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Powering Up Developing Countries through Integration?

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Abstract

Power market integration is analyzed in a two countries model with nationally regulated firms and costly public funds. If generation costs between the two countries are too similar negative business-stealing outweighs efficiency gains so that following integration welfare decreases in both regions. Integration is welfare-enhancing when the cost difference between the two regions is large enough. The benefit from export profits increases total welfare in the exporting country, while the importing country benefits from lower prices. This is a case where market integration also improves the incentives to invest compared to autarky. The investment levels remain inefficient though. With generation facilities over-investment occurs sometimes, while systematic under-investment occurs for transportation facilities. Free-riding reduces the incentives to invest in these public-good components, while business-stealing tends to reduce the capacity for financing new investment.

JEL-Code: L430, L510, F120, F150, R530.

Keywords: regulation, competition, market integration, investment, electricity.

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1 Introduction

World electricity demand is projected to double by year 2030 (International Electricity Agency, 2006). Financing the volume of investment required to meet this demand rise is a real challenge for developing countries.[1] With scarce public resources, little commitment from the private sector and limited aid,[2] they try to cope with their investment needs by creating regional power markets. Integrated power pools should allow for a better use of existing resources and infrastructures between the different countries involved, and also for the realization of projects that would otherwise be oversized for an isolated country. These benefits are conditional on the countries ability to efficiently coordinate production levels and investment. The problem is that in the absence of a legitimate supranational authority regulation still acts nationally. The paper studies the cost and benefit of such partial economic integration. It shows that coordination problems between independent regulators prevent them from using efficiently the stock of existing infrastructure and distort countries' incentives to invest in new generation and, more importantly, in interconnection facilities. In a nutshell, countries' competition for the sector rents yields inefficiencies that limit the benefit of integration. Because of these losses, the difference in countries generation costs has to be large for a regional power pool to successfully emerge.

Consistently with the theory, cost complementarities in generation are the main engine of integration in electricity markets. For instance in South America, countries that have large demand, such as Brazil or Chile, do not have sufficient energy resources, while countries with smaller markets, such as Paraguay, Venezuela, Bolivia, and Peru have large supply potential, in terms of hydropower, heavy oil and gas. Several generation

[1]The total cumulative investment in power generation, transmission and distribution necessary to meet this rise in demand is estimated to be $11.3 trillion by the International Electricity Agency, 2006. This amount covers investments in OECD countries, in fast-growing developing countries, such as India and China, as well as investments necessary to relieve the acute power penury experienced by some of the world's poorest nations, especially in Sub-Saharan Africa (International Electricity Agency, 2006).

[2]The share of infrastructure assistance in the energy and communications sectors has dramatically declined in the last years (Estache and Iimi, 2008). At the same time, as Estache and Wren-Lewis (2009) note, "for many countries, particularly those with the lowest income, private-sector participation has been disappointing". As rich countries emerge from the global financial crisis with high debt, it is unlikely that development assistance will increase significantly in the near future, and there is a risk that aid to large infrastructure project could be reduced. Yet in 2000, only 40% of the population of low income countries had access to electricity, and the percentage dropped to 10% for the poorest quintile (Estache and Wren-Lewis, 2009).

and interconnection projects have been launched to exploit efficiency gains between these unevenly endowed countries. Similarly in the Greater Mekong Subregion countries with large demand, such as Thailand and Vietnam, want to integrate with countries with large supply potential in terms of hydropower and gas resources and smaller markets, such as Laos and Myanmar. This is also to exploit the potential gains from cross-border trade and to increase their systems efficiency that African countries, sustained by the World Bank, have created several regional power pools: the South African power pool (SAPP), West African power pool (WAPP), Central African Power Pool (CAPP), East African Power Pool (EAPP), to which add interconnection initiatives in North Africa with ties to the Middle East. The pools, created to overcome Sub-Saharan acute shortage problems,[3] are supposed to foster the emergence of major projects such as large hydroelectric-generation facilities. These projects are unlikely to be achieved otherwise, as they are oversized for an isolated country. For instance in West Africa 91% of the hydroelectric potential is concentrated in only five countries. The hydro potential of the Democratic Republic of Congo alone is estimated to be sufficient to provide three times as much power as Africa currently consumes. Large hydroelectric projects, such as the Grand Inga in the region of the Congo River and the projects for the Senegal River basin, could hence be beneficial to all countries in the region, provided they manage to find a way to finance them.[4]

Despite the potential benefits of regional power pools, coordination problems tend to undermine their implementation. In practice governments focus on domestic welfare and are not indifferent between local and foreign producers. They favor the domestic firm, usually the (former) public monopoly,[5] over its foreign competitors. The government cares about the national firm's revenue as it seizes its profits when they are positive and subsidizes its losses when they are negative. As a result, conflicts between governments

[3]Although Africa is endowed with abundant energy sources access to electricity, estimated at 24% of the population by the International Energy Agency, is the lowest in the world. Most African utilities operate below efficient level of scale, due to the limited size of their markets. For instance Tovar and Trujillo (2004), studying electricity generation between 1998 and 2001 in 13 countries (mostly East African), show that inefficiencies of scale are in the order of 24%.

[4]The region possesses some of the largest water courses in the world (Nile, Congo, Niger, Volta and Zambezi river). Oil and gas reserves are concentrated in the north and west, coal reserves are in the south. Geothermal resources are largely in the Red Sea Valley and the Rift Valley. 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).

[5]In 2004, 60% of less developed countries had no significant private participation in electricity, Estache et al., 2005

often arise and slow down integration. For instance, since its creation in 1991, MERCOSUR has promoted energy market integration of its member countries (Argentina, Brazil, Paraguay and Uruguay). Several large bi-national hydro-projects have been started in the region.[6] By 2025 the full integration of their electricity markets is supposed to be achieved. However, recurrent conflicts between governments keep delaying the process. Countries' representatives, who meet occasionally in informal working groups, focus on their national interest and on the promotion of their major state-owned operator such as YPF (Argentina), Endesa (Chile), UTE (Uruguay), ANDE (Paraguay), and Eletrobras (Brazil). Achieving further integration will require the creation of a central body to coordinate the regulation of these different national electricity firms and markets (Pineau, Hira, and Froschauer, 2004).

The paper studies the welfare implications of sectorial integration in a two countries model with nationally regulated firms. It shows that market integration through the creation of a regional power pool is welfare-enhancing when the cost difference between the two regions is large enough. 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 domestic market benefits from the reduction in price caused by importation, which enhances consumer surplus in the importing country. By contrast sectorial integration is not likely to occur if the cost difference between the two countries is small. When the two firms have similar costs, competition for the market shares is fierce so that prices decrease in both countries. The negative business-stealing effect out-weighs the efficiency gains: welfare decreases in both regions following integration. It is worth noting that even if 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 prices converge after integration at some "average" of the two closed-economy prices, consumers in the formerly low-price region are worse off and might thus oppose it.

[6]Brazil and Paraguay share the Itaipu hydroelectric facility, one of the world's largest operating hydro complex. Argentina and Paraguay jointly own Ente Binacional Yacyreta (EBY) a hydroelectric dam on the Parana River and are also considering another hydro complex on the Parana River at Corpus.

The paper next studies the impact of regional integration on the countries' incentives to invest in new infrastructure. It distinguishes cost-reducing investment (e.g., a new generation facility) from investment in interconnection infrastructure (e.g., high voltage links). Compared to autarky, market integration improves 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 regional integration. It 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), but it rises compared to autarky. Moreover, the incentives to invest in obsolete technology decrease, while the incentives to invest in efficient technology increase. Second, when the two countries' technologies are not sufficiently differentiated, the firms that have to fight for their market shares, might overinvest compared to the optimal solution. In practice the risk of over-investment is limited as countries will resist the creation of a common power pool when their costs difference is not large enough.

For infrastructures that constitute a public good, such as interconnection or transportation facilities, there is a major risk of under-investment. 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 in autarky. In practice this risk is limited as the inefficient country will resist integration when costs difference is not large enough. However, even when the two countries have significantly different potential generation costs which implies that market enlargement benefits both of them, the investment level in the public good components of the network remains suboptimal. This structural under-investment problem has important policy implications. Several programs supported by the World Bank in Bangladesh, Pakistan and Sri-Lanka have failed because they omitted to address the interconnection 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.

Our results show that the countries involved in the creation of a power pool should setup at an early stage a supra-national body to deal with the financing and the management of interconnection links and other transmission infrastructures. A good example of a supra-national authority that has been created to address interconnection problems is given by the Electric Interconnection Project of Central America (SIEPAC). The six countries involved in the project (i.e., Guatemala, Nicaragua, El Salvador, Honduras, Panama, Costa Rica) have established a common regulatory body, the Regional Commission of Electricity Interconnection (CRIE). To attract investment and increase infrastructure capacity a new company (EPL) has been created with the goal to build a new regional interconnection line. It is controlled by the national transmission companies with the participation of the Spanish ENDESA. EPL's investment program has been financed through loans obtained from several European banks, together with the contributions of the member countries. CRIE is now in charge of setting the access tariffs needed to repay the loans that financed the investment. It is clear that the role of the regional regulator is crucial to ensure the viability of the transmission infrastructure and to create a favorable environment for new investments. Based on the CRIE experience the West African power pool (WAPP) is working on the creation of a regional regulatory body, "Organe de Régulation Régionale" (ORR), which should promote market integration and cooperation among national regulators (and/or governments). The analysis below shows that power markets integration is much likely to succeed with such a common regulator.

1.1 Relationship with the literature

Starting with the seminal paper of Brander and Spencer (1983), the literature on the interaction between public intervention and market integration has concentrated on the strategic effect of trade subsidization policies.[7] Subsidies have a rent-shifting effect that makes the domestic firm more aggressive in the common market. The strategic reaction of the rival government creates a prisoner's dilemma, with the consequence that firms would benefit from jointly reducing the subsidies. This classical trade-policy result is obtained under the assumptions that public funds are not costly and that domestic and foreign producers are identical. Neary (1994) enriches the analysis by showing that, when public funds are costly, the optimal unit subsidy is often negative and that, when the firms differ in productivity, it is in generally optimal to pay higher subsidies to the most efficient one (i.e. to increase its market share in the common market). Collie (2000) who adds consumer surplus to the analysis (but restricts the attention to the case of identical firms), shows that banning unit subsidies may increase welfare, offering a theoretical argument for the prohibition of state aids in the European Union. Since they focus on the desirability of allowing (or banning) trade subsidies, these contributions take as a starting point that the economies are already open to trade.

By contrast this paper, which focuses on electricity markets, studies the integration process.[8] The relevant analytical framework is that of asymmetric regulation. This framework has been first introduced in the literature by Caillaud (1990) and Biglaiser and Ma (1995) to study the liberalization of regulated industries. Both papers focus on the effects of unregulated competition in a closed economy.[9] Since market integration is generally a process of reciprocal market opening, the present paper extends the analysis to the case where the unregulated entrant is the incumbent of the foreign market, and the regulated national firm is also allowed to serve foreign demand. Considering both

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

[8] It is not enough to sign free trade agreement, nor even to be part of the same free exchange zone, to create a common market in electricity. For instance the European Commission promotes the formation of an integrated market and defines the programmatic lines of action for member countries. However, governments and national regulators retain jurisdiction over specific choices, while respecting the overall framework designed by the Commission. Despite the common framework given in the Commission's directives, in practice electricity market integration proceeds at different speeds in different regions. The integration of electricity markets is advanced between France and neighbor countries (Italy, Spain, United Kingdom) and the Nord Pool (regional market of the Scandinavian countries), while other countries are much less active in the development of cross-border networks and, more generally, less opened to the entry of foreign producers.

[9] Caillaud (1990) studies a regulated market in which a dominant incumbent is exposed to competition from an unregulated, competitive fringe, pricing 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.

countries simultaneously hence permits to open the black box of sectorial integration in non competitive industries. It help us to predict in which case such integration is likely to be consensual and successful, and in which cases it is doomed to fail.

We study a country's incentives to integrate its power market with its neighbor by comparing welfare in the case of integration with the case of autarky. With costly public funds the optimal autarky tariff is a Ramsey price so that taxation by regulation emerges. The operating profits of the regulated firm help covering the fixed costs of investment and reducing the total subsidies to the sector. In this context unregulated competition can have the adverse effect of undermining the tax base (Armstrong and Sappington, 2005). In light of the volume of investment required to power up developing countries this negative fiscal effect is a major concern.[10]

As it studies investment in an integrated market, this paper is also related 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) focus on the strategic motive for research 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 (2009) find that investment subsidies could end up being on the contrary too low 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. In the tradition of the trade and competition literature, these papers concentrate on the desirability of subsidies in an international context, while assuming that public funds are not costly and producers identical. By contrast, the present paper analyzes the consequences of regional integration on investment incentives, when the domestic and the foreign technologies are different and public funds are costly. We hence stress the role of cost asymmetries in affecting the incentives to invest. The impact of market integration on investment incentives depends crucially on these asymmetries. As in Leahy and Neary (2009), we distinguish between different types of investments with different impacts on a competitor's costs and profits (in our case, these would be generation technologies

[10]In 2000, only 40% of the population of low income countries had access to electricity, and the percentage dropped to 10% for the poorest quintile (Estache and Wren-Lewis, 2009). Investments have to be financed either by consumers or taxpayers. To find the right balance between the two, it is necessary to take into account the opportunity cost of public funds.

and transportation/interconnection infrastructures). Since the power industry has some substantial public good components (i.e., transmission and distribution facilities) it constitutes what Besley and Ghatak (2001, 2006) defined as a "market augmenting public good", a case where even a well-functioning market will not provide the correct level of provision.[11] In our analysis the under-investment problem is amplified by the fact that regulation is asymmetric. Market integration erodes the possibility of conducting taxation by regulation because regulators do not control foreign firms. This in turns might undermine further investment possibilities.

2 A model of sectorial integration with independently regulated firms

We consider two symmetrical countries, identified by $i = 1, 2$. The inverse demand in each country is given by:[12]

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

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. $Q = q_1 + q_2$).

[11] Besley and Ghatak (2001, 2006) deal with the optimal institutional arrangements for public goods provision in the form of regulation with transfers and/or public-private partnerships. Since we focus on the integration process, we abstract from this optimal institutional choice. We refer the reader to their contribution for this important practical question.

[12] For the use of linear demand models in international oligopoly contexts, one can refer to Neary (2003), who also discusses the interpretation of these models and their natural extension to a general equilibrium framework.

On the production side, firm $i = 1, 2$ incurs a fixed cost which measures the economies of scale in the industry. The fixed cost is sunk so that it does not play a role in the optimal production choices.[13] The firm also incurs a variable cost function given by:

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

The variable cost function includes both a linear term $\theta_i \in [\underline{\theta}, \overline{\theta}]$, which represents the production cost, and an additional quadratic term, weighted by γ, which represents a transportation cost. Indeed, the cost function (3) can be generated from an horizontal differentiation model à la Hotelling with linear transportation cost in which Firm 1 is located at the left extremity and Firm 2 at the right extremity of the unit interval. The linear market is first separated in two contiguous segments (the "national markets"). Market integration corresponds to the unification of the two segments: the common market is then represented by the full Hotelling line. To serve consumers, firms, that sell the good at an uniform price, have to cover the transportation cost. This Hotelling model generates exactly the cost function in (3), allowing the interpretation of γ as a transportation cost (see Auriol, 1998).[14]

The model supposes that the cost is increasing in the distance between the producer and the consumer. This assumption is legitimate in the electricity example because of the Joule effect and the associated transport charges and losses. Moreover in the interconnected network the transportation cost γ is the same for domestic and international consumers. This assumption is also consistent with the physical characteristics of electric networks. This physical unity, which comes from the fact that electricity cannot be routed, is what differentiates electric systems from other systems of distribution of goods and services. *"All components of an electric power system are physically connected, and all can be dramatically affected by events elsewhere in the system.* [...] *The failure of a single AC-DC converter in a Florida Power and Light Co. nuclear plant in December 1982, for instance, triggered loss of power to 556,000 customers from the Georgia border*

[13] Since it is already sunk at the time countries choose (or not) integration and their production levels, it does not play a role in decisions. We thus avoid introducing new notation for this sunk cost.

[14] That is, assume that consumers are uniformly distributed over $[0, 1]$. To deliver one unit to a consumer located at $q \in [0, 1]$ transportation cost 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 $c(\theta_i, q_i) = \int_0^{q_i} (\theta_i + \gamma\, q) \mathrm{d}q$, or equivalently $c(\theta_i, q_i) = \theta_i q_i + \gamma \frac{q_i^2}{2}$ $(i = 1, 2)$.

to the Florida Keys. [...] *A modern power system is in fact one large machine"* Joskow and Schmalensee (1985).

So to sum up, $\theta_i \in [\underline{\theta}, \overline{\theta}]$ 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). In what follow we assume that γ and θ_i are common knowledge.[15] Any distortions occurring at the equilibrium can thus be ascribed to a coordination failure between the national regulators. In order to rule out corner solution we make the following assumption.

A0 $$d > \overline{\theta}$$

Assumption A0 ensures that in equilibrium the quantities are strictly positive. The profit of firm $i = 1, 2$ is

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

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:

$$\Pi_i \geq 0 \tag{5}$$

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. In the case of electricity public and mixed firms are key players in most developing countries.[16] In 2004, 60% of less developed countries had indeed no significant private participation in electricity (Estache, Perelman, and Trujillo, 2005).

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

[15] 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.

[16] This is true also in many advanced economies. 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.

j). Rent extraction does not apply to foreign firms because they do not report their profits locally. The assumption that firm j production and investment decisions escape regulator i control is consistent with the situation of asymmetric regulation prevailing in liberalized power industries.

Each utilitarian regulator in country i maximizes the home welfare, $W_i = S(Q_i) - P(Q)\, Q_i + \Pi_i + (1+\lambda)t_i$, where $S(Q_i) = \int_0^{Q_i} p_i(Q)\mathrm{d}Q = dQ_i - \frac{Q_i^2}{2}$ is the gross consumer surplus, Π_i the profit of the national firm, and $(1+\lambda)t_i$ the opportunity cost of public transfers. 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 participation constraint of the national firm (5) always binds: $\Pi_i = 0$. The utilitarian welfare function in country $i = 1, 2$ is

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

Term $\lambda \geq 0$ can be interpreted as the shadow price of the government budget constraint. That is, government pursues multiple objectives, such as producing public goods, regulating noncompetitive industries, and controlling externalities, under a single budget constraint. The opportunity cost of public funds is the Lagrange multiplier of this constraint. It tells how much social welfare can be improved when the budget constraint is relaxed marginally; it includes forgone benefits of alternative investment choices and spending. In practice, any additional investment in public utilities implies a reduction of the production of essential public goods, such as national security and law enforcement, or any other commodities that generate externalities, such as health care and education. It may also imply a rise in taxes or public debt. All these actions have a social cost that must be compared with the social benefit of the additional investment. Conversely, when the transfer is positive (i.e. taxes on profits), it helps to reduce distortionary 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.[17] In what follows, it is convenient to express the results

[17] In developed countries λ is usually assumed to be equal to the deadweight loss due to imperfect income taxation. It is estimated at around 0.3 (Snow and Warren, 1996). In developing countries low income levels and difficulties implementing effective taxation are large constraints on the government budget. The ratio of tax revenue to GDP for 1995, for example, was 36.1 percent for OECD countries

in terms of

$$\Lambda = \frac{\lambda}{1+\lambda}. \tag{7}$$

It is straightforward to check that Λ increases with λ so that $\Lambda \in [0,1]$ when $\lambda \in [0,+\infty)$.

We first briefly describe the case of a closed economy, marked C. Each regulator maximizes expected national welfare (6) subject to the autarky production condition $Q_i = q_i$. Solving this problem the optimal autarky quantity is:

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

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 pubic fund Λ because the revenue of the regulated firm allows to decrease the level of other transfers in the economy (and thus distortionary taxation).

3 Common power pool

When barriers to trade in the power market are removed, firms can serve consumers in both countries so that 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 generation cost functions are different, which implies different level of production in the two 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.

(see OECD.org) compared with 18.2 percent for developing countries (based on a sample in Tanzi and Zee, 2001). All else being equal, the opportunity cost of public funds is higher when government revenue is lower, and as a result, the opportunity cost of public funds in developing countries is likely to be higher than 0.3. Bank (1998) suggests an opportunity cost of 0.9 as a benchmark. But the value is much higher in heavily indebted countries.

3.1 Full integration

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

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

with respect to quantities (Q_1, Q_2, q_1, q_2), under the constraint that consumption $Q = Q_1 + Q_2$ equals production $q = q_1 + q_2$. 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 $Q_1 + Q_2 = q_1 + q_2$. 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

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

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:*

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

The market share of firm $i = 1, 2$ at the duopoly solution is:

$$\frac{q_i^*}{Q^*} = \frac{1}{2} + \frac{\theta_j - \theta_i}{2\gamma Q^*} \qquad \text{if } |\Delta| \leq \Delta^* \quad (12)$$

Proof. See Appendix 1. ■

When the cost difference between the two firms is large (i.e., when $|\Delta| > \Delta^*$) 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. However the "shut down" result is upset with the introduction of transportation cost. When γ is positive both firms produce whenever $|\Delta| \leq \Delta^*$. The most efficient firm (i.e., the firm with the cost parameter $\theta_{\min}$) has a larger market share than its competitor (see 12). However, the market share differences decreases with γ.

In practice sectorial integration generally excludes fiscal and political institutions, which remain decentralized at the country level.[18] 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 equilibrium between the two governments.

3.2 Sectorial integration with asymmetric regulation

In the case of sectoral integration, marked O, national regulators simultaneously fix the quantity produced by the national firm, 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 sectorial integration game is:*

$$Q^O = \begin{cases} \frac{4}{3+4\gamma+\Lambda}\,(d-\theta_{\min}) & \textit{by a monopoly if } |\Delta| > \Delta^O = \frac{2(1+2\gamma)(d-\theta_{\min})}{3+4\gamma+\Lambda}; \\ \frac{4}{2(1+\gamma)+\Lambda}\,(d-\frac{\theta_1+\theta_2}{2}) & \textit{by a duopoly otherwise.} \end{cases} \tag{13}$$

The market share of firm $i = 1, 2$ at the duopoly solution is:

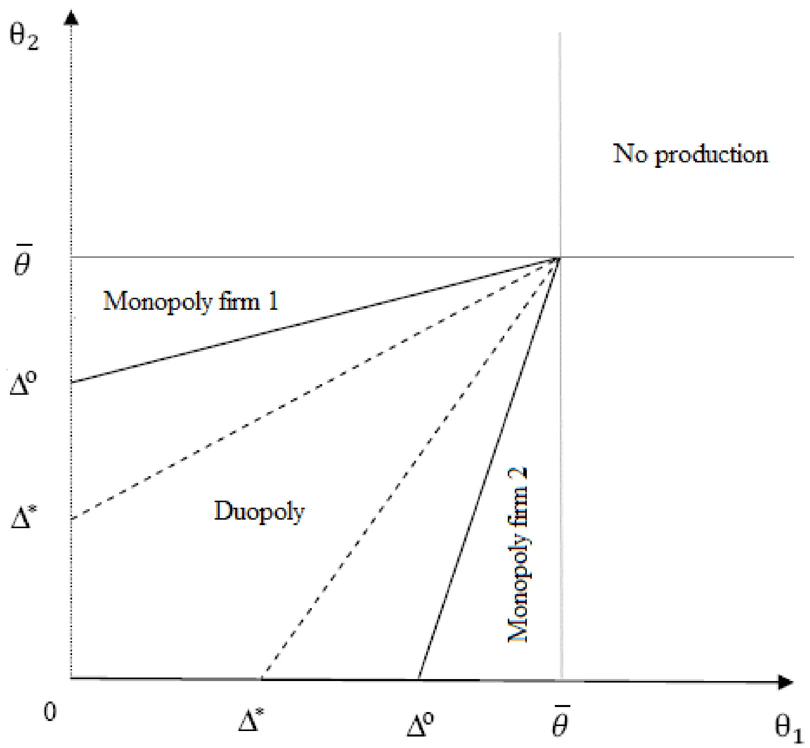
$$\frac{q_i^O}{Q^O} = \frac{1}{2} + \frac{\theta_j - \theta_i}{(1+2\gamma)Q^O} \qquad \textit{if} \quad |\Delta| \leq \Delta^O \tag{14}$$

Proof. See Appendix 2. ■

[18] The solution chosen by a global welfare maximizing social planner corresponds to perfect integration. 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. Consistently 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.

Comparing equations (13) and (11) the equilibrium solution implies that the shut down of the less efficient firm occurs *less often* than in the socially optimal solution. That is, $\Delta^O \geq \Delta^*$ under assumption A0. This result is illustrated in Figure 1. The solid lines represent the equilibrium shut down threshold of the less efficient firm in the integrated market with independent regulators. The dotted lines represent the optimal threshold.[19]

Figure 1: Shut down threshold of the less efficient firm. Dotted line: optimal threshold, Solid 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 (13) 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 $|\Delta| \leq \Delta^*$, it is easy to check that $Q^C = Q^*$ defined equation (11). We deduce

[19]The figure is plotted for $d = 1$, $\Lambda = 0.3$, $\gamma = 0.5$, $\theta_i \in [0, 1]$ and $\theta_{\min} = 0$. The same shape is obtained for any support such as $\overline{\theta} - \underline{\theta} > \frac{2\gamma(d-\theta_{\min})}{1+2\gamma+\Lambda}$.

that excessive production occurs in the common market. To be more specific comparing Q^O and Q^* yields

$$Q^O \geq Q^* \quad \Leftrightarrow \quad |\Delta| \leq \Delta^{O/*} = \tfrac{(2\gamma+\Lambda)(d-\theta_{\min})}{1+2\gamma+\Lambda}. \tag{15}$$

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

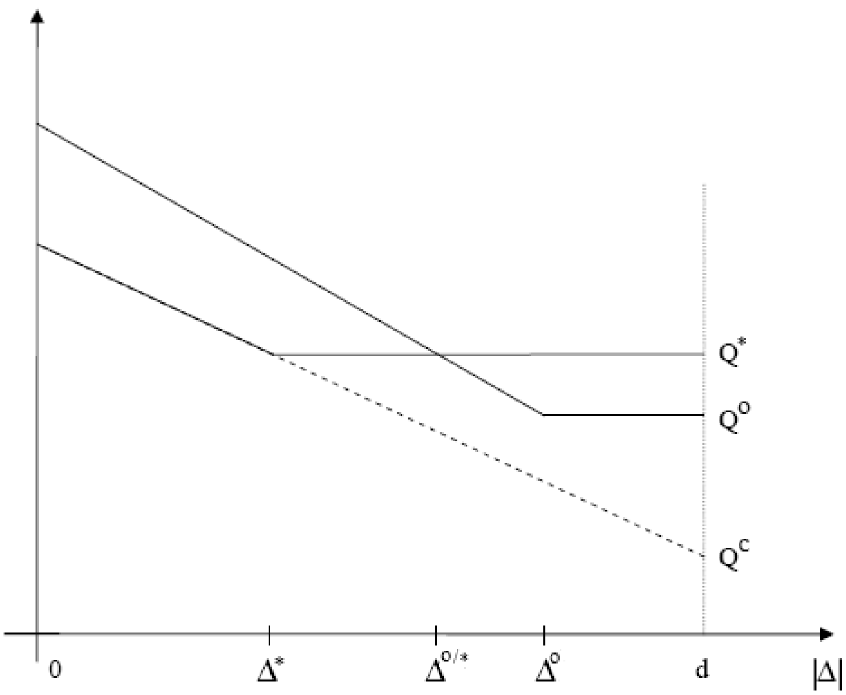


Figure 2 illustrates the results. It represents for a given $\theta_{\min}$ the quantity levels Q^*, Q^O and Q^C in function of $|\Delta| \in [0, d]$. The flat sections correspond to the shut down of the less efficient producer. When $|\Delta|$ is smaller than $\Delta^{O/*}$, regulators fight to maintain their market shares by boosting domestic production. Aggregate quantities are then larger in the common market than at the optimum. In a closed economy, the regulator with the less efficient technology 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 so that $Q^O > Q^*$.[20] Symmetrically, when $|\Delta|$ is larger than $\Delta^{O/*}$ the regulator of the most efficient country controls a large market share (the firm even becomes a monopolist in the common market when $|\Delta| > \Delta^O$). The problem is that she does not internalize the welfare of foreign consumers. She then chooses a suboptimal production level $Q^O < Q^*$.

3.3 The political economy of sectorial integration

Even if one country has lower generation costs than the other, sectorial integration might not be straightforward as competition for the rent sector yields inefficiencies. Both countries have to win from the creation of a common power pool for the integration to occur. Replacing the optimal quantities in the welfare function, we show the following result.

Proposition 3 *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.*

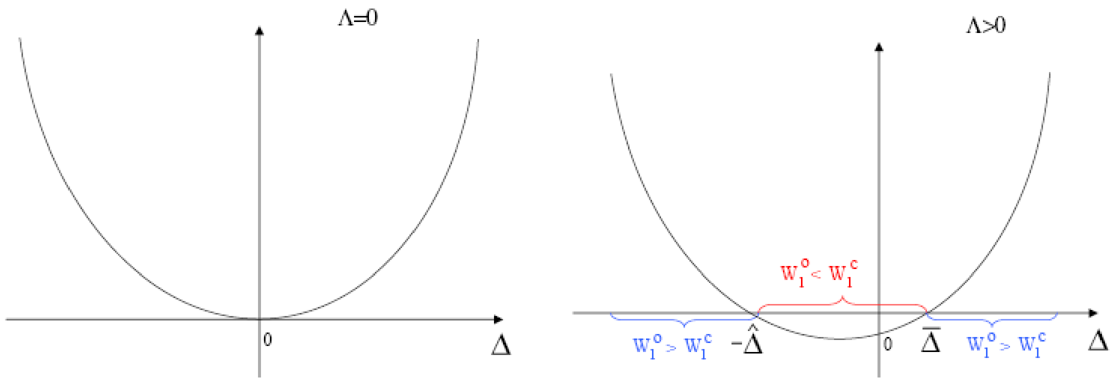
Proof. See Appendix 3. ■

Figure 3 illustrates Proposition 3. It contrasts the welfare gains of country 1 for $\Lambda > 0$ with the welfare gains of country 1 for $\Lambda = 0$. 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 (13) do not corresponds 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 (or alternatively subsidies increase). Yet competition does not increase efficiency because the firms have

[20] Substituting Q^O from equation (13) in equation (14) and comparing it with equation (8), yields: $q_i^O > q_i^C \Leftrightarrow \theta_j - \theta_i \geq -\frac{\Lambda(d-\theta_i)(1+\gamma)}{(1+\gamma+\Lambda)^2}$ $j \neq i$ $i = 1, 2$. A 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.

the same cost. The net welfare impact is negative for both countries. 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 $\hat{\Delta} \geq \overline{\Delta}$. The welfare gains are asymmetric and the country with the less efficient technology generally has lower gains from integration. This depends on the adverse effect of business stealing on the budget constraint of the less efficient firm, which will in general receive a higher transfer (or pay lower taxes) in the common market. It is clear that for Δ belonging to the interval $[-\overline{\Delta}, \overline{\Delta}]$, sectorial integration achieved by two independent countries is inefficient. Each country welfare is decreased by integration.[21] The region as a whole is better off with the co-existence of two separated markets. For value of $|\Delta| \in [\overline{\Delta}, \hat{\Delta}]$ 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 $\hat{\Delta}$, despite the uncoordinated policies. In other words, the theory predicts that integration will be easier to achieve when the costs difference between the two countries

[21]The 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.

is large.

As in the trade and competition literature (starting with Brander and Spencer, 1983), the welfare losses arise because of the two countries rivalry over the market shares. This literature shows that, when considering trade subsidies to identical firms, the welfare losses can be reduced by jointly banning the subsidies and commit to a laissez-faire policy (Brander and Spencer, 1983, Collie, 2000). We can recover this result by setting specific values of the parameters in our model. As show in Appendix 7, when firms are identical the countries could avoid the prisoner dilemma related to market share rivalry by banning quantity regulation for some values of Λ (as in the case studied in Collie, 2000) but the result does not hold in general for heterogeneous firms.[22]

In addition to the global welfare impact, the creation of an integrated market with common price $P(Q^O)$ has redistributive effects. To see this point let focus on $|\Delta| \leq \Delta^O$. We can then show that market integration induces a price reduction in country $i = 1, 2$ if and only if the costs difference is not too large.[23] That is,

$$P(Q^O) \leq P(q_i^c) \quad \Leftrightarrow \quad \theta_j - \theta_i \leq \frac{\Lambda(d - \theta_i)}{1 + \gamma + \Lambda} \qquad j \neq i \quad i = 1, 2 \tag{16}$$

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 (16) 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.[24] Consumers of the relatively efficient region are then worse off after integration. This can be a source of social discontent and opposition towards sectorial integration. 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

[22]When firms have different production costs, abandoning quantity regulation can improve welfare for the country with a relatively efficient firm but not for the other one.

[23]Substituting Q^O from equation (13) 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, $P(q_i^c) = \theta_i + (\Lambda + \gamma)\frac{d-\theta_i}{1+\gamma+\Lambda}$ yields equation (16).

[24]For 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.

share of these new market rents, it can use them to finance new investments or cross subsidies 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).

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. 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, 2007). When public funds are scarce and other sources of taxation are distortionary 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

The proponent of regional power pools claim that, by fostering the emergence of a larger market, they will stimulate investments. However, it is not clear that the model of integration favored by many regions in the world, especially by the African Union, provides an adequate framework for investment incentives. Unless the costs difference between two regions is sufficiently large, market integration with asymmetric regulation can decrease the aggregate capacity of financing new investment. Yet electricity demand is on the rise everywhere, and in many regions aging generation and transportation facilities need urgently to be upgraded and expanded. For instance in Sub-Saharan Africa the annualized investment costs required simply to maintain in 2015 current access rate (less than 30% of the population) are estimated to be around 5 percent of the region GDP. Moreover, specific investment, such as transportation and interconnection facilities, are required to achieve market integration. 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 in SSA (Rosnes and Vennemo, 2008). Similarly the vast hydropower potential of the continent is unexploited because of the lack of investment.

This section studies the investments made by firms subjected to asymmetric regulation. Our analysis focuses on two types of investment. The first type reduces the production cost of the investing firm (e.g., generation facilities). It is referred to as "production cost reducing" or "θ-reducing" investment. It only benefits the investing producer and makes it more aggressive in the common market. We assume that this investment is only possible in one country, by convention country 1, because of the availability of a specific input or technology. One can think of a dam. Hydropower potentials (but also natural resources such as oil or gas) are unevenly distributed across countries. Country 1 can reduce its production cost from θ_1 to $\delta\,\theta_1$ ($\delta < 1$) by investing a fixed amount I_θ.

The second type of investment 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 investment. One can think of investment in transmission, interconnection, or interoperability facilities. We assume that both countries can reduce the collective transportation cost from γ to $s\gamma$ with $s \in (0,1)$ by investing a fixed amount $I_\gamma > 0$.

For both types of investment we focus on interior solutions. Cost difference is assumed to be small enough so that the production of the two firms is positive in the common market. The following assumption ensures that there is no shut down in the first best case (see Δ^* in equation (11)).[25]

A1 $$|\theta_2 - \delta\theta_1| \leq \frac{2s\gamma(d - \min\{\delta\theta_1, \theta_2\})}{1 + 2s\gamma + \Lambda}.$$

4.1 Investment in generation

We start by considering 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 $\delta\theta_1$ ($\delta < 1$). 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 welfare gain of the investment, $W^{*I_\gamma} - W^*$, has to be compared with the social cost of the investment $(1 + \lambda)I_\theta$. The social cost of investment I_θ is weighted by the opportunity cost of public funds because devoting resources to investment decreases the firm's operating profit and

[25] Assumption A1 ensures that both firms produce in all possible cases. As illustrated by the analysis of Section 3 this assumption is not crucial. Our results are preserved when shut down cases are considered (computations are available on request). Yet it simplifies greatly their exposition.

thus the revenue of the government by I_θ, which has an opportunity cost of $(1+\lambda)$. 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:

$$I_\theta^* = \frac{1}{1+\lambda}[W^{*I_\theta} - W^*] \tag{17}$$

The non cooperative equilibrium quantities in the case of sectoral integration, $q_i^{OI_\theta}$, and the quantities in the case of a closed economy, $q_i^{CI_\theta}$, are derived in a similar way from equations (13) and (8) respectively where θ_1 is replaced by $\delta\theta_1$. Substituting the quantities $q_i^{kI_\theta}$ ($i = 1,2$ and $k = O,C$) in the welfare function of country 1 defined equation (6), the regulator of country 1 invests if and only if $W_1^{kI_\theta} - W_1^k \geq (1+\lambda)I_\theta$. We deduce the maximal level of investment that country 1 is willing to commit in the common market and in the closed economy:

$$I_\theta^k = \frac{1}{1+\lambda}[W_1^{kI_\theta} - W_1^k] \qquad k = O,C \tag{18}$$

Proposition 4 *Let* I_θ^* *and* I_θ^C*,* I_θ^O *be defined equation (17) and (18) respectively. Let* $\Lambda > 0$*,* $\Delta = \theta_2 - \theta_1$ *and* $\delta \in (0,1)$*. There are 3 thresholds values* $\hat{\Delta}_1 < \hat{\Delta}_2 < \hat{\Delta}_3$ *such that:*

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

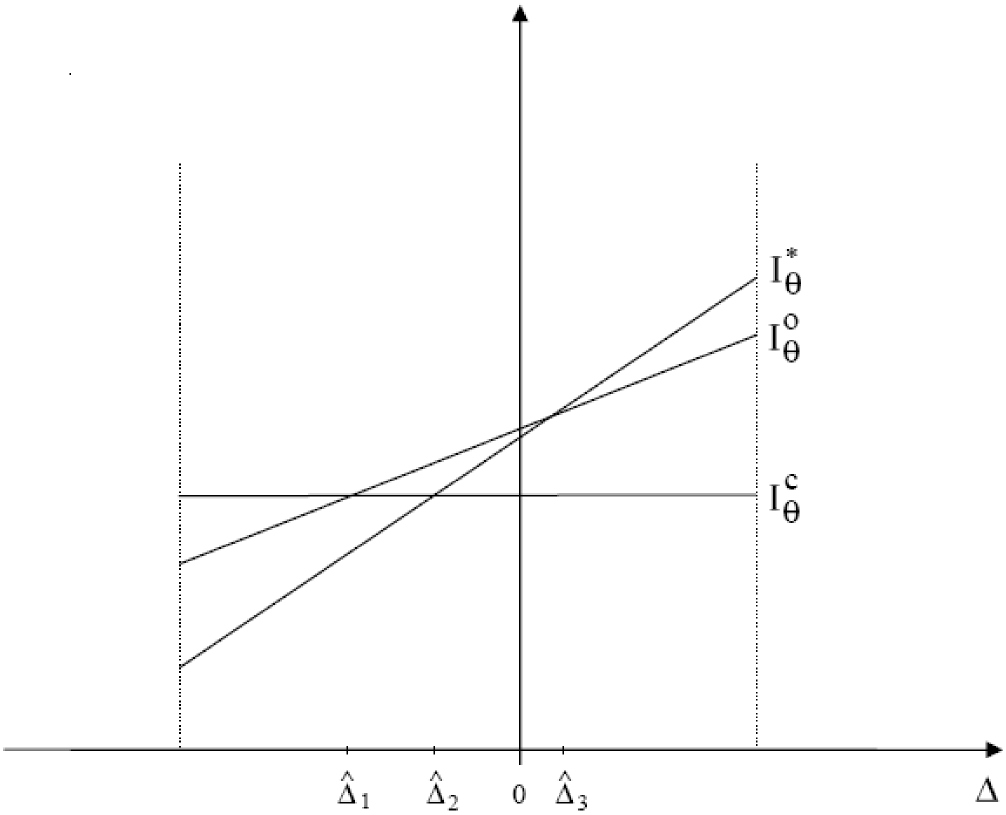
Proof. See Appendix 4. ■

Figure 4 illustrates the results of Proposition 4. It is drawn for a fixed value of $\delta\theta_1$. The static comparative parameter is Δ. When $\Lambda = 0$, business stealing has no adverse impact on national welfare so that $\hat{\Delta}_1 = \hat{\Delta}_2 = \hat{\Delta}_3 = \frac{(1-\delta)\theta_1}{2}$. 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 4).[26] When Λ is large enough Δ_3 becomes positive.

[26] When Λ increases, all thresholds I_θ^O, I_θ^* I_θ^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.

Figure 4: θ_1-reducing investment

θ_1 is fixed; Δ varies



In closed economy there is excessive investment if the investing firm is of a relatively high cost and under-investment otherwise. 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 shape of I_θ^C. Symmetrically when firm 1 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. This investment is a waste in the open economy as the market can be served by the other firm. Investing to improve the obsolete national technology is no longer optimal.

More interestingly for $\Delta > \hat{\Delta}_3$ and $\Delta < \hat{\Delta}_1$ market integration improves the situation with respect to autarky. 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 investment is too low because the investing country does not fully internalize the increase in the foreign consumer surplus (it internalizes sales). Symmetrically, when $\Delta \leq \hat{\Delta}_3$ it is too high: the possibility to reduce its cost gap and to expand its market share by serving foreign consumers makes a high level of investment attractive.

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. This would be a case in which market integration worsen the incentives to invest with respect to autarky. 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 with respect to autarky. However, the values of Δ corresponding to this situation, $[\hat{\Delta}_1, \hat{\Delta}_2]$ are generally included in the interval $[-\hat{\Delta}, \overline{\Delta}]$, for which the country with the less efficient technology would not accept integration in the first place (see Section 3).[27]

We conclude that when it occurs without pressure from the outside (i.e., when the costs difference between the two regions is large enough), power markets integration tends to improve the incentives to invest in efficient generation facilities. It allows more projects to be financed, as argued by its proponents.

[27] It is not easy to compare the relevant thresholds analytically. We have tested many values of the parameters by way of simulations and the intervals $\hat{\Delta}_1, \hat{\Delta}_2$ always fell in $[-\hat{\Delta}, 0]$. For instance, for $d = 2$, $\Lambda = 0.15$, $\theta_1 = 1/2$, $\delta = 9/10$, and $s = 9/10$, we have that $-\hat{\Delta} = -0.5$, $\overline{\Delta} = 0.01$, $\hat{\Delta}_1 = -0.23$, $\hat{\Delta}_2 = -0.08$ and $\hat{\Delta}_3 = 0.02$. Finally, the admissible values for Δ under Assumption A1 are in the interval $[-1.0, 0.57]$

4.2 Transportation Cost Reducing Investment

In this section we study the case where the collective transportation cost can be reduced from γ to $s\gamma$ with $s \in (0,1)$ by an investment of $I_\gamma > 0$. 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 $s\gamma$ 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 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:

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

The non cooperative equilibrium investment level of market integration is obtained in a similar way. The quantity produced by firm i after investment, $q_i^{OI_\gamma}$, is obtained by substituting $s\gamma$ in equation (13). Let $W_i^{OI_\gamma}$ be country $i = 1,2$ welfare function (6) evaluated at $(q_1^{OI_\gamma}, q_2^{OI_\gamma})$. The maximum level of investment that country i is willing to make in the common market is:

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

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 (14) 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 5 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 is always positive and higher than the maximal level of investment for the less efficient one. 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 by the other country.

Lemma 2 *Let* $\overline{I}_{\gamma}^{O}$ *be the maximal level of investment for the more efficient firm and* $\underline{I}_{\gamma}^{O}$ *the maximal level of investment for the less efficient one as defined in (20). Then, if* $I_{\gamma} > \overline{I}_{\gamma}^{O}$ *there is no investment. If* $\underline{I}_{\gamma}^{O} < I_{\gamma} \leq \overline{I}_{\gamma}^{O}$, *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.*[28]

Proof. See Appendix 5. ■

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

$$\overline{I}_{\gamma}^{O} \;\leq\; \overline{I}_{\gamma}^{O} + \underline{I}_{\gamma}^{O} \;\leq\; I_{\gamma}^{*} \qquad\qquad \forall \Delta, \Lambda \geq 0 \tag{21}$$

Proof. See Appendix 5. ■

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 $\overline{I}_{\gamma}^{O}$ is sub-optimal. The investing country does not take into account the impact of the investment on the 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 $\overline{I}_{\gamma}^{O} + \underline{I}_{\gamma}^{O}$ would still be

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

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 $s\gamma$ in equation (8). Let $W_i^{CI_\gamma}$ be the country $i = 1, 2$ welfare function (6) evaluated at $q_i^{CI_\gamma}$. Investment is optimal in country i if and only if $W_i^{CI_\gamma} - W_i^C \geq (1+\lambda)I_\gamma$ so that:

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

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

Proposition 6 *Let 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 I_γ^O be the maximal amount it is willing to invest in the common market. There exists $\tilde{\Delta} > 0$ such that $I_\gamma^O > I_\gamma^C$ if and only if $|\Delta| > \tilde{\Delta}$.*

Proof. See Appendix 6. ■

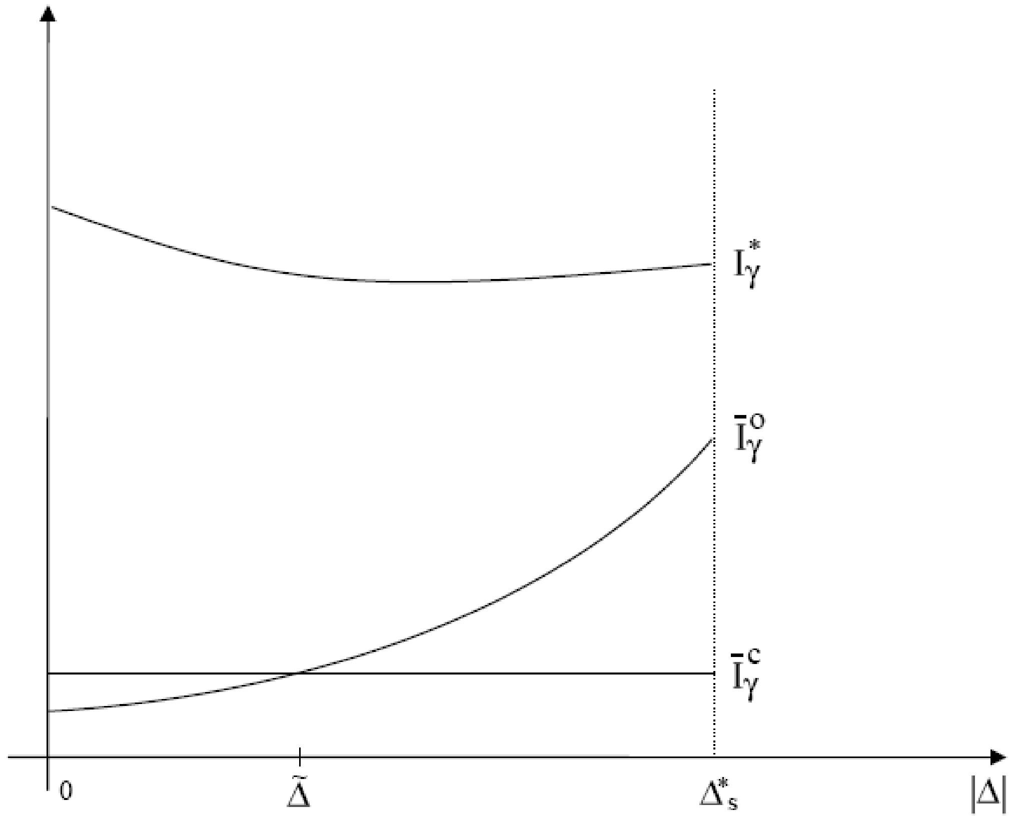
The maximal level of investment sustainable in the open economy is lower than in the case of autarky if Δ is relatively small. Indeed investment reduces the costs of the competitor and makes it more aggressive in the common market. The business stealing effect, while reducing investing country total 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. The second reason is that investment decreases the costs of the competitor, worsening the business stealing effect.[29]

Figure 5 illustrates the results of Propositions 5 and 6.

Under market integration, when Δ is relatively 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

[29]By contrast for $\Lambda = 0$, $I_\gamma^O > I_\gamma^C$ $\forall \Delta \geq 0$ and $I_\gamma^O - I_\gamma^C$ is an increasing function of Δ. When public funds are free business stealing is no longer a problem so that market integration always increases the level of sustainable investment compared to a closed economy.

Figure 5: γ-reducing investment



fierce. It reduces the capacity of financing new investment worsening the gap between the optimal investment and the equilibrium level. However this bad outcome is unlikely to occur if the less efficient country can resist integration. Indeed simulations suggest that $\tilde{\Delta}$ is higher then $\overline{\Delta}$, the threshold above which the most efficient country would win from market integration but below $\hat{\Delta}$, the equivalent threshold for the less efficient country (see Section 3).[30]

By contrast when one country has a significant cost advantage (i.e., $|\Delta| > \tilde{\Delta}$), it is willing to invest more in the common market than under closed economy because the investment increases its market share and profits. Integration can then help to increase investment, although not up to the first best level. With public good type of investment

[30]We have tested many value of the parameters by simulation and the threshold $\tilde{\Delta}$ was always larger than $\hat{\Delta}$. For instance, for $d = 2$, $\Lambda = 0.15$, $\theta_1 = 1/2$, $\delta = 9/10$ and $s = 9/10$, we have that $-\hat{\Delta} = -0.5$, $\overline{\Delta} = 0.01$ and $\tilde{\Delta} = 0.02$, while the admissible values under Assumption A1 are in the interval $[-1.0, 0.57]$.

there is always under-investment. This is in sharp contrast with investment in generation, where sectorial integration might lead to over-investment.[31]

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, 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 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 presented by its proponents as a powerful tool in stimulating investment in infrastructure industries. Intuitively, some investments that are oversized for a country should be profitable in an enlarged market. When the costs difference between the two countries is large enough market integration tends indeed to increase the level of sustainable investment. 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. Symmetrically when the investing country is less efficient than its competitor it overinvests to close its productivity gap and win market shares. With generation facilities, there is under-investment in efficient technologies and over-investment in inef-

[31]When 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 $-\hat{\Delta}_2 < \theta_1 - \theta_2 < \min\{\tilde{\Delta}, -\hat{\Delta}_2\}$ with $\tilde{\Delta}$ being defined Proposition 6, 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.

ficient ones. This is in contrast with the systematic under-investment 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 purpose. The issue of how to 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

The supra-national regulator i maximizes welfare (10) with respect to q_i, $i \in \{1, 2\}$. The first order condition gives:

$$(1+\lambda)(d - q_i(1+\gamma) - q_j - \theta_i) + \frac{q_i + q_j}{2} = 0 \tag{23}$$

Consider first the interior solution. Solving the system characterized in (23) for $i = 1, 2$ and letting $\Lambda = \frac{\lambda}{1+\lambda}$ we obtain:

$$q_i^* = \frac{d - \frac{\theta_1+\theta_2}{2}}{1+\Lambda+\gamma} + \frac{\theta_j - \theta_i}{2\gamma} \tag{24}$$

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 $\theta_i - \theta_j \geq \frac{2\gamma(d-\theta_j)}{1+\Lambda}$. 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. $\theta_j - \theta_i \geq \frac{2\gamma(d-\theta_i)}{1+\Lambda}$. 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

Maximizing the welfare function (6) we obtain the first order condition:

$$(1+\lambda)(d - \theta_i) - \frac{1}{4}[q_j(1+2\lambda) + q_i(3 + 4\lambda + 4\gamma(1+\lambda))] = 0 \tag{25}$$

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 $q_i(q_j)$:

$$q_i(q_j) = \frac{4(d - \theta_i) - q_j(1+\Lambda)}{3 + \Lambda + 4\gamma} \tag{26}$$

The equilibrium is given by the intersection of the two best response functions characterized in (26) (taking into account that quantities must be non negative). If the intersection is reached when both quantities are positive, we have:

$$q_i^O = 4\frac{d - \frac{\theta_1+\theta_2}{2}}{2(1+\gamma)+\Lambda} + \frac{\theta_j - \theta_i}{1 + 2\gamma} \tag{27}$$

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

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

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 $\theta_i - \theta_j \geq \frac{2(1+2\gamma)(d-\theta_i)}{3+4\gamma+\Lambda} < 0$. The shut down case thus writes, for $\theta_i > \theta_j$:

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

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 (13). Substituting in the inverse demand function (2) we then obtain the expression for the price given in (13).

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:

$$W_1^C = S(q_1^C) + \lambda P(q_1^C)q_1^C - (1+\lambda)(\theta_1 + \gamma\frac{q_1^C}{2})q_1^C - (1+\lambda)K \qquad (28)$$

Substituting for the value of the quantities (8) and (13) in (28) 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

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

$$I_\theta^* = \frac{(1-\delta)\theta_1 \left[d - \frac{(1+\delta)\theta_1}{2} + (1+\Lambda)\left(\frac{\Delta}{2\gamma} + \frac{(1-\delta)\theta_1}{4\gamma}\right)\right]}{1+\gamma+\Lambda}$$

$$I_\theta^C = \frac{(1-\delta)\theta_1 \left[d - \frac{(1+\delta)\theta_1}{2}\right]}{1+\gamma+\Lambda}$$

$$I_\theta^O = \frac{(1-\delta)\theta_1 \left[\left(d - \frac{(1+\delta)\theta_1}{2}\right)(4+8\gamma^2+(3+\Lambda)(\Lambda+4\gamma)) + \left[\frac{\Delta}{1+2\gamma} + \frac{(1-\delta)\theta_1}{2(1+2\gamma)}\right](1+\Lambda)(3+4\gamma+\Lambda)\right]}{(1+2\gamma)(2(1+\gamma)+\Lambda)^2}$$

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

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

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:

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

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

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

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 $\Lambda = 0$, $\hat{\Delta}_1 = \hat{\Delta}_2 = \hat{\Delta}_3 = -\frac{(1-\delta)\theta_1}{2} < 0$. 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.

Appendix 5

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

$$W_1^O = S(Q^O) - P(Q^O)q_2^O + \lambda P(Q^O)q_1^O - (1+\lambda)(\theta_1 + \gamma\frac{q_1^O}{2})q_1^O - (1+\lambda)K$$

$$W_1^{OI_\gamma} = S(Q^{OI_\gamma}) - P(Q^{OI_\gamma})q_2^{OI_\gamma} + \lambda P(Q^{OI_\gamma})q_1^{OI_\gamma} - (1+\lambda)(\theta_1 + s\gamma\frac{q_1^{OI_\gamma}}{2})q_1^{OI_\gamma} - (1+\lambda)K - (1+\lambda)I_\gamma$$

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:

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

$$\Lambda_2^{ii} = \frac{\Lambda(3+4s\gamma+\Lambda)}{(1+2s\gamma)(2(1+s\gamma)+\Lambda)^2} - \frac{\Lambda(3+4\gamma+\Lambda)}{(1+2\gamma)(2(1+\gamma)+\Lambda)^2}$$

$$\Lambda_3^{ii} = \frac{2(1-s)\gamma(4(1+\gamma)(1+s\gamma)-\Lambda)^2}{(1+2s\gamma)^2(2(1+s\gamma)+\Lambda)^2}$$

Λ_1^{ii} and Λ_2^{ii} are positive $\forall s \in (0,1), \Lambda \in [0,1)$. $I_{\gamma i}^O$ 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: $\overline{I}_\gamma^O > \underline{I}_\gamma^O$.

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 $\overline{I}_\gamma^O > \underline{I}_\gamma^O$. Then, for $\underline{I}_\gamma^O < I_\gamma < \overline{I}_\gamma^O$ 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 $\overline{I}_\gamma^O$ with the optimal level I_γ^* and the closed economy $\overline{I}_\gamma^*$, 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, $\overline{I}_\gamma^O$ is strictly positive and increasing in $|\Delta|$, while $\underline{I}_\gamma^O$ is U shaped. The sign of $\underline{I}_\gamma^O$ 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 $\underline{I}_\gamma^O$ 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 $\underline{I}_\gamma^O$ is positive. In $\Delta = 0$, $\underline{I}_\gamma^O$ is positive and decreasing in $|\Delta|$. We have to prove that $\underline{I}_\gamma^O$ might be negative for some $\Delta < 0$. In $\Delta = -\frac{2(1+2s\gamma)(d-\theta_2)}{1+\Lambda}$ (the minimal admissible value under A1) $W_1^{I_\gamma} - W_1$ is negative if and only if $\Lambda > \overline{\Lambda} = \frac{\sqrt{9+8s\gamma+4\gamma(10+7s\gamma+\gamma(3+\gamma(1+s))(5+\gamma(1+s)))}-(1+2\gamma(2+\gamma(1+s)))}{1+2\gamma}$. Then, $\Lambda > \overline{\Lambda}$ 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:

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

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

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:

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

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 ($\Lambda_1^i > 0, \forall s \in (0,1), \Lambda \in [0,1)$).

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

$$I^*_\gamma - I^O_\gamma = \Delta^2\Lambda^{iii}_1 + (d-\theta_i)\Delta\Lambda^{iii}_2 - (d-\theta_i)^2\Lambda^{iii}_3$$

$$\begin{aligned}
\Lambda^{iii}_1 &= \frac{1}{s\gamma} + \frac{1}{1+s\gamma+\Lambda} - \frac{2(1+s\gamma(1-\Lambda))(3+4s\gamma+\Lambda)}{(2(1+s\gamma))(2(1+s\gamma)+\Lambda)^2} \\
&\quad -\frac{1}{\gamma} - \frac{1}{1+\gamma+\Lambda} + \frac{2(1+\gamma(1-\Lambda))(3+4\gamma+\Lambda)}{(2(1+\gamma))(2(1+\gamma)+\Lambda)^2} \\
\Lambda^{iii}_2 &= -\frac{1}{1+2s\gamma} - \frac{1}{1+s\gamma+\Lambda} + \frac{4(1+s\gamma)^2+\Lambda}{(1+2s\gamma)((2(1+s\gamma)+\Lambda)^2)} \\
&\quad +\frac{1}{1+2\gamma} + \frac{1}{1+\gamma+\Lambda} - \frac{4(1+\gamma)^2+\Lambda}{(1+2\gamma)((2(1+\gamma)+\Lambda)^2)} \\
\Lambda^{iii}_3 &= \frac{1}{1+s\gamma+\Lambda} - \frac{2(1+s\gamma)}{(2(1+s\gamma)+\Lambda)^2} - \frac{1}{1+\gamma+\Lambda} + \frac{2(1+\gamma)}{(2(1+\gamma)+\Lambda)^2}
\end{aligned}$$

Λ^{iii}_1 is positive for all $s \in (0,1), \Lambda \in [0,1)$. Then, $I^*_\gamma - I^O_\gamma$ is a U shaped function of Δ. Moreover, one can easily show that $I^*_\gamma - I^O_\gamma$ decreases with Λ. An increase in Λ shifts the U curve downwards. Than, a sufficient condition for $I^*_\gamma - I^O_\gamma$ to be always positive is to have a positive minimum when $\Lambda = 1$. Since $I^*_\gamma - I^O_\gamma$ is a convex function of Δ, the minimum is obtained from the first order condition $\frac{\partial(I^*_\gamma - I^O_\gamma)}{\partial\Delta} = 0$. In $\Lambda = 1$, this minimum is equal to:

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

Then, $I^*_\gamma - I^O_\gamma$ is always positive.

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

$$\overline{I}^O_\gamma + \underline{I}^O_\gamma = \Delta^2\Lambda^{iv}_1 + (d-\theta_i)\Delta\Lambda^{iv}_2 + (d-\theta_i)^2\Lambda^{iv}_3$$

where:

$$\begin{aligned}
\Lambda^{iv}_1 &= \frac{(1-s)\gamma(3+4(\gamma+s\gamma(1+\gamma))}{(1+2\gamma)^2(1+2s\gamma)^2} - \frac{1+\gamma}{(2(1+\gamma)+\Lambda)^2} + \frac{1+s\gamma}{(2(1+s\gamma)+\Lambda)^2} \\
\Lambda^{iv}_2 &= -\frac{4(1-s)\gamma(4(1+\gamma)(1+s\gamma)-\Lambda^2)}{(2(1+\gamma)+\Lambda)^2(2(1+s\gamma)+\Lambda)^2} \\
\Lambda^{iv}_3 &= \frac{4(1-s)\gamma(4(1+\gamma)(1+s\gamma)-\Lambda^2)}{(2(1+\gamma)+\Lambda)^2(2(1+s\gamma)+\Lambda)^2}
\end{aligned}$$

Then,

$$I^*_\gamma - \overline{I}^O_\gamma - \underline{I}^O_\gamma = \Delta^2 \Lambda^v_1 + (d-\theta_i)\Delta\Lambda^v_2 - (d-\theta_i)^2\Lambda^v_3$$

where:

$$\begin{aligned}
\Lambda^v_1 &= \frac{1+\gamma}{(2(1+\gamma)+\Lambda)^2} - \frac{1+s\gamma}{(2(1+s\gamma)+\Lambda)^2} - \frac{1}{4(1+\gamma+\Lambda)} + \frac{1}{4(1+s\gamma+\Lambda)} \\
&\quad - \frac{1}{4\gamma(1+2\gamma)^2} + \frac{1}{4s\gamma(1+2s\gamma)^2} \\
\Lambda^v_2 &= \frac{1}{(1+\gamma+\Lambda)} - \frac{1}{(1+s\gamma+\Lambda)} + \frac{4(1+\gamma)}{(2(1+\gamma)+\Lambda)^2} - \frac{4(1+s\gamma)}{(2(1+s\gamma)+\Lambda)^2} \\
\Lambda^v_3 &= \frac{(1-s)\gamma\Lambda^2 4(1+s(1+s))\gamma^2 + 4(1+s)\gamma(3+2\Lambda) + (2+\Lambda)(6+5\Lambda)}{(1+\gamma+\Lambda)(1+s\gamma+\Lambda)(2(1+\gamma)+\Lambda)^2(2(1+s\gamma)+\Lambda)^2}
\end{aligned}$$

Λ^v_1 is positive $s \in (0,1), \Lambda \in [0,1)$, then $I^*_\gamma - I^J_\gamma$ is a convex U-shaped function of Δ. Moreover, one can verify that the difference $I^*_\gamma - I^J_\gamma$ is decreasing with Λ. Then, the difference is minimal in $\Lambda = 0$, where:

$$I^*_\gamma - \overline{I}^O_\gamma - \underline{I}^O_\gamma = \frac{\gamma(1+2\gamma)^2 - s\gamma(1+2s\gamma)^2}{4\gamma(1+2\gamma)^2(1+2s\gamma)^2} > 0, \ \ \forall \ s \in (0,1)$$

Then, $I^*_\gamma - \overline{I}^O_\gamma - \underline{I}^O_\gamma$ is always positive.

Appendix 6

In the case of closed economy, welfare with no investment is given by (28). If I_γ is invested, the welfare function becomes:

$$W^{CI_\gamma}_i = S(q^{CI_\gamma}_i) + \lambda P(q^{CI_\gamma}_i) - (1+\lambda)(\theta_i + s\gamma\frac{q^C_i}{2})q^{CI_\gamma}_i - (1+\lambda)K - (1+\lambda)I_\gamma$$

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:

$$I^C_{\gamma i} = \frac{(1-s)\gamma(d-\theta_i)^2}{2(1+\gamma+\Lambda)(1+s\gamma+\Lambda)}$$

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

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

Then, $I^O_\gamma - I^C_\gamma$ is always positive.

We now compare I^O_γ and I^C_γ. Because I^O_γ is increasing and convex, while I^C_γ is constant, $I^O_\gamma - I^C_\gamma$ is also increasing and convex in Δ. In particular, if $\Lambda = 0$:

$$I^O_\gamma - I^C_\gamma = \frac{(1-s)\gamma(11+4\gamma(3(2+\gamma)+s(3+4\gamma)(2+\gamma(1+s))))}{8(1+\gamma)(1+s\gamma)(1+2\gamma)^2(1+2s\gamma)^2}\Delta^2 \geq 0 \;\; \forall s \in (0,1)$$

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

$$I^O_\gamma - I^C_\gamma = -\frac{1}{2}(1-s)\gamma(d-\theta_i)^2 \left[\frac{1}{(1+s\gamma+\Lambda)} - \frac{1}{(1+\gamma+\Lambda)} + \frac{4(1+s\gamma)}{(2(1+s\gamma)+\Lambda)} - \frac{4(1+\gamma)}{(2(1+\gamma)+\Lambda)}\right]$$

This is negative for all $s \in (0,1), \Lambda \in [0,1)$. From the increasing shape of I^O_γ, there exists $\tilde{\Delta} > 0$ such that for all $\Delta > \tilde{\Delta}$, $I^O_\gamma > I^C_\gamma$.

Appendix 7

If quantity regulation is banned, each producer maximizes profit (4) choosing the Cournot quantities:

$$q_1^N = \begin{cases} 0 & \text{if } \Delta < -(1+2\gamma)(d-\theta_1); \\ \frac{2(d(1+2\gamma)-2(1+\gamma)\theta_1+\theta_2)}{3+4\gamma(2+\gamma)} & \text{if } -(1+2\gamma)(d-\theta_1) \leq \Delta \leq (1+2\gamma)(d-\theta_2); \\ \frac{d-\theta_1}{1+\gamma} & \text{if } \Delta > (1+2\gamma)(d-\theta_2). \end{cases} \quad (29)$$

$$q_2^N = \begin{cases} \frac{d-\theta_2}{1+\gamma} & \text{if } \Delta < -(1+2\gamma)(d-\theta_1); \\ \frac{2(d(1+2\gamma)-2(1+\gamma)\theta_2+\theta_1)}{3+4\gamma(2+\gamma)} & \text{if } -(1+2\gamma)(d-\theta_1) \leq \Delta \leq (1+2\gamma)(d-\theta_2); \\ 0 & \text{if } \Delta > (1+2\gamma)(d-\theta_2). \end{cases} \quad (30)$$

Where N stands for "no regulation". As in appendix 3, we consider country 1 (the same holds for country 2 inverting θ_1 and θ_2 and replacing Δ with $-\Delta$ in all expressions). Replacing the quantities q_1^N and q_1^N in the welfare function (6) and letting $\theta_2 = \theta_1 + \Delta$ gives:

$$W_1^N = \Delta^2\Lambda_1^N + \Delta(d-\theta_1)\Lambda_2^N + (d-\theta_1)^2\Lambda_3^N - \frac{1}{1-\Lambda}K$$

Where:

$$\Lambda_1^N = \begin{cases} \frac{1}{8(1+\gamma)^2}, & \text{if } \Delta < -(1+2\gamma)(d-\theta_1); \\ \frac{(4\gamma(\gamma(1-\Lambda)+2-\Lambda)+5-\Lambda)}{2(4\gamma(\gamma+2)+3)^2(1-\Lambda)}, & \text{if } -(1+2\gamma)(d-\theta_1) \leq \Delta \leq (1+2\gamma)(d-\theta_2); \\ 0, & \text{if } \Delta > (1+2\gamma)(d-\theta_2). \end{cases}$$

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

$$\Lambda_3^N = \begin{cases} \frac{1}{8(1+\gamma^2)}, & \text{if } \Delta < -(1+2\gamma)(d-\theta_1); \\ \frac{4\gamma(\gamma(1-\Lambda)+2-\Lambda)+5-\Lambda}{2(3+4\gamma(\gamma+2))^2(1-\Lambda)}, & \text{if } (1+2\gamma)(d-\theta_1) \leq \Delta \leq (1+2\gamma)(d-\theta_2); \\ \frac{5+4\gamma-\Lambda}{8(1+\gamma)^2(1-\Lambda)}, & \text{if } \Delta > (1+2\gamma)(d-\theta_1). \end{cases}$$

We compare this function with the welfare of country i in our base case computed replacing in (6) the quantities derived in Appendix 2:

$$W_1^O = \Delta^2\Lambda_1^O + \Delta(d-\theta_1)\Lambda_2^O + (d-\theta_1)^2\Lambda_3^O - \frac{1}{1-\Lambda}K$$

Where:

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

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

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

One can check that both welfare W_1^N and W_1^O are U-shape. Moreover, if $\Delta = 0$, we can easily calculate:

$$W_1^N - W_1^O = -\frac{2(d-\theta_1)^2(1+\gamma(1-3\Lambda)-\Lambda(3+\Lambda))}{(3+2\gamma)^2(2+2\gamma+\Lambda)^2}$$

This is positive if and only if $\Lambda \geq \Lambda^N = \frac{1}{2}\left(\sqrt{13+9\gamma^2+22\gamma} - 3(1+\gamma)\right)$. For each $\gamma \geq 0$, the threshold Λ^N is included in the interval $[0.3, 0.33]$. Then, for Λ greater than $\Lambda^N \approx 1/3$, banning quantity regulation would increase welfare in both countries. For Λ lower than Λ^N, keeping quantity regulation is Pareto-improving. The result is a reminiscence of the findings of Collie (2000), although it is not exactly identical due to the difference in the policy considered (Collie, 2000 considers unit trades subsidies instead of quantity regulation and find a closed interval of values of Λ for which banning these subsidies is Pareto-improving).

However the result does not necessarily hold for $\Delta \neq 0$. Take for instance the interior solution which arises when $-(1+2\gamma)(d-\theta_1) \leq \Delta \leq (1+2\gamma)(d-\theta_2)$. In this case, $W_1^N > W_1^O$ if and only if $\Delta > \frac{2(1+2\gamma)(d-\theta_1)(1+\gamma(1-3\Lambda)-\Lambda(3+\Lambda)}{7+6\gamma^2(1-\Lambda)+\gamma(13-\Lambda(7+2\Lambda))-\Lambda^2}$. This can be positive or negative depending on the values of γ and Λ. In any case, when $|\Delta|$ is sufficiently large, the less efficient country prefers to keep quantity regulation while the more efficient prefers deregulation.

For the cases in which $W_i^N > W_i^O$ for both countries $i = \{1,2\}$, the shape of the welfare gains with respect to autarky is not qualitatively affected. Comparing W_i^N and W_i^C with the same methodology as in Appendix 3, a similar result arises: even after allowing for quantity deregulation, integration increases welfare in both countries if and only if production costs are sufficiently different.