated market is equal to the average marginal cost. Since the average marginal cost is the average of the prices in the two closed economies, the price increases in the more efficient country and decreases in the less efficient one.

(Italy, Spain, United Kingdom). The difference between generation costs is the engine of integration. Countries with high costs (Italy, Spain, UK) benefit from low prices, while the country at low cost (France) benefits from new profit opportunities. Consistently with the theory empirical evidence shows prices rise in domestic electricity market of EU exporting countries, such as France. The interests of the national firm/taxpayers are conflicting with the interests of the domestic consumers. Market integration increases the profit opportunities of the efficient firm, by increasing the number of potential consumers. If the government is able to extract a fair share of these new market rents, it can use this to finance new investments or cross subsidize for the benefit of taxpayers. If the government is unable to size the firm's rents, both domestic taxpayers and consumers are worse off (shareholders are the only winner).¹⁷

By contrast if the firms are not drastically different (i.e., if $|\Delta| \leq \frac{\Lambda(d-\theta_{\min})}{1+\gamma+\Lambda}$) prices decrease in *both* countries because of the business stealing effect. Benevolent regulators are willing to increase their transfers to the national firm to sustain low prices so that taxation by regulation decreases. This result is consistent with Laffont and Tirole (2000) claim that pro-competitive reforms in telecommunications may have had the effect of increasing the total transfers paid to the industry. The negative fiscal effect is a major concern in developing countries where tariffs play an important role in raising funds (see Laffont, 2005 and Auriol and Picard, 2008). When public funds are scarce and other sources of taxation are distortive or limited, market integration, which has a negative impact on taxpayers and on the industry ability to finance new investments, induces welfare losses.

4 Investment

One of the aims of market integration is to increase the incentives to invest by creating a larger and more efficient market in regulated industries. However, it is not clear that the model of integration with asymmetric regulation favored by many regions in the world, including the European and the African Union, provides an adequate framework

¹⁷France is the world's largest net exporter of electricity due to its low cost of nuclear generation. It gains over EUR 3 billion per year from this trade. The French, government which is the main shareholder of EDF, manages to reap a fair share of its profit each year (more than EUR 2 billion in 2007). The French electricity market is extensively discussed and documented in Finon and Glachant (2008).

for investment incentives. Unless the costs difference between two regions is large, market integration can decrease the aggregate capacity of financing new investment. This is a major concern in electricity because demand is on the rise everywhere, and in many regions aging generation and transportation facilities need urgently to be upgraded and expanded. Moreover, specific investment, such as transportation and interconnection facilities, are required to achieve market integration in emerging markets. For instance in Sub-Saharan Africa it is estimated that some 26 GW of interconnectors, for a cost of \$ 500 million per year, are lacking for the creation of a regional power-trading market (Rosnes and Vennemo, 2008). Similarly the vast hydropower potential of the continent is unexploited because of the lack of investment.¹⁸

This section studies the incentive to invest of national firms subjected to asymmetric regulation. Our analysis focuses on two types of investment. The first type decreases the transportation cost γ . We refer to this kind of investment as “transportation cost reducing” or “ γ -reducing” investment. In the integrated market the competitor of the investing firm also benefit from the cost reduction. One can think of investment in transmission, interconnection, or interoperability facilities. The second type of investment reduces the production cost of the investing firm. It is referred to as “production cost reducing” or “ θ -reducing” investment. This kind of investment only benefits the national producer and makes it more aggressive in the common market. In both cases the analysis focuses on interior solution. Costs difference is assumed to be small enough so that the production of the two firms is positive in the common market. As illustrated by the analysis of market integration in Section 3 this assumption is not crucial for the results.¹⁹ However it simplifies their exposition.

4.1 Transportation Cost Reducing Investment

We assume that country $i = 1, 2$ can reduce the collective transportation cost from γ to $t\gamma$ with $t \in (0, 1)$ by investing a fixed amount $I_\gamma > 0$. Since γ -reducing investment increases the efficiency of all firms, it has a public good nature. Examples are high tension transportation power lines and cross border interconnection facilities. To rule out corner

¹⁸The annualized investment costs required to simply maintain current access rate in SSA (less than 30% of the population) in 2015 are estimated to be around 5 percent of the region GDP.

¹⁹They are preserved when shut down cases are considered (computations are available on request).

solution (i.e., shut down cases) we make the following assumption.

$$\mathbf{A1} \quad |\Delta| \leq \Delta_i^*(\theta_{\min}) = \frac{2t\gamma(d-\theta_{\min})}{1+2t\gamma+\Lambda}.$$

Assumption A1 intuitively requires that the difference in firms cost is not too large. We first consider the level of investment induced by the global welfare maximizer of Section 3.1. Let $q_i^{*I_\gamma}$ be the quantity produced by firm $i = 1, 2$ in the case of investment. The optimal quantities are obtained by substituting $t\gamma$ in equations (11) and (12). The gross utilitarian welfare in the case of investment is the welfare function defined equation (10) evaluated at the actualized quantities: $W^{*I_\gamma} = W(q_1^{*I_\gamma}, q_2^{*I_\gamma})$. The welfare gain of the investment, $W^{*I_\gamma} - W^*$, has to be compared with the social cost of the investment $(1 + \lambda)I_\gamma$. The social cost of investment I_γ is weighted by $(1 + \lambda)$ because devoting resources to investment decreases the operating profits, thus increasing transfers. The global welfare maximizer chooses to invest if and only if: $W^{*I_\gamma} - W^* \geq (1 + \lambda)I_\gamma$. Let I_γ^* be the maximal level of investment which satisfy this inequality:

$$I_\gamma^* = \frac{1}{1 + \lambda} [W^{*I_\gamma} - W^*] \quad (19)$$

We next study the non cooperative equilibrium investment level in the case of market integration. The quantity produced by firm i after investment, $q_i^{OI_\gamma}$, is obtained by substituting $t\gamma$ in equation (14). Let $W_i^{OI_\gamma}$ be country $i = 1, 2$ welfare function (6) evaluated at $(q_1^{OI_\gamma}, q_2^{OI_\gamma})$. Investment is optimal in country i if and only if $W_i^{OI_\gamma} - W_i^O \geq (1 + \lambda)I_\gamma$. The maximum level of investment that country i is willing to make in the common market is:

$$I_{\gamma i}^O = \max \left[0, \frac{1}{1 + \lambda} [W_i^{OI_\gamma} - W_i^O] \right] \quad (20)$$

Intuitively transportation cost reducing technology increases the business stealing effect. Although this has an adverse effect on both countries, the negative impact is larger for the high cost firm. One can hence check equation (15) that the market share of the less efficient country decreases after the investment. For this reason, the welfare effect generated by the transportation cost reducing investment in the less efficient country can be negative so that $I_{\gamma i}^O$ can be equal to zero. In particular, this occur for large values of Λ

(see Appendix 4 for details). By contrast the investment always increases the gross welfare of the most efficient country. The maximal level of investment for the more efficient firm (i.e., $\min\{\theta_1, \theta_2\}$), is always positive and higher than the maximal level of investment for the less efficient one (i.e., $\max\{\theta_1, \theta_2\}$). Since γ -reducing investment benefit equally the two producers, in the common market the level of investment that each country is willing to finance depends on the investment choice of the other country.

Lemma 2 *Let \bar{I}_γ^O be the maximal level of investment for the more efficient firm and \underline{I}_γ^O the maximal level of investment for the less efficient one as defined in (20). Then, if $I_\gamma > \bar{I}_\gamma^O$ there is no investment. If $\underline{I}_\gamma^O < I_\gamma \leq \bar{I}_\gamma^O$, the more efficient firm invests and the less efficient one does not. If $I_\gamma \leq \underline{I}_\gamma^O$ there are two Nash equilibria in pure strategies in which one of the firm invests and the other does not.²⁰*

Proof. See Appendix 4. ■

By virtue of Lemma 2 the decision of the more efficient firm determines the maximal equilibrium level of investment attainable in the common market. Comparing the maximum investment level in open economy with the optimal level yields the following result.

Proposition 4 *In the integrated market the investment level in γ -reducing technology is always suboptimal:*

$$\bar{I}_\gamma^O \leq \bar{I}_\gamma^O + \underline{I}_\gamma^O \leq I_\gamma^* \quad \forall \Delta, \Lambda \geq 0 \quad (21)$$

Proof. See Appendix 4. ■

In our specification, γ -reducing investment increases the efficiency of all firms. Since it reduces the transportation costs both in investing and non-investing countries, a reduction in γ has a public good nature. It is thus intuitive that investment level \bar{I}_γ^O is sub-optimal. The investing country does not take into account the impact of the investment on the

²⁰We focus on pure strategies. Yet there is a mixed strategy equilibrium in which firm i , $i \neq j$ invests with probability $\pi_i = \frac{W_j^{CI} - (1+\lambda)I_\gamma - W_j^C}{W_j^{CI} - W_j^C}$. This equilibrium is inefficient because with positive probability both firms invest, or alternatively, no firm invests.

foreign country. However the under-investment problem goes deeper than simple free-riding. Even if each country was willing to contribute up to the point where the cost of investment outweighs the welfare gains generated by investment (i.e., without free-riding on the investment made by the other) the total investment level $\bar{I}_\gamma^O + \underline{I}_\gamma^O$ would still be sub-optimal. To analyze the origin of this inefficiency we study countries' incentives to invest in a closed economy.

Let $q_i^{CI_\gamma}$ be the quantity produced by firm i in the case of investment in a closed economy. It is obtained by substituting $t\gamma$ in equation (8). Let $W_i^{CI_\gamma}$ be the country $i = 1, 2$ welfare function (6) evaluated at $(q_1^{CI_\gamma}, q_2^{CI_\gamma})$. Investment is optimal in country i if and only if $W_i^{CI_\gamma} - W_i^C \geq (1 + \lambda)I_\gamma$ so that:

$$I_{\gamma i}^C = \frac{1}{1 + \lambda} [W_i^{CI_\gamma} - W_i^C]. \quad (22)$$

Comparing (22) with (20) yields the next proposition.

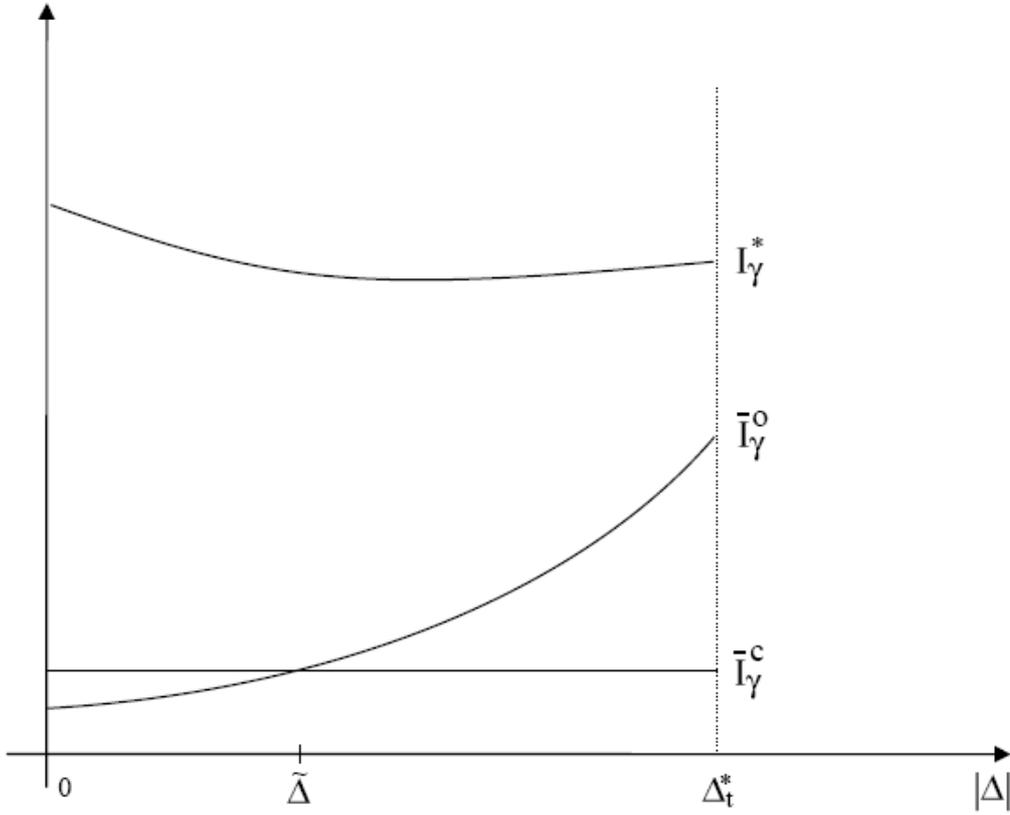
Proposition 5 *Let \bar{I}_γ^C be the maximal amount that the most efficient country is willing to invest to reduce transportation costs in the closed economy and \bar{I}_γ^O be the maximal amount it is willing to invest in the common market.*

- For $\Lambda = 0$, $\bar{I}_\gamma^O > \bar{I}_\gamma^C \forall \Delta \geq 0$ and $\bar{I}_\gamma^O - \bar{I}_\gamma^C$ is an increasing function of Δ .
- For $\Lambda > 0$, there exists $\tilde{\Delta} > 0$ such that $\bar{I}_\gamma^O > \bar{I}_\gamma^C$ if and only if $|\Delta| > \tilde{\Delta}$.

Proof. See Appendix 5. ■

Figure 4 illustrates the results of Propositions 4 and 5 for the case $\Lambda > 0$. When public funds are costly, the maximal level of investment sustainable in the open economy is lower than in the case of autarky if Δ is small. Indeed investment reduces the costs of the competitor and makes it more aggressive in the common market. The business stealing effect, while reducing investing country total welfare, also reduces its capacity to finance new investment. Market integration may thus generate an insufficient level of γ -reducing investment for two reasons. The first reason is that investment has a public good feature. The investing country does not internalize the benefits on foreign stakeholders.

Figure 4: γ -reducing investment
 θ_{\min} is fixed, $|\Delta|$ varies,



The second reason is that investment decreases the costs of the competitor, worsening the business stealing effect.

Under market integration, when Δ is small (i.e., $(|\Delta| \leq \tilde{\Delta})$, the maximal level of investment is not only sub-optimal, but it is also smaller than under a closed economy. When the two regions' cost are not drastically different business stealing is fierce. It reduces the capacity of financing new investment worsening the gap between the optimal investment and the equilibrium level. By contrast when one country has a drastic cost advantage (i.e., $|\Delta| > \tilde{\Delta}$), it is willing to invest more in the common market than under closed economy because the investment increase its market share and profits. Integration can then help to increase investment, although not up to the first best level. Similarly when $\Lambda = 0$ public funds are free. Business stealing is no longer a problem so that market

integration increases the level of sustainable investment compared to a closed economy.

4.2 Production Cost Reducing Investment

We next focus on a production cost reducing, or “ θ -reducing”, investment. We assume that this investment is only possible in country 1, because of the availability of a specific input or technology. For instance in electricity the investment can be the construction of a dam, which reduces generation cost. Hydropower potential is unevenly distributed across countries. Country 1 can reduce the production cost from θ_1 to $c\theta_1$ ($c < 1$) by investing a fixed amount I_θ . We focus on cases in which both firms produce in the common market. The following assumption ensures that there is no shut down in equilibrium.

$$\mathbf{A2} \quad |\theta_2 - c\theta_1| \leq \frac{2\gamma(d - c\min\{c\theta_1, \theta_2\})}{1 + 2\gamma + \Lambda}.$$

We first consider the solution induced by the global welfare maximizer of Section 3.1. Let $q_i^{*I_\theta}$ be the quantity produced by firm $i = 1, 2$ in the case of θ -reducing investment by firm 1. The optimal quantities are given by equations (11) and (12) where θ_1 is replaced by $c\theta_1$. Substituting the quantities $q_i^{*I_\theta}$ ($i = 1, 2$) in the welfare function defined equation (10), the gross utilitarian welfare is $W^{*I_\theta} = W(q_1^{*I_\theta}, q_2^{*I_\theta})$. The global welfare maximizer regulator invests if and only if $W^{*I_\theta} - W^* \geq (1 + \lambda)I_\theta$. Let denote I_θ^* the maximal level of investment which satisfies this inequality:

$$I_\theta^* = \frac{1}{1 + \lambda} [W^{*I_\theta} - W^*] \quad (23)$$

We derive next the non cooperative equilibrium quantities in the open economy, $q_i^{OI_\theta}$, from equation (14) where θ_1 is replaced by $c\theta_1$. Substituting the quantities $q_i^{OI_\theta}$ ($i = 1, 2$) in the welfare function defined equation (10), the gross utilitarian welfare in the case of investment by firm 1 is $W^{OI_\theta} = W(q_1^{OI_\theta}, q_2^{OI_\theta})$. Regulator of country 1 invests if and only if $W^{OI_\theta} - W^O \geq (1 + \lambda)I_\theta$. Similarly the quantities in the case of a closed economy are derived from equation (8) where θ_1 is replaced by $c\theta_1$. Substituting the quantities $q_i^{CI_\theta}$ ($i = 1, 2$) in the welfare function defined equation (10), the gross utilitarian welfare in the case of investment by firm 1 is $W^{CI_\theta} = W(q_1^{CI_\theta}, q_2^{CI_\theta})$. In a closed economy country 1 invests if and only if $W^{CI_\theta} - W^C \geq (1 + \lambda)I_\theta$. We deduce the maximal level of investment that country 1 is willing to commit in the common market and in the closed economy:

$$I_\theta^k = \frac{1}{1 + \lambda} [W_1^{kI_\theta} - W_1^k] \quad k = O, C \quad (24)$$

Proposition 6 Let I_θ^* , and I_θ^C , I_θ^O be defined equation (23) and (24) respectively. Let $\Delta = \theta_2 - \theta_1$. Then, there exist 3 thresholds values $\hat{\Delta}_1 = \hat{\Delta}_2 = \hat{\Delta}_3$ for $\Lambda = 0$, and $\hat{\Delta}_1 < \hat{\Delta}_2 < \hat{\Delta}_3$ for all $\Lambda > 0$ such that $\forall c \in (0, 1)$:

- $I_\theta^O > I_\theta^C \Leftrightarrow 0 > \Delta > \hat{\Delta}_1$.
- $I_\theta^* > I_\theta^C \Leftrightarrow 0 > \Delta > \hat{\Delta}_2$.
- $I_\theta^* > I_\theta^O \Leftrightarrow \Delta > \hat{\Delta}_3$.

Proof. See Appendix 6. ■

Figure 5: θ_1 -reducing investment
 θ_1 is fixed; Δ varies

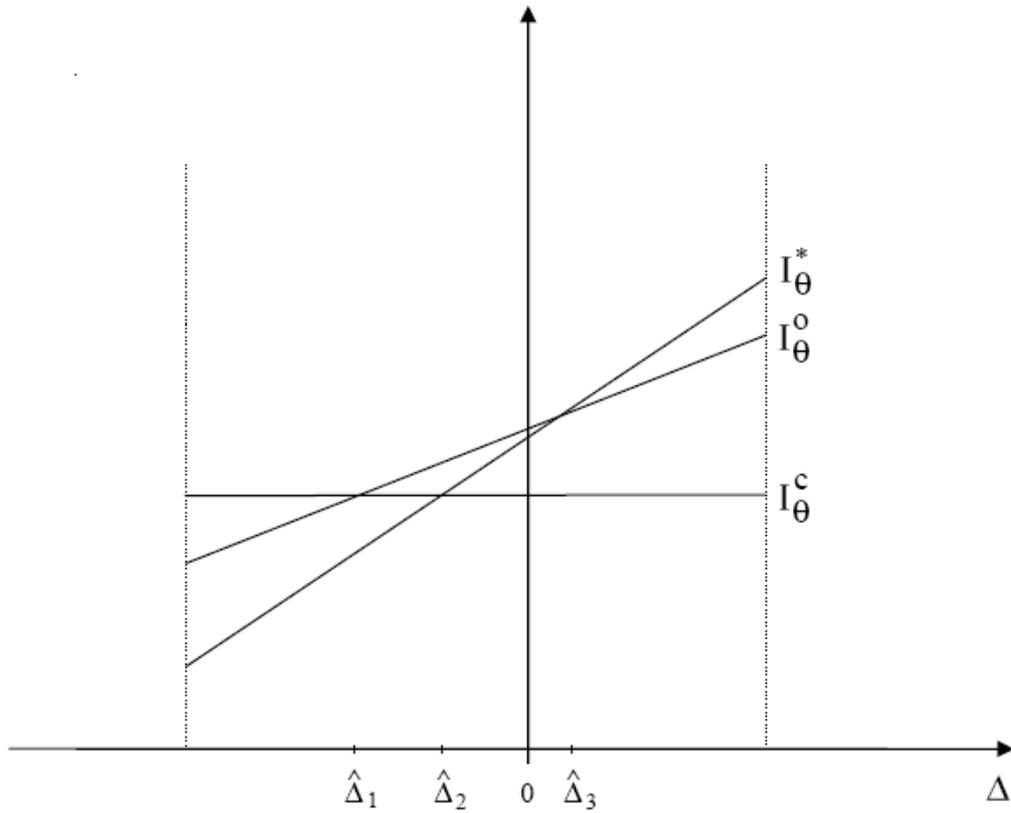


Figure 5 illustrates the results of Proposition 6 in the case $\Lambda > 0$. It is drawn for a fixed value of $c\theta_1$. The static comparative parameter is Δ .

When $\Lambda = 0$, business stealing has no adverse impact on national welfare so that $\hat{\Delta}_1 = \hat{\Delta}_2 = \hat{\Delta}_3 = \frac{(1-c)\theta_1}{2}$. In this case market integration unambiguously reduces the gap between optimal and equilibrium level of investment. However when $\Lambda > 0$, the threshold $\hat{\Delta}_1$ and $\hat{\Delta}_3$ shifts to the left and to the right respectively while $\hat{\Delta}_2$ is not affected (see Appendix 6).²¹ When Λ is large enough Δ_3 becomes positive.

In closed economy there is excessive investment if the investing firm is of a relatively high cost and under-investment otherwise. When the national firm is inefficient (i.e. $\Delta < \hat{\Delta}_2 < 0$), the only way to increase the level of consumption (and thus total welfare) in autarky is through the cost reducing investment. In the open economy the market can be served by the other firm, so that investing to improve the inefficient national technology is no longer optimal. When $\Delta > \hat{\Delta}_2$ the autarky equilibrium level of investment is too low because in the absence of trade the national regulator does not care about country 2. The investment level of country 1 is thus independent of firm 2, which explains the flat investment shape in Figure 5. Since regulator focuses on domestic consumers surplus and national firm rent, these inefficiency results are hardly surprising. A more interesting issue is whether economic integration can improve the autarky outcome or not.

For $\Delta > \hat{\Delta}_3$ and $\Delta < \hat{\Delta}_1$ market integration improves the situation with respect to the closed economy. When $\Delta > \hat{\Delta}_3$, country 1 chooses a level of investment in autarky that is too low. Without an access to the foreign market, the investment is oversized for the domestic demand. Market integration helps to increase the level of investment that country 1 is willing to sustain by enlarging the market size. Symmetrically, in the closed economy, when $\Delta < \hat{\Delta}_1$ country 1 overinvests in marginal improvements of its technology because it has no access to the foreign technology. In the common market, the national consumers can be served by the foreign firm at a lower price. Investing to improve the inefficient national technology is not attractive anymore. Market opening improves the situation with respect to autarky by reducing the level of wasteful investments. However it does not restore the first best level. When $\Delta > \hat{\Delta}_3$ the open market equilibrium of

²¹When Λ increases, all thresholds $I_\theta^O, I_\theta^*, I_\theta^C$ are shifted downwards because the social cost of investment increases. However, I_θ^O decreases less because investment becomes important to reduce business stealing effect in the common market. As a result, the region of overinvestment increases.

investment is too low because the investing country does not fully internalize the increase in the foreign consumer surplus. Symmetrically, when $\Delta \leq \hat{\Delta}_3$ the possibility to reduce its cost gap and to expand its market share by serving foreign consumers makes a high level of investment attractive. Incentives to invest improve compared to autarky but are still too high for inefficient firm and too low for efficient one compared to the optimum.

For $\hat{\Delta}_1 < \Delta < \hat{\Delta}_2$, there is excessive investment both under closed and open economy. However the over-investment problem is more severe in the open economy. When $\Delta > \hat{\Delta}_1$ a production cost reducing investment raises the relative efficiency of the national firm. It invests to strengthen its position in the common market and to reduce the business stealing problem. It does not internalize the cost it imposes on country 2 and overinvests. Markets integration thus improves incentives to invest in cost reducing technologies when the costs difference between the two regions is large and it leads to over-investment when the costs difference is small. This is in sharp contrast with transportation infrastructure investment, where integration leads to under-investment.²²

5 Conclusion

Market integration has complex welfare implications in non-competitive industries controlled by national regulators. Unless the difference in production costs between two regions is large enough, economic integration achieved by sovereign countries is unlikely to be successful. When the two national champions are not sufficiently differentiated in terms of productivity, the competition for market shares induced by the integration process is welfare-degrading in both countries. Even when the efficiency gains from integration are large enough so that both countries win from integration, opposition might still subsist internally. Indeed market integration has redistributive effects. For instance, when the cost difference between the two countries is large enough, the possible adverse

²²When the initial level of costs difference between the two regions is not large enough the business stealing effect tilts the investment incentives in the wrong direction. For instance if $-\Delta_2 < \theta_1 - \theta_2 < \min\{\tilde{\Delta}, -\hat{\Delta}_2\}$ with $\tilde{\Delta}$ being defined Proposition 5, then under market integration country 2 under-invests in γ -reducing technology while country 1 over-invests in θ -reducing technology. The latter investment reduces the gap between the two regions production costs, which reduces further the incentives of country 2 to invest in transportation and interconnection facilities. By virtue of Proposition 3 welfare decreases in both regions.

impact of price convergence on consumers in the low-price region will be a source of opposition and discontent toward the integration process.

Integration of market economies is generally perceived to be a powerful tool in stimulating investment in infrastructure industries. Intuitively, some investments that are oversized for a particular country should be profitable in an enlarged market. This paper shows that with cost-reducing technology, market integration tends indeed to increase the level of sustainable investment. When one country is much more efficient than the other, integration stimulates investment in the cost-reducing technology. However, the investment level remains suboptimal because the countries endowed with cheap power (e.g., hydropower) do not fully internalize the surplus of the consumers in the foreign countries. They internalize the sales only. It remains the case that with generation facilities, the only problem to fear, compared to autarky, is overinvestment. This is in contrast with the systematic underinvestment problem arising for interconnection and transportation facilities, and other public-good components of the industry, such as reserve margins. Free-riding reduces the incentives to invest, while business-stealing reduces the capacity for financing new investment, especially in the importing country. This result is important for policy purposes. The issue of how to collectively finance these essential facilities needs to be addressed upfront. This is clearly a case where international organizations/agencies can play an important role in coordinating sustainable level of investment.

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Appendix 1

Since Λ is positive, leaving a rent to the firms is costly. The transfers t_1 and t_2 are chosen so that the (IR) constraints are binding. Setting $\Pi_i = 0$ implies $t_i = -P(Q)q_i + (\theta_i + \gamma \frac{q_i}{2})q_i + K$ ($i = 1, 2$). Substituting the transfers value into the global welfare $W = W_1 + W_2$ yields:

$$W = S(Q) + \lambda P(Q)(q_1 + q_2) - (1 + \lambda)(\theta_1 + \gamma \frac{q_1}{2})q_1 - (1 + \lambda)(\theta_2 + \gamma \frac{q_2}{2})q_2 - 2(1 + \lambda)K \quad (25)$$

The supra-national regulator maximizes welfare with respect to q_i , $i \in \{1, 2\}$. The first order condition gives:

$$(1 + \lambda)(d - q_i(1 + \gamma) - q_j - \theta_i) + \frac{q_i + q_j}{2} = 0 \quad (26)$$

Consider first the interior solution. Solving the system characterized in (26) for $i = 1, 2$ and letting $\Lambda = \frac{\lambda}{1 + \lambda}$ we obtain:

$$q_i = \frac{d - \frac{\theta_1 + \theta_2}{2}}{1 + \Lambda + \gamma} + \frac{\theta_j - \theta_i}{2\gamma} \quad (27)$$

In this case, the total quantity Q is given by:

$$Q^* = q_1 + q_2 = 2 \frac{d - \frac{\theta_1 + \theta_2}{2}}{1 + \Lambda + \gamma}$$

We now consider the shut down case $q_i = 0$. This arises when $\theta_j - \theta_i \leq -\frac{2(1+2\gamma)(d-\theta_i)}{1+\Lambda}$. In this case, only the most efficient firm j is allowed to produce and the total quantity is given by:

$$q_j = Q^* = 2 \frac{(d - \theta_j)}{1 + 2\gamma + \Lambda}$$

If $\theta_i < \theta_j$, a symmetric condition describes the shut down case for firm j , $i \neq j$, i.e. $\theta_j - \theta_i \geq \frac{2(1+2\gamma)(d-\theta_i)}{1+\Lambda}$. Letting $\theta_{\min} = \min\{\theta_1, \theta_2\}$ and $|\Delta| = |\theta_2 - \theta_1| = |\theta_1 - \theta_2|$, Equation (11) resumes the results. Substituting in the inverse demand function (2) we then obtain the expression for the price.

Appendix 2

Replacing the participation constraint of the national firm in the welfare function (6), in the case of open economy welfare in country i writes:

$$W_i^O = S(Q_i) - P(Q_i)q_j + \lambda P(Q_i)q_i - (1 + \lambda)(\theta_i + \gamma \frac{q_i}{2})q^i - (1 + \lambda)K \quad (28)$$

Where $P(Q) = d - \frac{Q}{2}$ and $S(Q_i) = \int_0^{Q_i} P(Q)dQ$. Regulator i maximizes (5) with respect to q_i . The first order condition gives:

$$(1 + \lambda)(d - \theta_i) - \frac{1}{4}[q_j(1 + 2\lambda) + q_i(3 + 4\lambda + 4\gamma(1 + \lambda))] = 0 \quad (29)$$

Rearranging terms and taking letting $\Lambda = \frac{\lambda}{1+\lambda}$, we obtain the reaction function of regulator i to the quantity induced by regulator j ($i \neq j$), namely $q_i(q_j)$:

$$q_i(q_j) = \frac{4(d - \theta_i) - q_j(1 + \Lambda)}{3 + \Lambda + 4\gamma} \quad (30)$$

The equilibrium is given by the intersection of the two best response functions characterized in (30) (taking into account that quantities must be non negative). If the intersection is reached when both quantities are positive, we have:

$$q_i = 4 \frac{d - \frac{\theta_1 + \theta_2}{2}}{2(1 + \gamma) + \Lambda} + \frac{\theta_j - \theta_i}{1 + 2\gamma} \quad (31)$$

In this case, the total quantity Q is given by:

$$Q = q_1 + q_2 = 4 \frac{d - \frac{\theta_1 + \theta_2}{2}}{2(1 + \gamma) + \Lambda}$$

However, we also have to consider the shut down case $q_i = 0$. This arises when $q_j \geq 4 \frac{d - \theta_i}{1 + \Lambda}$, or equivalently $\Delta \geq \frac{2(1+2\gamma)(d-\theta_i)}{1+2\gamma+\Lambda} < 0$. The shut down case thus writes, for $\theta_i > \theta_j$:

$$Q = q_j(q_i = 0) = 4 \frac{d - \theta_j}{3 + 4\gamma + \Lambda}$$

If $\theta_i < \theta_j$, a symmetric condition describes the shut down case for firm j , $i \neq j$. Letting $\theta_{\min} = \min\{\theta_1, \theta_2\}$ and $|\Delta| = |\theta_2 - \theta_1| = |\theta_1 - \theta_2|$, the expression for the optimal quantity is thus reassumed in (14). Substituting in the inverse demand function (2) we then obtain the expression for the price given in (14).

Appendix 3

Consider country 1 (the same holds for country 2 inverting θ_1 and θ_2 and replacing Δ with $-\Delta$ in all expressions). Replacing for the participation constraint of the national firm, welfare in country 1 in the case of closed economy writes:

$$W_1^C = S(q_1^C) + \lambda P(q_1^C)q_1^C - (1 + \lambda)(\theta_1 + \gamma \frac{q_1^C}{2})q_1^C - (1 + \lambda)K \quad (32)$$

Substituting for the value of the quantities (8) and (14) in (32) and (5) respectively, we compute the welfare gains from integration $W_i^O - W_i^C$. Rearranging terms we obtain:

$$W_1^O - W_1^C = \Delta^2 \Lambda_1 + \Delta(d - \theta_1)\Lambda_2 + (d - \theta_1)^2 \Lambda_3$$

Where:

$$\Lambda_1 = \begin{cases} \frac{2}{(3+4\gamma+\Lambda)^2}, & \text{if } \Delta < -\frac{2(1+2\gamma)(d-\theta_2)}{3+4\gamma+\Lambda}; \\ \frac{(1+\gamma(1-\Lambda))(3+4\gamma+\Lambda)}{2(1+2\gamma)^2(1-\Lambda)(2(1+\gamma)+\Lambda)^2}, & \text{if } -\frac{2(1+2\gamma)(d-\theta_2)}{3+4\gamma+\Lambda} \leq \Delta \leq \frac{2(1+2\gamma)(d-\theta_1)}{3+4\gamma+\Lambda}; \\ 0, & \text{if } \Delta > \frac{2(1+2\gamma)(d-\theta_1)}{3+4\gamma+\Lambda}. \end{cases}$$

$$\Lambda_2 = \begin{cases} -\frac{8}{(3+4\gamma+\Lambda)^2}, & \text{if } \Delta < -\frac{2(1+2\gamma)(d-\theta_2)}{3+4\gamma+\Lambda}; \\ \frac{\Lambda(3+4\gamma+\Lambda)}{(1+2\gamma)(1+\Lambda)(2(1+\gamma)+\Lambda)^2}, & \text{if } -\frac{2(1+2\gamma)(d-\theta_2)}{3+4\gamma+\Lambda} \leq \Delta \leq \frac{2(1+2\gamma)(d-\theta_1)}{3+4\gamma+\Lambda}; \\ 0, & \text{if } \Delta > \frac{2(1+2\gamma)(d-\theta_1)}{3+4\gamma+\Lambda}. \end{cases}$$

$$\Lambda_3 = \begin{cases} \frac{15+16\gamma^2+4\gamma(5+3\Lambda)+\Lambda(6+5\Lambda)}{2(1-\Lambda)(1+\gamma+\Lambda)(3+4\gamma+\Lambda)^2}, & \text{if } \Delta < -\frac{2(1+2\gamma)(d-\theta_2)}{3+4\gamma+\Lambda}; \\ -\frac{\Lambda^2}{2(1-\Lambda)(1+\gamma+\Lambda)(2(1+\gamma)+\Lambda)^2}, & \text{if } -\frac{2(1+2\gamma)(d-\theta_2)}{3+4\gamma+\Lambda} \leq \Delta \leq \frac{2(1+2\gamma)(d-\theta_1)}{3+4\gamma+\Lambda}; \\ \frac{1+3\Lambda}{2(1-\Lambda)(1+\gamma+\Lambda)(3+4\gamma+\Lambda)}, & \text{if } \Delta > \frac{2(1+2\gamma)(d-\theta_1)}{3+4\gamma+\Lambda}. \end{cases}$$

$W_1^O - W_1^C$ is a U shaped function of Δ . For $\Lambda = 0$, $W_1^O - W_1^C$ is always non negative, with a the minimum $\Delta = 0$, where $W_1^O - W_1^C = 0$. For $\Lambda > 0$ the minimum is attained in $\Delta = -\frac{\Lambda(1+2\gamma)(d-\theta_1)}{1+\gamma(1+\Lambda)} < 0$. In this case, in $\Delta = 0$, $W_1^O - W_1^C = -\frac{\Lambda^2}{2(1-\Lambda)(1+\gamma+\Lambda)(2(1+\gamma)+\Lambda)^2} < 0$. The U shape and the condition $|\Delta| \leq d$ ensure the behavior described in Proposition 3.

Appendix 4

We start computing the maximal level of investment Country 1 at the non cooperative equilibrium. We have:

$$\begin{aligned}
W_1^O &= S(Q^O) - P(Q^O)q_2^O + \lambda P(Q^O)q_1^O - (1 + \lambda)(\theta_1 + \gamma \frac{q_1^O}{2})q_1^O - (1 + \lambda)K \\
W_1^{OI_\gamma} &= S(Q^{OI_\gamma}) - P(Q^{OI_\gamma})q_2^{OI_\gamma} + \lambda P(Q^{OI_\gamma})q_1^{OI_\gamma} - (1 + \lambda)(\theta_1 + t\gamma \frac{q_1^{OI_\gamma}}{2})q_1^{OI_\gamma} - (1 + \lambda)K - (1 + \lambda)L
\end{aligned}$$

Replacing for the relevant quantities in Equation (20) and rearranging terms we obtain:

$$I_{\gamma 1}^O = \Delta^2 \Lambda_1'' + (d - \theta_1) \Delta \Lambda_2'' + (d - \theta_1)^2 \Lambda_3''$$

Where:

$$\begin{aligned}
\Lambda_1^{ii} &= \frac{(1 + t\gamma(1 - \Lambda))(3 + 4t\gamma + \Lambda)}{(1 + 2t\gamma)^2(2(1 + t\gamma) + \Lambda)^2} - \frac{(1 + \gamma(1 - \Lambda))(3 + 4\gamma + \Lambda)}{(1 + 2\gamma)^2(2(1 + \gamma) + \Lambda)^2} \\
\Lambda_2^{ii} &= \frac{\Lambda(3 + 4t\gamma + \Lambda)}{(1 + 2t\gamma)(2(1 + t\gamma) + \Lambda)^2} - \frac{\Lambda(3 + 4\gamma + \Lambda)}{(1 + 2\gamma)(2(1 + \gamma) + \Lambda)^2} \\
\Lambda_3^{ii} &= \frac{2(1 - t)\gamma(4(1 + \gamma)(1 + t\gamma) - \Lambda)^2}{(1 + 2t\gamma)^2(2(1 + t\gamma) + \Lambda)^2}
\end{aligned}$$

Λ_1^{ii} and Λ_2^{ii} are positive $\forall t \in (0, 1), \Lambda \in [0, 1)$. $I_{\gamma i}^O$ is a upward sloping parabola with axis of symmetry in $\Delta = -\frac{\Lambda_2^{ii}(d - \theta_i)}{2\Lambda_1^{ii}} < 0$. This implies the following result:

Result 1 $I_{\gamma 1}^O > I_{\gamma 2}^O$ if and only if $\theta_1 < \theta_2$.

Which by definition implies: $\bar{I}_\gamma^O > \underline{I}_\gamma^O$.

This result is useful to prove Lemma 2.

Proof of Lemma 2

Since investment reduces the costs of both firms, if one firm invests, the best response of the other is not to invest. However, if one firm does not invest, the best response of the other firm is to invest whenever $I_\gamma < I_{\gamma i}^O$. From Result 1, we know that $\bar{I}_\gamma^O > \underline{I}_\gamma^O$. Then, for $\underline{I}_\gamma^O < I_\gamma < \bar{I}_\gamma^O$ the less efficient firm never invests and the more efficient does. For $I_\gamma < \underline{I}_\gamma^O$ a firm invests if and only if the other does not.

Before comparing the maximum level of investment \bar{I}_γ^O with the optimal level I_γ^* and the closed economy \bar{I}_γ^* , we prove that γ -investment can reduce the welfare of the less efficient country. We have: $\frac{\partial I_{\gamma 1}^O}{\partial \Delta} = 2\Delta \Lambda_1^{ii} + (d - \theta_1) \Lambda_2^{ii}$. Then, \bar{I}_γ^O is strictly positive and increasing in $|\Delta|$, while \underline{I}_γ^O is U shaped. The sign of \underline{I}_γ^O is thus ambiguous. Let $W_1^{I_\gamma} - W_1$ be the impact of γ -reducing investment country 1 when $\Delta < 0$ (i.e. $\theta_2 < \theta_1$). By the definition of \underline{I}_γ^O we can write:

$$W_1^{I_\gamma} - W_1 = \frac{\underline{I}_\gamma^O}{1 - \Lambda}.$$

Then, the welfare gains of country 1 are positive if and only if I_γ^O is positive. In $\Delta = 0$, I_γ^O is positive and decreasing in $|\Delta|$. We have to prove that I_γ^O might be negative for some $\Delta < 0$. In $\Delta = -\frac{2(1+2t\gamma)(d-\theta_2)}{1+\Lambda}$ (the minimal admissible value under A1) $W_1^{I_\gamma} - W_1$ is negative if and only if $\Lambda > \bar{\Lambda} = \frac{\sqrt{9+8t\gamma+4\gamma(10+7t\gamma+\gamma(3+\gamma(1+t))(5+\gamma(1+t)))-(1+2\gamma(2+\gamma(1+t)))}}{1+2\gamma}$. Then, $\Lambda > \bar{\Lambda}$ is a sufficient (although non necessary) condition for having the gains in the less efficient country smaller than zero for some $\Delta < 0$.

Proof of Proposition 4

The maximal investment at the global optimum is defined by (19). Global welfare in the case of non investment and investment are respectively:

$$W^* = S(Q^*) + \lambda P(Q^*)(q_1^* + q_2^*) - (1 + \lambda)(\theta_1 + \gamma \frac{q_1^*}{2})q_1^* - (1 + \lambda)(\theta_2 + \gamma \frac{q_2^*}{2})q_2^* - 2(1 + \lambda)K$$

$$\begin{aligned} W^{*I_\gamma} &= S(Q^{*I_\gamma}) + \lambda P(Q^{*I_\gamma})(q_1^{*I_\gamma} + q_2^{*I_\gamma}) - (1 + \lambda)(\theta_1 + t\gamma \frac{q_1^{*I_\gamma}}{2})q_1^{*I_\gamma} - (1 + \lambda)(\theta_2 + t\gamma \frac{q_2^{*I_\gamma}}{2})q_2^{*I_\gamma} \\ &\quad - 2(1 + \lambda)K - (1 + \lambda)I_\gamma \end{aligned}$$

Replacing for the relevant quantities and rearranging terms we obtain:

$$I_\gamma^* = \Delta^2 \Lambda_1^i + (d - \theta_{\min})|\Delta| \Lambda_2^i + (d - \theta_{\min})^2 \Lambda_3^i$$

Where:

$$\begin{aligned} \Lambda_1^i &= \frac{1-t}{4\gamma} \left[\frac{1}{t} + \frac{\gamma^2}{(1+t\gamma+\Lambda)(1+\gamma+\Lambda)} \right] \\ \Lambda_2^i &= -\frac{(1-t)\gamma}{(1+\gamma+\Lambda)(1+t\gamma+\Lambda)} \\ \Lambda_3^i &= \frac{(1-t)\gamma}{(1+\gamma+\Lambda)(1+t\gamma+\Lambda)} \end{aligned}$$

I_γ^* is symmetric with respect to the origin ($\Delta = 0$), because at the global optimum production is always reallocated in favor of the most efficient firm. Moreover, for both $\Delta > 0$ and $\Delta < 0$ it has an U shape in Δ ($\Lambda_1^i > 0, \forall t \in (0, 1), \Lambda \in [0, 1)$).

We now compare the thresholds I_γ^* and I_γ^O .

$$I_\gamma^* - I_\gamma^O = \Delta^2 \Lambda_1^{iii} + (d - \theta_i) \Delta \Lambda_2^{iii} - (d - \theta_i)^2 \Lambda_3^{iii}$$

$$\Lambda_1^{iii} = \frac{1}{t\gamma} + \frac{1}{1+t\gamma+\Lambda} - \frac{2(1+t\gamma(1-\Lambda))(3+4t\gamma+\Lambda)}{(2(1+t\gamma))(2(1+t\gamma)+\Lambda)^2}$$

$$\begin{aligned}\Lambda_2^{iii} &= -\frac{1}{\gamma} - \frac{1}{1+\gamma+\Lambda} + \frac{2(1+\gamma(1-\Lambda))(3+4\gamma+\Lambda)}{(2(1+\gamma))(2(1+\gamma)+\Lambda)^2} \\ &= -\frac{1}{1+2t\gamma} - \frac{1}{1+t\gamma+\Lambda} + \frac{4(1+t\gamma)^2+\Lambda}{(1+2t\gamma)((2(1+t\gamma)+\Lambda)^2)} \\ &\quad + \frac{1}{1+2\gamma} + \frac{1}{1+\gamma+\Lambda} - \frac{4(1+\gamma)^2+\Lambda}{(1+2\gamma)((2(1+\gamma)+\Lambda)^2)} \\ \Lambda_3^{iii} &= \frac{1}{1+t\gamma+\Lambda} - \frac{2(1+t\gamma)}{(2(1+t\gamma)+\Lambda)^2} - \frac{1}{1+\gamma+\Lambda} + \frac{2(1+\gamma)}{(2(1+\gamma)+\Lambda)^2}\end{aligned}$$

Λ_1^{iii} is positive for all $t \in (0, 1)$, $\Lambda \in [0, 1)$. Then, $I_\gamma^* - I_\gamma^O$ is a U shaped function of Δ . Moreover, one can easily show that $I_\gamma^* - I_\gamma^O$ decreases with Λ . An increase in Λ shifts the U curve downwards. Then, a sufficient condition for $I_\gamma^* - I_\gamma^O$ to be always positive is to have a positive minimum when $\Lambda = 1$. Since $I_\gamma^* - I_\gamma^O$ is a convex function of Δ , the minimum is obtained from the first order condition $\frac{\partial(I_\gamma^* - I_\gamma^O)}{\partial \Delta} = 0$. In $\Lambda = 1$, this minimum is equal to:

$$[(1-t)^2(57+292(1+t)\gamma+252(1+t(3+2t))\gamma^2+48(1+t)(7+t(12+7t))\gamma^3+16(5+t(33+t(43+t(33+5t))))\gamma^4+28t(1+t)(1+t(1+t))\gamma^5+64t^2(1+t^2)\gamma^6)]/[t(2+\gamma)(2+t\gamma)(1+2t\gamma)^2(3+2t\gamma)^2(3+4\gamma(2+\gamma))] > 0 \quad \forall t \in (0, 1)$$

Then, $I_\gamma^* - I_\gamma^O$ is always positive.

We now show that $I_\gamma^* - \bar{I}_\gamma^O - \underline{I}_\gamma^O$ is also positive. If $\underline{I}_\gamma^O = 0$, then $\bar{I}_\gamma^O + \underline{I}_\gamma^O = \bar{I}_\gamma^O$ and the result has been proved above. If $\underline{I}_\gamma^O > 0$, we have:

$$\bar{I}_\gamma^O + \underline{I}_\gamma^O = \Delta^2 \Lambda_1^{iv} + (d - \theta_i) \Delta \Lambda_2^{iv} + (d - \theta_i)^2 \Lambda_3^{iv}$$

where:

$$\begin{aligned}\Lambda_1^{iv} &= \frac{(1-t)\gamma(3+4(\gamma+t\gamma(1+\gamma)))}{(1+2\gamma)^2(1+2t\gamma)^2} - \frac{1+\gamma}{(2(1+\gamma)+\Lambda)^2} + \frac{1+t\gamma}{(2(1+t\gamma)+\Lambda)^2} \\ \Lambda_2^{iv} &= -\frac{4(1-t)\gamma(4(1+\gamma)(1+t\gamma)-\Lambda^2)}{(2(1+\gamma)+\Lambda)^2(2(1+t\gamma)+\Lambda)^2} \\ \Lambda_3^{iv} &= \frac{4(1-t)\gamma(4(1+\gamma)(1+t\gamma)-\Lambda^2)}{(2(1+\gamma)+\Lambda)^2(2(1+t\gamma)+\Lambda)^2}\end{aligned}$$

Then,

$$I_\gamma^* - \bar{I}_\gamma^O - \underline{I}_\gamma^O = \Delta^2 \Lambda_1^v + (d - \theta_i) \Delta \Lambda_2^v - (d - \theta_i)^2 \Lambda_3^v$$

where:

$$\Lambda_1^v = \frac{1+\gamma}{(2(1+\gamma)+\Lambda)^2} - \frac{1+t\gamma}{(2(1+t\gamma)+\Lambda)^2} - \frac{1}{4(1+\gamma+\Lambda)} + \frac{1}{4(1+t\gamma+\Lambda)}$$

$$\begin{aligned} & -\frac{1}{4\gamma(1+2\gamma)^2} + \frac{1}{4t\gamma(1+2t\gamma)^2} \\ \Lambda_2^v &= \frac{1}{(1+\gamma+\Lambda)} - \frac{1}{(1+t\gamma+\Lambda)} + \frac{4(1+\gamma)}{(2(1+\gamma)+\Lambda)^2} - \frac{4(1+t\gamma)}{(2(1+t\gamma)+\Lambda)^2} \\ \Lambda_3^v &= \frac{(1-t)\gamma\Lambda^2 4(1+t(1+t))\gamma^2 + 4(1+t)\gamma(3+2\Lambda) + (2+\Lambda)(6+5\Lambda)}{(1+\gamma+\Lambda)(1+t\gamma+\Lambda)(2(1+\gamma)+\Lambda)^2(2(1+t\gamma)+\Lambda)^2} \end{aligned}$$

Λ_1^v is positive $\forall t, \Lambda \in (0, 1)$, then $I_\gamma^* - I_\gamma^J$ is a convex U-shaped function of Δ . Moreover, one can verify that the difference $I_\gamma^* - I_\gamma^J$ is decreasing with Λ . Then, the difference is minimal in $\Lambda = 0$, where:

$$I_\gamma^* - \bar{I}_\gamma^O - \underline{I}_\gamma^O = \frac{\gamma(1+2\gamma)^2 - t\gamma(1+2t\gamma)^2}{4\gamma(1+2\gamma)^2(1+2t\gamma)^2} > 0, \quad \forall t \in (0, 1)$$

Then, $I_\gamma^* - \bar{I}_\gamma^O - \underline{I}_\gamma^O$ is always positive.

Appendix 5

In the case of closed economy, welfare with no investment is given by (32). If I_γ is invested, the welfare function becomes:

$$W_i^{CI_\gamma} = S(q_i^{CI_\gamma}) + \lambda P(q_i^{CI_\gamma}) - (1+\lambda)(\theta_i + t\gamma \frac{q_i^C}{2})q_i^{CI_\gamma} - (1+\lambda)K - (1+\lambda)I_\gamma$$

Then, replacing for the expression for the quantities and using equation (22), the maximal investment regulator i is willing to under closed economy can be written:

$$I_{\gamma i}^C = \frac{(1-t)\gamma(d-\theta_i)^2}{2(1+\gamma+\Lambda)(1+t\gamma+\Lambda)}$$

We first check that I_γ^C is smaller than I_γ^* . Because I_γ^* is a convex function of Δ , while I_γ^C is constant, $I_\gamma^O - I_\gamma^C$ is also convex in Δ . In particular, it attains a minimum in $\Delta = \frac{2t\gamma^2(d-\theta_i)}{2t\gamma^2+(1+t)\gamma(1+\Lambda)+(1+\Lambda)^2}$ where its value is:

$$\frac{(1+t)\gamma(d-\theta_i)^2(1+\Lambda)(1+\gamma(1+t)+\Lambda)}{2(1+\gamma+\Lambda)(1+t\gamma+\Lambda)(2t\gamma+(1+t)\gamma(1+\Lambda)(1+\gamma)^2)} > 0$$

Then, $I_\gamma^O - I_\gamma^C$ is always positive.

We now compare I_γ^O and I_γ^C . Because I_γ^O is increasing and convex, while I_γ^C is constant, $I_\gamma^O - I_\gamma^C$ is also increasing and convex in Δ . In particular, if $\Lambda = 0$:

$$I_\gamma^O - I_\gamma^C = \frac{(1-t)\gamma(11+4\gamma(3(2+\gamma)+t(3+4\gamma)(2+\gamma(1+t))))}{8(1+\gamma)(1+t\gamma)(1+2\gamma)^2(1+2t\gamma)^2} \Delta^2 \geq 0 \quad \forall t \in (0, 1)$$

Then, for $\Lambda = 0$, the minimum is attained in $\Delta = 0$, and $I_\gamma^O - I_\gamma^C$ is increasing with $|\Delta|$. On the other hand, if $\Lambda > 0$ and $\Delta = 0$:

$$I_\gamma^O - I_\gamma^C = -\frac{1}{2}(1-t)\gamma(d-\theta_i)^2 \left[\frac{1}{(1+t\gamma+\Lambda)} - \frac{1}{(1+\gamma+\Lambda)} + \frac{4(1+t\gamma)}{(2(1+t\gamma)+\Lambda)} - \frac{4(1+\gamma)}{(2(1+\gamma)+\Lambda)} \right]$$

This is negative for all $t \in (0, 1), \Lambda \in [0, 1)$. From the increasing shape of I_γ^O , there exists $\hat{\Delta} > 0$ such that for all $\Delta > \hat{\Delta}$, $I_\gamma^O > I_\gamma^C$.

Appendix 6

The maximal levels of investment are derived with the same methodology used in Appendix 4 for the case of γ -investment. We have:

$$\begin{aligned} I_\theta^* &= \frac{(1-c)\theta_1 \left[d - \frac{(1+c)\theta_1}{2} + (1+\Lambda) \left(\frac{\Delta}{2\gamma} + \frac{(1-c)\theta_1}{4\gamma} \right) \right]}{1+\gamma+\Lambda} \\ I_\theta^C &= \frac{(1-c)\theta_1 \left[d - \frac{(1+c)\theta_1}{2} \right]}{1+\gamma+\Lambda} \\ I_\theta^O &= \frac{(1-c)\theta_1 \left[\left(d - \frac{(1+c)\theta_1}{2} \right) (4+8\gamma^2+(3+\Lambda)(\Lambda+4\gamma)) + \left[\frac{\Delta}{1+2\gamma} + \frac{(1-c)\theta_1}{2(1+2\gamma)} \right] (1+\Lambda)(3+4\gamma+\Lambda) \right]}{(1+2\gamma)(2(1+\gamma)+\Lambda)^2} \end{aligned}$$

Then, $I_\theta^* > I_\theta^C$ if and only if:

$$\Delta > \hat{\Delta}_1 = -\frac{(1-c)\theta_1}{2} - \left[d - \frac{(1+c)\theta_1}{2} \right] \Gamma_1(\Lambda, \gamma)$$

Where:

$$\Gamma_1(\Lambda, \gamma) = \frac{2\Lambda\gamma(1+2\gamma)(3+4\gamma^2+\Lambda(3+\Lambda+\gamma(7+3\Lambda)))}{(1+\Lambda)(8\gamma^4+(2+\lambda)^2+2\gamma(3+\Lambda)^2+\gamma^3(26+6\Lambda)+2\gamma^2(16+\Lambda(7+\Lambda)))}$$

$I_\theta^* > I_\theta^O$ if and only if:

$$\Delta > \hat{\Delta}_2 = -\frac{(1-c)\theta_1}{2}$$

$I_\theta^O > I_\theta^C$ if and only if:

$$\Delta > \hat{\Delta}_3 = -\frac{(1-c)\theta_1}{2} + \left[d - \frac{(1+c)\theta_1}{2} \right] \Gamma_2(\Lambda, \gamma)$$

Where:

$$\Gamma_2(\Lambda, \gamma) = \frac{\Lambda(1+2\gamma)(3+4\gamma^2+\Lambda(3+\Lambda+\gamma(7+3\Lambda)))}{(1+\Lambda)(1+\gamma)(1+\gamma+\Lambda)(3+4\gamma+\Lambda)}$$

It is easy to see that, if $\Lambda = 0$, $\hat{\Delta}_1 = \hat{\Delta}_2 = \hat{\Delta}_3 = -\frac{(1-c)\theta_1}{2} < 0$. Moreover, for all $\Lambda > 0$, $\hat{\Delta}_1 < \hat{\Delta}_2 < \hat{\Delta}_3$. Finally, $\hat{\Delta}_1$ decreases in Λ while $\hat{\Delta}_3$ increases. For Λ large enough, $\hat{\Delta}_3$ is always positive.