# Powering Up Developing Countries through Integration?*

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**Abstract**

**Abstract:** Power market integration is analyzed in a two countries model with nationally regulated firms and costly public funds. Integration is welfare-enhancing only if the difference in generation costs between the two regions is large enough. The benefits from export profits increase 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. Uncoordinated policies imply an under-investment in relatively efficient generation facilities and an over-investment in inefficient ones. They also imply a systematic under-investment in transportation facilities. Free-riding reduces the incentives to invest in these public-good components, while business-stealing tends to decrease the capacity for financing new investment.

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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. In most cases, this integration is likely to occur in the absence of a legitimate supranational regulation. 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 market shares limit the benefit of integration. Because of the 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, several generation and interconnection projects have been launched to exploit efficiency gains between countries that do not have sufficient energy resources, such as Brazil or Chile, and countries that have large supply potential in terms of hydropower, heavy oil and gas, such as Paraguay, Venezuela, Bolivia, and Peru. Similarly in the Greater Mekong Subregion countries such as Thailand and Vietnam, want to integrate with countries with large

[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). Indeed 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).

[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.

supply potential in terms of hydropower and gas resources, 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, are designed to foster the emergence of major projects such as large hydroelectric-generation facilities. These projects are unlikely to be achieved otherwise, as they are out of scale with the local demand. 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 benefit all countries in the region.[3] The challenging question, however, is how to finance them.

Electricity is a non storable good that requires large specific investments, such as transportation and interconnection facilities, to be transferred to other markets. For instance 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). This is a major difference between electricity and trade of standard commodities. In the absence of a binding commitment mechanism, firms and governments are unwilling to sink huge investments with the sole purpose of selling electricity to a neighbor country in the future. Once these specific investments are realized, they would incur a classic hold up problem. The trade partner could always renegotiate the price, while the investor has no possibility to sell the energy elsewhere. This commercial risk is particularly acute in developing countries.[4] In this context the creation of a power pool, with a free trade agreement and a sound mechanism for dispute resolution, mitigates

[3]For West Africa, Sparrow et al. (2002) estimate between 5 and 20% the potential cost reduction associated with market integration (based on the expansion of the thermal and hydroelectric capacities).

[4]For instance in 2009 the electricity ministry of Iraq announced that it couldn't pay the $2.4 billion bill to G.E. and hence power production would stop (Attwood, 2009), in Madagascar the Enelec firm decreased its provision of electricity to the public distributor company Jirama leading to power shortage because of billions of unpaid bills (Navalona, 2012), in Zimbabwe the utility Zesa Holdings failed to pay for electricity imports because of US $ 537 million in unpaid electricity bills (The Herald, 2011).

commercial, political and regulatory risks, as it strengthens countries' coordination and limits political interference. This structure has hence been chosen to promote investment in neighboring developing countries endowed with unequal energy resources.[5]

The paper studies the impact of the creation of a regional power pool (i.e., an integrated electricity market with a free trade agreement) on energy production and on the incentives to invest in generation and in transmission infrastructures in a two countries model. Since the integration is imperfect (i.e., it is not political, nor fiscal), governments focus on their national welfare. They are biased in favor of their national (public) firm because they are residual claimant for its profits and losses. Theoretically, the relevant analytical framework is that of asymmetric regulation (i.e., each firm is nationally regulated) with costly public funds. This framework has been first introduced by Caillaud (1990) and Biglaiser and Ma (1995) to study the liberalization of regulated industries.[6] Since market integration is a process of reciprocal market opening, the present paper extends their analysis, which focus on the effects of unregulated competition in a closed economy, to the case where the unregulated entrant is the incumbent of the foreign market. Considering both countries simultaneously 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 successful, and in which cases it is likely to fail.

We show that integration of power markets is welfare-enhancing for both countries when the cost difference between the two regions is large enough. For the low cost region, the benefits from increased export profit (due to the possibility of serving also foreign demand) increase total welfare in the exporting country. For the high cost region, the domestic market benefits from the reduction in price caused by importation, which enhances consumer surplus.[7] By contrast sectorial integration is not likely to occur if the cost dif-

[5]For instance, in December 2003 the member of the Economic Community of West African States (ECOWAS) signed the ECOWAS Energy Protocol, which calls for the elimination of cross-border barriers to trade in energy. The project, known as the West African Power Pool (WAPP), started with Nigeria, Benin, Togo, Ghana, Côte d'Ivoire, Burkina Faso and Niger as they were already interconnected.

[6]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.

[7]Even if the efficiency gains from integration are large enough so that both countries win from integration, opposition might still subsist internally because while reallocating production towards the more efficient providers, trade liberalization creates winners and losers internally.

ference between the two countries is small. Indeed unregulated competition undermines the tax base (Armstrong and Sappington, 2005). Without a significant technological gap, competition for the market shares is fierce between the two countries so that the negative business-stealing out-weights the gain from trade. In contrast to the literature on trade subsidization policies (see Brander, 1997), welfare can *decrease* in both regions following integration. All countries might loose from trade even in the absence of sizeable transportation costs and/or non-convexities.[8]

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 generation. 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 those to invest in efficient technology increase. Second, when the two countries' technology are similar, the firms have to fight for their market shares and might thus overinvest in generation compared to the optimal solution. In practice this risk of over-investment is nil. First, countries will resist the creation of a power pool if their costs difference is not large enough. Second, developing countries suffer from massive under-investment in generation. By stimulating investment market integration can only alleviate this problem.

By contrast 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

[8]This finding strikingly differs from results in the trade literature. Starting with Brander and Spencer (1983), a part of this literature has focused on the strategic effect of trade subsidization policies. They have a rent-shifting effect that creates a prisoner's dilemma, so that firms would benefit from jointly reducing the subsidies. However, even if the benefit from trade is lower, it is always positive. Similarly in models à la Brander and Krugman (1983) welfare loss cannot occur with trade unless transportation costs are very high, or there are non-convexities (see Markusen (1981)).

that global investment decreases compared to autarky. That is, when the firms generation costs are too close, 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 the generation costs are too close. However, even if the costs' gap is large so that integration benefits both countries, 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 World 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.

Section 2 of the paper presents the model and the benchmark of a closed economy. Section 3 studies sectoral integration, while Section 4 focuses on the countries incentives to invest in generation (i.e., in section 4.1) and in transportation infrastructure (i.e., in section 4.2). Finally, section 5 offers some concluding remarks.

# 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:[9]

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

where $Q_i$ is the home demand in country $i = 1, 2$. The demand symmetry assumption is made to ease on the exposition. Appendix G shows that our main results are robust

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

to asymmetric demands (i.e., different $d_1 \neq d_2$). 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. $Q = q_1 + q_2$).

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.[10] We thus avoid introducing new notation for this sunk cost. 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 $\gamma$, 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 the cost function in (3), allowing the interpretation of $\gamma$ as a transportation cost (see Auriol, 1998).[11]

[10] 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.

[11] 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 $\gamma q$ 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 $c(\theta_i, q_i) = \theta_i q_i + \gamma \frac{q_i^2}{2}$ $(i = 1, 2)$.

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 $\gamma$ 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.[12]

So to sum up, $\theta_i \in [\underline{\theta}, \overline{\theta}]$ can be interpreted as a generation cost, constant after some fixed investment has been done, while $\gamma$ is a measure of transportation costs (i.e., transport charges and losses). In what follow we assume that $\gamma$ and $\theta_i$ are common knowledge. Any distortions occurring at the equilibrium can thus be ascribed to a coordination failure between the national regulators. However our results are robust to the assumption of asymmetric information on these parameters.[13] 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

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

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 quantities and the investments of the firm and is allowed to transfer funds from and

[12] For more details on the specificities of electric markets see Joskow and Schmalensee (1985).

[13] Since $\gamma$ 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 $\theta_i$, some rent has to be abandoned to the producer in order to extract this information. The cost parameter is replaced by the virtual cost (i.e., production cost plus information rent, $\theta_i + \Lambda \frac{F(\theta_i)}{f(\theta_i)}$, where $f$ and $F$ are the density and repartition functions of $\theta_i$). Introducing asymmetric information then does not change our main results except for the inflated cost parameter (computations available upon request). In the event of the creation of a supranational regulator, the impact of asymmetric information will depend on its ability to gather information on the firms compared to the national regulators.

to it. She taxes operating profits when they are positive, and subsidizes losses. This is consistent with public ownership. In the case of electricity public and mixed firms are indeed key players in most developing countries: In 2004, 60% of less developed countries had no significant private participation in electricity (Estache, Perelman, and Trujillo, 2005).[14] In contrast, rent extraction does not apply to foreign firms because they do not report their profits locally. The regulator does not seize the rent of foreign firm and does not have to subsidize the losses. Moreover, the regulator of country $i$ does not control the production nor the investment of firm $j$ (i.e., asymmetric regulation).

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, $\Pi_i$ the profit of the national firm, and $(1+\lambda)t_i$ the opportunity cost of public transfers. Since $W_i$ is decreasing in $\Pi_i$ when $\lambda \geq 0$, leaving rents to the monopoly is socially costly. The participation constraint of the national firm (5) always binds: $\Pi_i = 0$.[15] The utilitarian welfare function in country $i = 1, 2$ is

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

The regulator of country $i$ is not indifferent between producing power locally (i.e., $q_i$) and importing it (i.e., $Q_i - q_i$). She is biased in favor of local production. This national preference, which is consistent with countries' objective of energy independence, reflects the fact that the regulator is residual claimant for the firm profit and loss. The bias hence increases with $\lambda \geq 0$, which can be interpreted as the shadow price of the government budget constraint (i.e., the Lagrange multiplier of this constraint).[16] Any additional investment in public utilities implies a reduction of the production of essential public goods, or any other commodities that generate positive externalities, such as health care.

[14] 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.

[15] Here regulation is effective (there is no problem of reducing the monopoly power in the closed economy). We thus abstract from a possible alternative motivation for integration as a way to reduce the market power of the incumbent.

[16] 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 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 advanced economies $\lambda$ is usually estimated at around 0.3 (Snow and Warren, 1996). In developing countries low income levels and difficulties implementing effective taxation imply higher values for $\lambda$. The World Bank (1998) suggests an opportunity cost of 0.9 as a benchmark, but it can be much higher in heavily indebted countries.

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. To avoid introducing a bias in the integration decision we assume that both countries have the same cost of public funds $\lambda$. In what follows, we express the results in terms of $\Lambda$, which increases with $\lambda \in [0, +\infty)$:

$$\Lambda = \frac{\lambda}{1+\lambda} \in [0, 1]. \tag{7}$$

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 $Q_i = q_i$. The optimal autarky quantity is:

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

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

The closed economy case corresponds to a pure autarky model in which the electricity is distributed and produced internally. Alternatively, we could consider other forms of import and export of energy, without the formation of a power pool or the existence of a free trade agreement. In this case, countries could negotiate to import a certain quantity of electricity from abroad (at a given price) and then sell it internally at the regulated price. This differs from the integrated case studied bellow, because the regulator would be able to control the total quantity sold in the internal market. This case of negotiated import (or equivalently regulated import quotas) boils down for the national regulator to a problem of production allocation over two plants with different cost functions (one plant would be the national producer, and the other the import possibility). This would lead to a different (lower) aggregate cost function. Nevertheless the regulator would still choose total quantity sold in the market. Given the demand and the new cost function she would determine a Ramsey-price similar to the one described above. This solution, which does not differs qualitatively from autarky, would allow exploiting a superior foreign technology without incurring the coordination problems related to business stealing.

In practice import agreements of this kind remains small in size and do not constitute a valid solution to the capacity shortage faced by most developing countries as they do not stimulate investment. The complexity and financial commitments in international electricity trade projects require a level of coordination among the parties that cannot be achieved by a simple ex-post purchase agreement. The creation of a power pool will encourage investment in the energy sector by providing for international arbitration for dispute resolution, repatriation of profits, protection against expropriation of assets, and other terms considered attractive by potential investors. The next section studies the impact of the creation of an integrated power pool on energy production.

# 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. In section 3.1 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 politically and fiscally. In section 3.2, we consider sectorial integration with two independent regulators. Finally in section 3.3 we perform a welfare analysis and determine the distributive impact of integration.

## 3.1 Full integration

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

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

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, 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 that the optimal consumption allocations are $Q_1 = Q_2 = \frac{Q_1+Q_2}{2}$. Hence the supranational utilitarian objective function (9) becomes

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

Let $\theta_{\min} = \min\{\theta_1, \theta_2\}$ and $\Delta = \theta_2 - \theta_1$, which can be positive or negative. Second, (10) is optimized with respect to the quantities $q_1$ and $q_2$.

**Proposition 1** *The socially optimal quantity is:*

$$Q^* = \begin{cases} \frac{2}{1+\Lambda+2\gamma}(d-\theta_{\min}) & \textit{by monopoly if } |\Delta| > \Delta^* = \frac{2\gamma(d-\theta_{\min})}{1+2\gamma+\Lambda} \\ \frac{2}{1+\Lambda+\gamma}\ (d - \frac{\theta_1+\theta_2}{2}) & \textit{by duopoly } i = 1,2 \textit{ with } q_i^* = \frac{Q^*}{2} + \frac{\theta_j - \theta_i}{2\gamma} \textit{ otherwise.} \end{cases} \tag{11}$$

**Proof.** See Appendix A. ■

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 of the less efficient firm. However the "shut down" result is upset with the introduction of transportation cost. When $\gamma$ 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 (11)). However, the market share differences decreases with $\gamma$.

In practice sectorial integration generally excludes fiscal and political institutions, which remain decentralized at the country level.[17] 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 national welfare (6). The system of reaction functions of the regulators determine the non cooperative equilibrium.

**Proposition 2** *The quantity produced at the non cooperative equilibrium of the sectorial integration game is:*

$$Q^O = \begin{cases} \frac{4}{3+4\gamma+\Lambda}\left(d-\theta_{\min}\right) & \textit{by monopoly if } |\Delta| \geq \Delta^O = \frac{2(1+2\gamma)(d-\theta_{\min})}{3+4\gamma+\Lambda} \\ \frac{4}{2+2\gamma+\Lambda}\left(d-\frac{\theta_1+\theta_2}{2}\right) & \textit{by duopoly } i=1,2 \textit{ with } q_i^O = \frac{Q^O}{2}+\frac{\theta_j-\theta_i}{1+2\gamma} \textit{ otherwise} \end{cases} \tag{12}$$

**Proof.** See Appendix B. ■

Comparing equations (12) 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.

Comparing the common market with the closed economy case, it is straightforward to check that $Q^O$ defined equation (12) 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 $|\Delta| \leq \Delta^*$, we have that $Q^C = Q^*$ defined equation (11). We deduce that excessive production occurs in the common market. To be more specific comparing $Q^O$ and $Q^*$ yields

$$Q^O \geq Q^* \quad \Leftrightarrow \quad |\Delta| \leq \Delta^{O/*} = \frac{(2\gamma+\Lambda)(d-\theta_{\min})}{1+2\gamma+\Lambda}. \tag{13}$$

[17] The 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.

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 $Q^O > Q^*$.[18] 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, competition for the rents of the sector yields inefficiencies that might prevent sectorial integration. 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 $\Lambda$ strictly positive, market integration increases welfare in both countries if and only if the difference in the marginal costs $|\Delta|$ is large enough.*

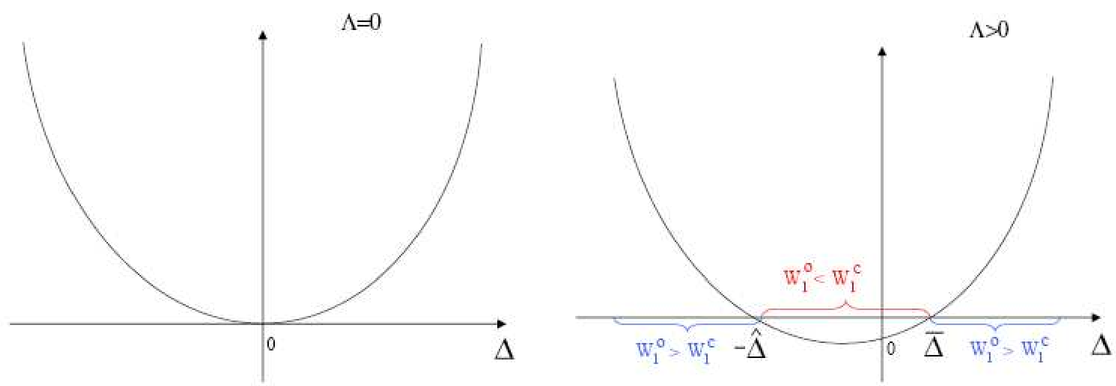
**Proof.** See Appendix C. ■

Figure 1 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 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

[18] Substituting $Q^O$ from equation (12) in market share equation $q_i^O$ 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.

increase in consumer surplus in the country with a smaller market share. However, the equilibrium quantities (12) do not corresponds with the optimal levels (11) as not all gains from trade are exploited. The results are modified when $\Lambda > 0$. In this case 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 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. For $|\Delta|$ big enough, the welfare gains are positive in both countries.

Figure 1: Welfare gains from integration, $W_1^O - W_1^C$




The country with the less efficient technology generally has lower gains from integration ($\hat{\Delta} \geq \overline{\Delta}$). 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 $\Delta$ belonging to the interval $[-\overline{\Delta}, \overline{\Delta}]$, the creation of a power pool managed by two independent regulators is inefficient. Each country welfare is decreased by integration. The region as a whole is better off with the co-existence of two separated markets. This result is not related to the assumption of a limited competition (i.e., duopoly). Increasing the number of unregulated competitors, including foreign firm reporting its profit in a 3rd country, would only worsen the negative business stealing. Similarly laissez-faire policy would not suppress the welfare losses related to business stealing.[19]

For values 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 increases in both countries for values of $\Delta$ 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 is large.

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 $|\Delta| \leq \Delta^O$. Market integration induces a price reduction in country $i = 1, 2$ if and only if the costs difference is not too large, that is if $\theta_j - \theta_i \leq \frac{\Lambda(d-\theta_i)}{1+\gamma+\Lambda}$.[20] 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.[21] If the government is unable to seize 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, harming taxpayers and thus total welfare. 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,

[19] The trade and competition literature shows that, when firms are identical, the welfare losses can be reduced by jointly banning the subsidies and commit to a laissez-faire policy (Brander and Spencer, 1983, Collie, 2000). When firms are identical we obtain similar result for some values of $\Lambda$ (as in Collie, 2000). However, this result is not robust to the assumption of heterogeneous firms.

[20] Substituting $Q^O$ from equation (12) 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 the result.

[21] In the international trade literature a similar conflict of interest generally arises between domestic producers and consumers (see Feenstra, 2008).

induces welfare losses.

Our welfare analysis is conducted under several simplifying assumptions that need to be discussed. First, we have focused on asymmetry in costs. Yet countries might differ in other dimensions. In particular they might have different market size (i.e., $d_1 \neq d_2$). We have explored this possibility in the appendix G. Because of the quadratic transportation costs, a smaller country has a smaller marginal cost in a closed economy. Market integration generates additional efficiency gains by reallocating production towards the producers which had initially the smaller internal demand. We hence show in the appendix that the smaller country always wins more for integration than the large one. This result is in line with the finding in the international trade literature that smaller economies tend to gain more from trade in oligopolistic markets than large one (see Markusen, 1981). The appendix G also shows that our main result is robust: sectoral integration is welfare degrading if the countries are too similar (i.e., in cost and in demand).

Second, one could think that the inefficiency result yields by sectoral integration is related to the limited set of tax instruments used by the regulator. Indeed we concentrate on profit taxation of regulated firms and we do not study the possibility of introducing additional taxes (e.g. a general tax on consumer such as a VAT or a tax on transport or distribution). In a closed economy this is done without loss of generality because there is no need for additional taxes when it is possible to fix both the price and the tax on total industry profits. In the integrated market, this irrelevance result does not hold because the national regulator is unable to tax the importing firm profit, nor control its offer. Competition for the market shares erodes the national firm profit and thus the possibility of taxation. Assuming new instruments are introduced, if the regulator is allowed to use different tax rates on foreign and domestic firms, she will be able to influence the volume of import. The regulator uses the tax structure to reduce the market share of the foreign firm, whenever it does not bring enough efficiency gains (i.e. by reducing the market share of the competitor in such a way that it does not "steal" demand with respect to autarky). However such asymmetric treatment is incompatible with the creation of an integrated electricity market aimed at promoting investment. Investors need to be sure that they will be able to sell their production in the foreign market without facing the ex-post threat of abusive taxation, nor other hold up problems. In this case, the regulator is obliged to apply the same tax rate to local and foreign firms. Adding taxes on the volume of transaction could be used to generate an income on the activities of the foreign firm, as well as to influence somehow its scale of production. However in addition to greatly complicates the model resolution, this form of taxation cannot restore efficiency. The heart of the problem is not the nature of the tax instrument used to collect revenue and influence production but rather that each firm' profits (and also consumer surplus) are accounted for locally.[22] This creates an asymmetry (i.e., a national preference) between the valuation of local and foreign production, which is at the heart of the inefficiency result.

# 4 Investment

Their proponents claim that, by fostering the emergence of a larger market, regional power pools will stimulate investments. However, it is not clear that the model of integration favored by international aid agencies in many cases, especially in Africa, provides an adequate framework for investment incentives. Unless the costs difference between two regions is sufficiently large, market integration with asymmetric regulation can decrease total welfare and thus undermine the global capacity of financing new investment. 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 "$\theta$-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 $\theta_1$ to $\delta\,\theta_1$ ($\delta < 1$) by investing a fixed amount $I_\theta$.

The second type of investment decreases the transportation cost $\gamma$. We refer to this kind of investment as "transportation cost reducing" or "$\gamma$-reducing" investment. In the integrated market the competitor of the investing firm also benefit from the investment.

[22] To see this point more clearly, let focus on the case where $\Lambda = 0$ so that fiscal issues are irrelevant for the regulators. Substituting $\Lambda = 0$ in (13) one can easily check that the inefficiency in production levels remain. The equilibrium is always sub-optimal, and this is worse when $\Lambda > 0$.

One can think of investment in transmission, interconnection, or interoperability facilities. We assume that both countries can reduce the collective transportation cost from $\gamma$ 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.[23]

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

## 4.1 Investment in generation

We start by considering the solution induced by the global welfare maximizer of Section 3.1 in the case of $\theta$-reducing investment by firm 1. The optimal quantities, denoted $q_i^{*I_\theta}$ $(i=1,2)$, are given by equations (11) where $\theta_1$ 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, $W^{*I_\theta} - W^*$, has to be compared with the social cost of the investment $(1+\lambda)I_\theta$. The social cost of investment $I_\theta$ is weighted by the opportunity cost of public funds because devoting resources to investment decreases the firm's operating profit and thus the revenue of the government by $I_\theta$, 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 $I_\theta^*$ the maximal level of investment which satisfies this inequality:

$$I_\theta^* = \frac{1}{1+\lambda}[W^{*I_\theta} - W^*] \tag{14}$$

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 (12) and (8) respectively where $\theta_1$ 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 $W_1^{kI_\theta} - W_1^k \geq (1+\lambda)I_\theta$.

[23] Assumption A1, which is the condition in equation (11) with $\Delta^*$ evaluated at $\delta\theta_1$ instead of $\theta_1$ and $s\gamma$ instead of $\gamma$, ensures that both firms produce in all possible cases. As illustrated by the analysis of Section 3 this assumption is not crucial but it simplifies greatly their exposition. Our results are preserved when shut down cases are considered (computations are available on request).

We deduce the maximal level of investment that country 1 is willing to commit in the common market and in the closed economy:

$$I_\theta^k = \frac{1}{1+\lambda}[W_1^{kI_\theta} - W_1^k] \qquad\qquad k = O, C \tag{15}$$

The next Proposition compares the different investment levels (i.e. when $k = *, O, C$) in function of the initial cost difference $\Delta = \theta_2 - \theta_1$.

**Proposition 4** *Let $\Lambda > 0$, $\delta \in (0,1)$ and $\Delta = \theta_2 - \theta_1$. Let $I_\theta^*$ and $I_\theta^k$ ($k = O, C$) be defined in (14) and (15) respectively. There are 3 thresholds $\hat{\Delta}_a < \hat{\Delta}_b < \hat{\Delta}_c$ such that:*

- $I_\theta^O > I_\theta^C \Leftrightarrow 0 > \Delta > \hat{\Delta}_a$.
- $I_\theta^* > I_\theta^C \Leftrightarrow 0 > \Delta > \hat{\Delta}_b$.
- $I_\theta^* > I_\theta^O \Leftrightarrow \Delta > \hat{\Delta}_c$.

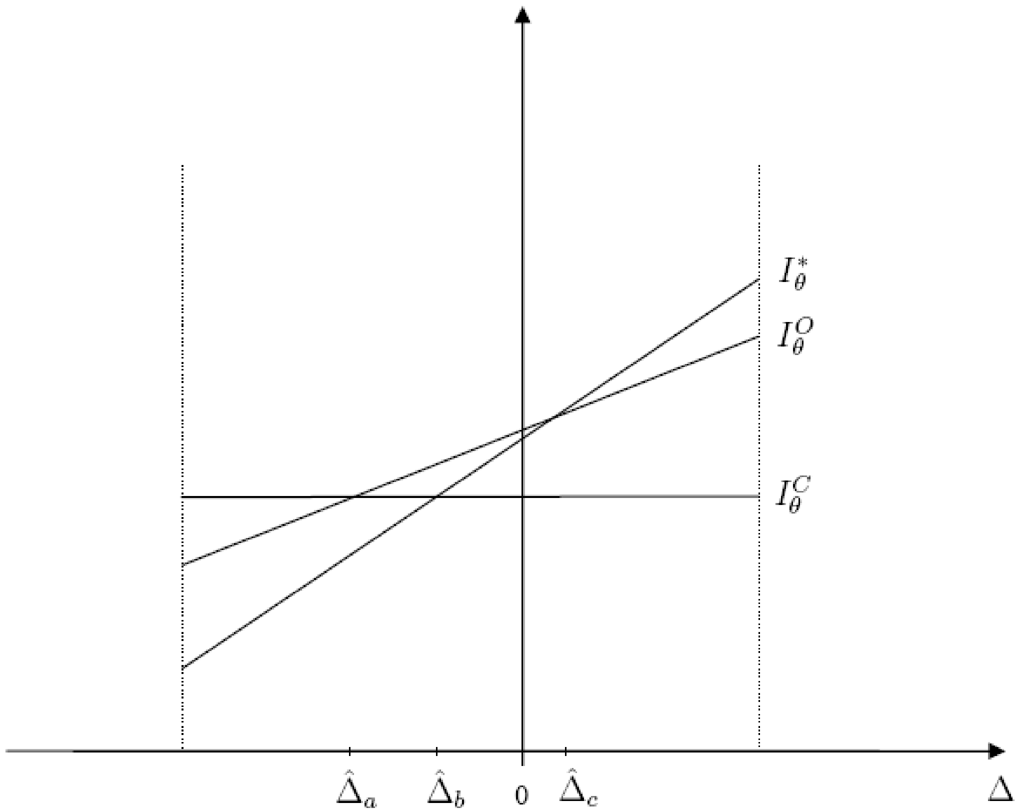
**Proof.** See Appendix D. ■

Figure 2 illustrates the results of Proposition 4. It is drawn for a fixed value of $\delta\theta_1$. The static comparative parameter is $\Delta$. The flat line $I_\theta^C$ represents the autarky equilibrium level of investment of country 1. It is independent of the efficiency of firm 2 (i.e., it is independent of $\Delta$ hence the flat shape) because in the absence of trade what happens in country 2 does not influence the investment choice of regulator in country 1. The line $I_\theta^O$ represents the equilibrium investment in the open market, and $I_\theta^*$ the optimal level. Both increase with $\Delta$: the gains from trade, and hence the incentives to invest, are larger when the gap in generation costs is large.

One relevant policy question is wether economic integration can improve the autarky outcome or not. When $\Lambda = 0$, business stealing has no adverse impact on national welfare so that $\hat{\Delta}_a = \hat{\Delta}_b = \hat{\Delta}_c = \frac{(1-\delta)\theta_1}{2}$. In this case market integration unambiguously reduces (without closing it) the gap between optimal and equilibrium level of investment. However when $\Lambda > 0$, the threshold $\hat{\Delta}_a$ and $\hat{\Delta}_c$ shifts to the left and to the right respectively while $\hat{\Delta}_b$ is not affected (see Appendix D).[24] Theoretically there are thus cases where integration worsens the gap between the equilibrium investment level and the optimum.

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

Figure 2: $\theta_1$-reducing investment




To be more specific, Proposition 4 implies that market integration improves the situation with respect to autarky when the initial cost difference between the two regions is large. First when $\Delta > \hat{\Delta}_c$, country 1 chooses a level of investment in autarky which is inefficiently low. The region is endowed with abundant ressources (e.g., hydroelectric potential) but the investment $I_\theta^O$ is oversized for its domestic demand. Integration helps to increase the level of investment that country 1 is willing to sustain by enlarging its market size through the access to the foreign demand. This is a case where the creation of a power pool moves the equilibrium investment closer to the optimal level $I_\theta^*$. However it does not restore the first best level. When $\Delta > \hat{\Delta}_c$ the open market equilibrium of investment, $I_\theta^O$, is lower than the optimal level, $I_\theta^*$, because the investing country does not fully internalize the increase in the foreign consumer surplus (it internalizes sales only). Second, when $\Delta < \hat{\Delta}_a$ country 1 is very inefficient.[25] In autarky, the only way to increase the level of consumption (and thus total welfare) is through the cost-reducing investment. Yet in the open economy this investment is a waste as the market can be served by the foreign superior technology. The creation of a power pool improves the situation by reducing the level of investment in obsolete technology. However it does not restore efficiency. The possibility to reduce its cost gap and to expand its market share by serving foreign consumers makes a higher than optimal level of investment attractive (i.e., $I_\theta^O$ is higher than $I_\theta^*$).

For $\hat{\Delta}_a < \Delta < \hat{\Delta}_b$, the level of investment is inefficiently high both under closed and open economy.[26] But the over-investment problem is more severe in the open economy because of the business stealing problem. 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 its competitive gap. It does not internalize the cost it imposes on country 2 and overinvests. This is a case in which market integration *worsens* the incentives to invest with respect to autarky. However, the values of $\Delta$ corresponding to this situation, $[\hat{\Delta}_a, \hat{\Delta}_b]$ 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 3.3).[27] So unless the creation of a power pool is forced on the countries, it is very unlikely that this over-investment problem will ever arise in equilibrium. In practice developing countries face chronic under-investment problem. Market integration should thus improve their incentives to invest in generation facilities. As argued by its proponents, it should allow more projects to be financed.

## 4.2 Transportation Cost Reducing Investment

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

[25] Indeed we have that $\hat{\Delta}_a < \hat{\Delta}_b < 0$ and in the closed economy investment is higher than the optimal value for the integrated market (i.e., it is inefficiently high) as soon as $\Delta < \hat{\Delta}_b$.

[26] There is over-investment problem in the open market if $\Delta \leq \hat{\Delta}_c$ and in the closed economy if $\Delta \leq \hat{\Delta}_b$.

[27] We have tested many values of the parameters by way of simulations. The intervals $\hat{\Delta}_a, \hat{\Delta}_b$ 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 $-\hat{\Delta} = -0.5$, $\overline{\Delta} = 0.01$, $\hat{\Delta}_a = -0.23$, $\hat{\Delta}_b = -0.08$ and $\hat{\Delta}_c = 0.02$. Finally, the admissible values for $\Delta$ under Assumption A1 are in the interval $[-1.0, 0.57]$

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). 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 $I_\gamma^*$ be the maximal level of investment which satisfy this inequality:

$$I_\gamma^* = \frac{1}{1+\lambda}[W^{*I_\gamma} - W^*] \tag{16}$$

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 (12). 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:

$$I_{\gamma i}^O = \max\left[0, \frac{1}{1+\lambda}[W_i^{OI_\gamma} - W_i^O]\right] \tag{17}$$

Intuitively, reducing transportation costs 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 (12) 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 $\Lambda$ (see Appendix E 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 $\gamma$-reducing investment is a public good, in the common market the level of investment that each country is willing to finance depends on the investment choice by the other country. The next Lemma focuses on equilibria in pure strategy.[28]

[28] There is also 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 one invests. Moreover it is not very realistic. Investment in transportation infrastructure requires a good deal of coordination between the two regions, and are observed by all.

**Lemma 1** *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 (17).*

- *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 is the only one to invest.*
- *If $I_{\gamma} \leq \underline{I}_{\gamma}^{O}$ there are two Nash equilibria in pure strategy in which one of the firm invests and the other does not.*

**Proof.** See Appendix E. ■

Because of the public good nature of the investment, only one of the two firms invest, while the other free-rides on the investment. The decision of the most efficient firm generally determines the maximal level of investment attainable in the common market.[29] We are now ready to compare the equilibrium level with the optimum.

**Proposition 5** *In the integrated market the investment level in $\gamma$-reducing technology is always suboptimal:*

$$\overline{I}_{\gamma}^{O} \;\leq\; \overline{I}_{\gamma}^{O} + \underline{I}_{\gamma}^{O} \;\leq\; I_{\gamma}^{*} \qquad\qquad \forall \Delta, \Lambda \geq 0 \tag{18}$$

**Proof.** See Appendix E. ■

In our specification, $\gamma$-reducing investment has a public good nature. It reduces the transportation costs both in investing and non-investing countries equally. 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 standard free-riding in public good problem. 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

[29]Lemma 1 implies that the most efficient firm is willing to sustain relatively high levels of investment, while both firms are able to sustain lower levels. Because of the public good nature of the investment, the identity of the investing firm in this case is not important (and in practice might be determined by local circumstances). Our model just predicts that one of the firm will always want to invest for the defined thresholds. For projects above the maximal threshold there will be no investment.

investment made by the other) the total investment level $\overline{I}_\gamma^O + \underline{I}_\gamma^O$ would still be sub-optimal. To analyze the origin of this inefficiency it is useful to 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:

$$I_{\gamma i}^C = \frac{1}{1+\lambda}[W_i^{CI_\gamma} - W_i^C]. \tag{19}$$

Comparing (19) with (17) yields the next proposition.

**Proposition 6** *Let $I_\gamma^C$ be the maximal amount that the most efficient country is willing to invest to reduce transportation costs in the closed economy and $I_\gamma^O$ 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 $|\Delta| > \tilde{\Delta}$.*

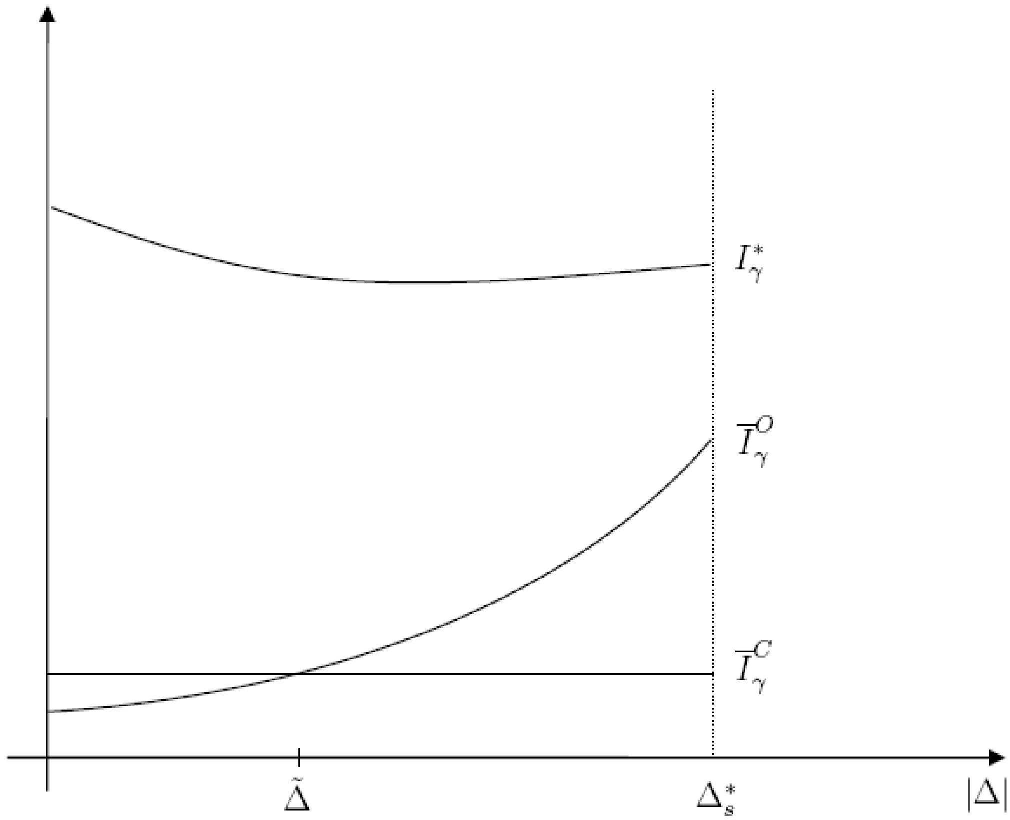
**Proof.** See Appendix F. ■

The maximal level of investment sustainable in the open economy is lower than in the case of autarky if $\Delta$ 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 $\gamma$-reducing investment for two reasons. The first reason is that investment has a public good nature. 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.[30] Figure 3 illustrates the results of Propositions 5 and 6.

Under market integration, when $\Delta$ 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

[30]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 $\Delta$. 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 3: $\gamma$-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 than $\overline{\Delta}$, 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 Figure 1).[31]

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

[31] 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 a level of investment that is inefficiently high.[32]

# 5 Conclusion

Integration of market economies is generally presented by its proponents as a powerful tool to stimulate investment in infrastructure industries. Intuitively, some investments that are oversized for a country should be profitable in an enlarged market. Yet market integration in non-competitive industries has complex implications on welfare, and on investment.

When the costs difference between the two countries is large enough market integration tends to increase the level of sustainable investment in generation. 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 chooses an inefficiently high level of investment to close its productivity gap and win market shares. With generation facilities, there is under-investment in efficient technologies and over-investment in inefficient ones, as compared to the optimum. 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.

These nuanced results are important for policy purpose. 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

[32] 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 $\hat{\Delta}_b < \theta_1 - \theta_2 < \min\{\tilde{\Delta}, -\hat{\Delta}_b\}$ with $\tilde{\Delta}$ being defined Proposition 6, then under market integration country 2 under-invests in $\gamma$-reducing technology while country 1 over-invests in $\theta$-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.

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). Investment programs have 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. Based on the CRIE experience the West African power pool (WAPP) is also working on the creation of a regional regulatory body, "Organe de Régulation Régionale" (ORR). International organizations and aid agencies can play an important role in fostering the creation of such regional regulation authorities.

In addition to coordinate sustainable levels of investment in public good infrastructures, a central authority could also help to move the non-cooperative equilibrium closer to the globally optimal solution. This objective is more ambitious and challenging than the former. Indeed to mimic perfect integration, these agencies should be able to redistribute (i.e., share) the gains from trade and thus to transfer funds between countries. Yet in their quest for revenues and energy independence, governments are reluctant to abandon their national firm and to rely on their neighbors for their electricity supply.

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# Appendix

## A Proof of Proposition 1

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

$$(1+\lambda)(d - q_i(1+\gamma) - q_j - \theta_i) + \frac{q_i + q_j}{2} = 0 \tag{20}$$

Consider first the interior solution. Solving the system characterized in (20) for $i = 1, 2$ and letting $\Lambda = \frac{\lambda}{1+\lambda}$ we obtain:

$$q_i^* = \frac{d - \frac{\theta_1+\theta_2}{2}}{1 + \Lambda + \gamma} + \frac{\theta_j - \theta_i}{2\gamma} \tag{21}$$

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

## B Proof of Proposition 2

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

$$(1+\lambda)(d-\theta_i) - \frac{1}{4}[q_j(1+2\lambda) + q_i(3+4\lambda+4\gamma(1+\lambda))] = 0 \tag{22}$$

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 $q_i(q_j)$:

$$q_i(q_j) = \frac{4(d-\theta_i) - q_j(1+\Lambda)}{3+\Lambda+4\gamma} \tag{23}$$

The equilibrium is given by the intersection of the two best response functions characterized in (23) (taking into account that quantities must be non negative). If the intersection is reached when both quantities are positive, we have:

$$q_i^O = 4\frac{d - \frac{\theta_1+\theta_2}{2}}{2(1+\gamma)+\Lambda} + \frac{\theta_j - \theta_i}{1+2\gamma} \tag{24}$$

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 (12). Substituting in the inverse demand function (2) we then obtain the expression for the price given in (12).

Figure 4 illustrates the quantities result. 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.

Finally comparing the shut down threshold in the optimal case with shut down threshold of the less efficient firm in the integrated market with independent regulators yield $\Delta^O > \Delta^*$. Figure 5 illustrates this result. 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. 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 $\overline{\theta} - \underline{\theta} > \frac{2\gamma(d-\theta_{\min})}{1+2\gamma+\Lambda}$.

Figure 4: Total Quantities $Q^*$, $Q^O$ and $Q^C$ in function of $|\Delta|$

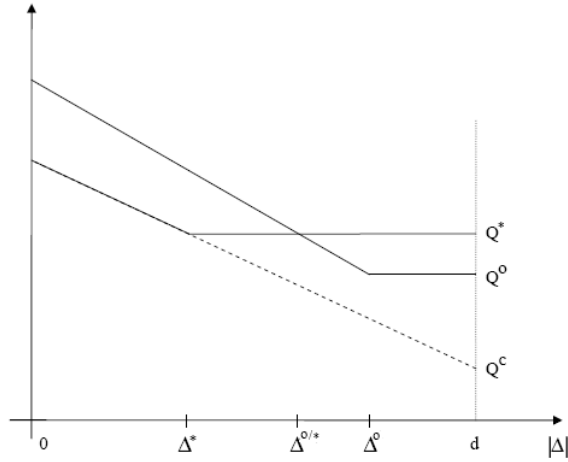
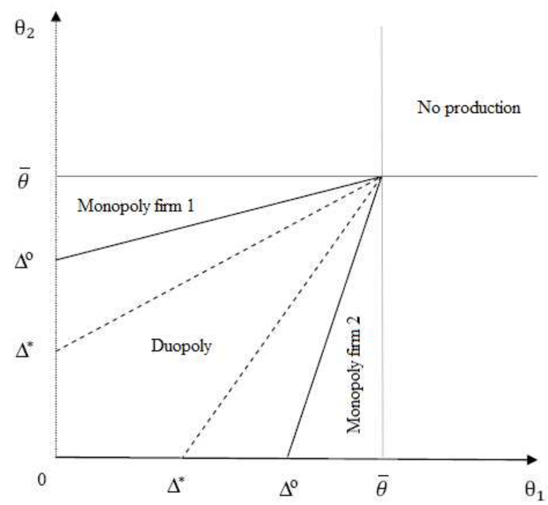



Figure 5: Shut down threshold of the less efficient firm. Dotted line: optimal threshold, Solid line: non-cooperative equilibrium.




# C Proof of Proposition 3

Consider country 1 (the same holds for country 2 inverting $\theta_1$ and $\theta_2$ and replacing $\Delta$ 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:

$$W_1^C = S(q_1^C) + \lambda P(q_1^C)q_1^C - (1+\lambda)(\theta_1 + \gamma\frac{q_1^C}{2})q_1^C \tag{25}$$

and in the case of an open economy

$$W_1^O = S(Q_1^O) - P(Q^O)Q_1^O + \lambda P(Q^O)q_1^O - (1+\lambda)(\theta_1 + \gamma\frac{q_1^O}{2})q_1^O \tag{26}$$

Substituting for the value of the quantities (8) and (12) in (25) and (26) respectively, we compute the welfare gains from integration $W_1^O - W_1^C$.

$$W_1^O - W_1^C = \Delta^2\Gamma_1(\gamma,\Lambda) + \Delta(d-\theta_1)\Gamma_2(\gamma,\Lambda) + (d-\theta_1)^2\Gamma_3(\gamma,\Lambda)$$

Where:

$$\Gamma_1(\gamma,\Lambda) = \begin{cases} \frac{2}{(3+4\gamma+\Lambda)^2}, & \text{if } \Delta < -\frac{2(1+2\gamma)(d-\theta_2)}{3+4\gamma+\Lambda}; \\ \frac{(1+\gamma(1-\Lambda))(3+4\gamma+\Lambda)}{2(1+2\gamma)^2(1-\Lambda)(2(1+\gamma)+\Lambda)^2}, & \text{if } -\frac{2(1+2\gamma)(d-\theta_2)}{3+4\gamma+\Lambda} \le \Delta \le \frac{2(1+2\gamma)(d-\theta_1)}{3+4\gamma+\Lambda}; \\ 0, & \text{if } \Delta > \frac{2(1+2\gamma)(d-\theta_1)}{3+4\gamma+\Lambda}. \end{cases}$$

$$\Gamma_2(\gamma,\Lambda) = \begin{cases} -\frac{8}{(3+4\gamma+\Lambda)^2}, & \text{if } \Delta < -\frac{2(1+2\gamma)(d-\theta_2)}{3+4\gamma+\Lambda}; \\ \frac{\Lambda(3+4\gamma+\Lambda)}{(1+2\gamma)(1+\Lambda)(2(1+\gamma)+\Lambda)^2}, & \text{if } -\frac{2(1+2\gamma)(d-\theta_2)}{3+4\gamma+\Lambda} \le \Delta \le \frac{2(1+2\gamma)(d-\theta_1)}{3+4\gamma+\Lambda}; \\ 0, & \text{if } \Delta > \frac{2(1+2\gamma)(d-\theta_1)}{3+4\gamma+\Lambda}. \end{cases}$$

$$\Gamma_3(\gamma,\Lambda) = \begin{cases} \frac{15+16\gamma^2+4\gamma(5+3\Lambda)+\Lambda(6+5\Lambda)}{2(1-\Lambda)(1+\gamma+\Lambda)(3+4\gamma+\Lambda)^2}, & \text{if } \Delta < -\frac{2(1+2\gamma)(d-\theta_2)}{3+4\gamma+\Lambda}; \\ -\frac{\Lambda^2}{2(1-\Lambda)(1+\gamma+\Lambda)(2(1+\gamma)+\Lambda)^2}, & \text{if } -\frac{2(1+2\gamma)(d-\theta_2)}{3+4\gamma+\Lambda} \le \Delta \le \frac{2(1+2\gamma)(d-\theta_1)}{3+4\gamma+\Lambda}; \\ \frac{1+3\Lambda}{2(1-\Lambda)(1+\gamma+\Lambda)(3+4\gamma+\Lambda)}, & \text{if } \Delta > \frac{2(1+2\gamma)(d-\theta_1)}{3+4\gamma+\Lambda}. \end{cases}$$

$W_1^O - W_1^C$ is a U-shaped function of $\Delta$. 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 $|\Delta| \le d$ ensure the behavior described in Proposition 3.

# D Proof of Proposition 4

We start computing the maximal level of investment Country 1 at the non cooperative equilibrium. The welfare in the absence of investment is defined in (26) and with investment it is:

$$W_1^{OI_\theta} = S(Q_1^{OI_\theta}) - P(Q^{OI_\theta})Q_1^{OI_\theta} + \lambda P(Q^{OI_\theta})q_1^{OI_\theta} - (1+\lambda)(\delta\theta_1 + \gamma\frac{q_1^{OI_\theta}}{2})q_1^{OI_\theta} - (1+\lambda)I_\theta$$

Replacing for the relevant quantities in Equation (15) and rearranging terms we obtain:

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

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

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

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

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

Where:

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

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

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

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

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

Where:

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

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

# E Proof of Lemma 1 and Proposition 5

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

$$W_1^{OI_\gamma} = S(Q_1^{OI_\gamma}) - P(Q^{OI_\gamma})Q_1^{OI_\gamma} + \lambda P(Q^{OI_\gamma})q_1^{OI_\gamma} - (1+\lambda)(\theta_1 + s\gamma\frac{q_1^{OI_\gamma}}{2})q_1^{OI_\gamma} - (1+\lambda)I_\gamma$$

Substituting the relevant quantities in this welfare function and in (26) and replacing them in Equation (17), we obtain:

$$I_{\gamma 1}^O = \Delta^2\Gamma_1^{ii}(\gamma,\Lambda) + (d-\theta_1)\Delta\Gamma_2^{ii}(\gamma,\Lambda) + (d-\theta_1)^2\Gamma_3^{ii}(\gamma,\Lambda)$$

Where:

$$\begin{aligned}
\Gamma_1^{ii}(\gamma,\Lambda) &= \frac{(1+s\gamma(1-\Lambda))(3+4s\gamma+\Lambda)}{(1+2s\gamma)^2(2(1+s\gamma)+\Lambda)^2} - \frac{(1+\gamma(1-\Lambda))(3+4\gamma+\Lambda)}{(1+2\gamma)^2(2(1+\gamma)+\Lambda)^2} \\
\Gamma_2^{ii}(\gamma,\Lambda) &= \frac{\Lambda(3+4s\gamma+\Lambda)}{(1+2s\gamma)(2(1+s\gamma)+\Lambda)^2} - \frac{\Lambda(3+4\gamma+\Lambda)}{(1+2\gamma)(2(1+\gamma)+\Lambda)^2} \\
\Gamma_3^{ii}(\gamma,\Lambda) &= \frac{2(1-s)\gamma(4(1+\gamma)(1+s\gamma)-\Lambda)^2}{(1+2s\gamma)^2(2(1+s\gamma)+\Lambda)^2}
\end{aligned}$$

$\Gamma_1^{ii}(\gamma,\Lambda)$ and $\Gamma_2^{ii}(\gamma,\Lambda)$ 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 $\Delta = -\frac{(d-\theta_i)\Gamma_2^{ii}(\gamma,\Lambda)}{2\Gamma_1^{ii}(\gamma,\Lambda)} < 0$. 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 1.

## Proof of Lemma 1

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 $I_\gamma^*$ and the closed economy $\overline{I}_\gamma^*$, we prove that $\gamma$-investment can reduce the welfare of the less efficient country. We have: $\frac{\partial I_{\gamma 1}^O}{\partial \Delta} = 2\Delta\Gamma_1^{ii}(\gamma,\Lambda) + (d-\theta_1)\Gamma_2^{ii}(\gamma,\Lambda)$. 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 $\gamma$-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 5

Let $Q^* = q_1^* + q_2^*$ and $Q^{*I_\gamma} = q_1^{*I_\gamma} + q_2^{*I_\gamma}$. The maximal investment at the global optimum is defined by (16). Global welfare in the case of non investment and investment are respectively:

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

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

Replacing for the relevant quantities and rearranging terms we obtain:

$$I_\gamma^* = \Delta^2\Gamma_1^{iii}(\gamma,\Lambda) + (d-\theta_{\min})|\Delta|\Gamma_2^{iii}(\gamma,\Lambda) + (d-\theta_{\min})^2\Gamma_3^{iii}(\gamma,\Lambda)$$

Where:

$$\begin{aligned}
\Gamma_1^{iii}(\gamma,\Lambda) &= \frac{1-s}{4\gamma}\left[\frac{1}{s} + \frac{\gamma^2}{(1+s\gamma+\Lambda)(1+\gamma+\Lambda)}\right]\\
\Gamma_2^{iii}(\gamma,\Lambda) &= -\frac{(1-s)\gamma}{(1+\gamma+\Lambda)(1+s\gamma+\Lambda)}\\
\Gamma_3^{iii}(\gamma,\Lambda) &= \frac{(1-s)\gamma}{(1+\gamma+\Lambda)(1+s\gamma+\Lambda)}
\end{aligned}$$

$I_\gamma^*$ 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 is U-shaped in $\Delta$ ($\Gamma_1^{iii}(\gamma,\Lambda) > 0, \forall s \in (0,1), \Lambda \in [0,1), \gamma \geq 0$).

We now compare the thresholds $I_\gamma^*$ and $I_\gamma^O$.

$$I_\gamma^* - I_\gamma^O = \Delta^2\Gamma_1^{iv}(\gamma,\Lambda) + (d-\theta_i)\Delta\Gamma_2^{iv}(\gamma,\Lambda) - (d-\theta_i)^2\Gamma_3^{iv}(\gamma,\Lambda)$$

$$\begin{aligned}
\Gamma_1^{iv}(\gamma,\Lambda) &= \frac{1}{s\gamma} + \frac{1}{1+s\gamma+\Lambda} - \frac{2(1+s\gamma(1-\Lambda))(3+4s\gamma+\Lambda)}{(2(1+s\gamma))(2(1+s\gamma)+\Lambda)^2}\\
&\quad -\frac{1}{\gamma} - \frac{1}{1+\gamma+\Lambda} + \frac{2(1+\gamma(1-\Lambda))(3+4\gamma+\Lambda)}{(2(1+\gamma))(2(1+\gamma)+\Lambda)^2}\\
\Gamma_2^{iv}(\gamma,\Lambda) &= -\frac{1}{1+2s\gamma} - \frac{1}{1+s\gamma+\Lambda} + \frac{4(1+s\gamma)^2+\Lambda}{(1+2s\gamma)((2(1+s\gamma)+\Lambda)^2)}\\
&\quad +\frac{1}{1+2\gamma} + \frac{1}{1+\gamma+\Lambda} - \frac{4(1+\gamma)^2+\Lambda}{(1+2\gamma)((2(1+\gamma)+\Lambda)^2)}\\
\Gamma_3^{iv}(\gamma,\Lambda) &= \frac{1}{1+s\gamma+\Lambda} - \frac{2(1+s\gamma)}{(2(1+s\gamma)+\Lambda)^2} - \frac{1}{1+\gamma+\Lambda} + \frac{2(1+\gamma)}{(2(1+\gamma)+\Lambda)^2}
\end{aligned}$$

$\Gamma_1^{iv}(\gamma,\Lambda)$ is positive for all $s \in (0,1), \Lambda \in [0,1), \gamma > 0$. Then, $I_\gamma^* - I_\gamma^O$ is a U shaped function of $\Delta$. Moreover, one can easily show that $I_\gamma^* - I_\gamma^O$ decreases with $\Lambda$. An increase in $\Lambda$ shifts the U curve downwards. Than, a sufficient condition for $I_\gamma^* - I_\gamma^O$ to be always positive is to have a positive minimum when $\Lambda = 1$. Since $I_\gamma^* - I_\gamma^O$ is a convex function of $\Delta$, the minimum is obtained from the first order condition $\frac{\partial(I_\gamma^* - I_\gamma^O)}{\partial\Delta} = 0$. In $\Lambda = 1$, this minimum is equal to:
$[(1-s)^2(57+292(1+s)\gamma+252(1+s(3+2s))\gamma^2+48(1+s)(7+s(12+7s))\gamma^3+16(5+s(33+s(43+s(33+5s))))\gamma^4+28s(1+s)(1+s(1+s))\gamma^5+64s^2(1+s^2)\gamma^6)]/[s(2+\gamma)(2+s\gamma)(1+2s\gamma)^2(3+2s\gamma)^2(3+4\gamma(2+\gamma))] > 0 \;\forall\; s \in (0,1)$

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

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

$$\overline{I}_\gamma^O + \underline{I}_\gamma^O = \Delta^2\Gamma_1^v(\gamma,\Lambda) + (d-\theta_i)\Delta\Gamma_2^v(\gamma,\Lambda) + (d-\theta_i)^2\Gamma_3^v(\gamma,\Lambda)$$

where:

$$\begin{aligned}
\Gamma_1^v(\gamma,\Lambda) &= \frac{(1-s)\gamma(3+4(\gamma+s\gamma(1+\gamma))}{(1+2\gamma)^2(1+2s\gamma)^2} - \frac{1+\gamma}{(2(1+\gamma)+\Lambda)^2} + \frac{1+s\gamma}{(2(1+s\gamma)+\Lambda)^2}\\
\Gamma_2^v(\gamma,\Lambda) &= -\frac{4(1-s)\gamma(4(1+\gamma)(1+s\gamma)-\Lambda^2)}{(2(1+\gamma)+\Lambda)^2(2(1+s\gamma)+\Lambda)^2}\\
\Gamma_3^v(\gamma,\Lambda) &= \frac{4(1-s)\gamma(4(1+\gamma)(1+s\gamma)-\Lambda^2)}{(2(1+\gamma)+\Lambda)^2(2(1+s\gamma)+\Lambda)^2}
\end{aligned}$$

Then,

$$I_\gamma^* - \overline{I}_\gamma^O - \underline{I}_\gamma^O = \Delta^2\Gamma_1^{vi}(\gamma,\Lambda) + (d-\theta_i)\Delta\Gamma_2^{vi}(\gamma,\Lambda) - (d-\theta_i)^2\Gamma_3^{vi}(\gamma,\Lambda)$$

where:

$$\begin{aligned}
\Gamma_1^{vi}(\gamma,\Lambda) &= \frac{1+\gamma}{(2(1+\gamma)+\Lambda)^2} - \frac{1+s\gamma}{(2(1+s\gamma)+\Lambda)^2} - \frac{1}{4(1+\gamma+\Lambda)} + \frac{1}{4(1+s\gamma+\Lambda)}\\
&\quad - \frac{1}{4\gamma(1+2\gamma)^2} + \frac{1}{4s\gamma(1+2s\gamma)^2}\\
\Gamma_2^{vi}(\gamma,\Lambda) &= \frac{1}{(1+\gamma+\Lambda)} - \frac{1}{(1+s\gamma+\Lambda)} + \frac{4(1+\gamma)}{(2(1+\gamma)+\Lambda)^2} - \frac{4(1+s\gamma)}{(2(1+s\gamma)+\Lambda)^2}\\
\Gamma_3^{vi}(\gamma,\Lambda) &= \frac{(1-s)\gamma\Lambda^2 4(1+s(1+s))\gamma^2 + 4(1+s)\gamma(3+2\Lambda) + (2+\Lambda)(6+5\Lambda)}{(1+\gamma+\Lambda)(1+s\gamma+\Lambda)(2(1+\gamma)+\Lambda)^2(2(1+s\gamma)+\Lambda)^2}
\end{aligned}$$

$\Gamma_1^{vi}(\gamma,\Lambda)$ is positive for $s\in(0,1), \Lambda\in[0,1), \gamma\geq 0$, then $I_\gamma^* - I_\gamma^J$ is a convex U-shaped function of $\Delta$. Moreover, one can verify that the difference $I_\gamma^* - I_\gamma^J$ is decreasing with $\Lambda$. Then, the difference is minimal in $\Lambda = 0$, where:

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

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

# F Proof of Proposition 6

In the case of closed economy, welfare with no investment is given by (25). If $I_\gamma$ is invested, the welfare function becomes:

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

Substituting in this expression the equilibrium quantities and using equation (19), the maximal amount regulator $i$ is willing to invest in a closed economy is:

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

We first check that $I^C_\gamma$ is smaller than $I^*_\gamma$. Since $I^*_\gamma$ is a convex function of $\Delta$, while $I^C_\gamma$ is constant, $I^O_\gamma - I^C_\gamma$ is also convex in $\Delta$. Its derivative is zero at $\Delta = \frac{2s\gamma^2(d-\theta_i)}{2s\gamma^2+(1+s)\gamma(1+\Lambda)+(1+\Lambda^2)}$ where it reaches the minimum value:

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

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

We now compare $I^O_\gamma$ and $I^C_\gamma$. Because $I^O_\gamma$ is increasing and convex, while $I^C_\gamma$ is constant, $I^O_\gamma - I^C_\gamma$ is also increasing and convex in $\Delta$. 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 $s \in (0,1), \Lambda \in [0,1), \gamma \geq 0$. From the increasing shape of $I^O_\gamma$, there exists $\tilde{\Delta} > 0$ such that for all $\Delta > \tilde{\Delta}$, $I^O_\gamma > I^C_\gamma$.

# G Asymmetric Demand

In the main text, we have assumed that countries differ in their available technology only. We now check the robustness of our results to the case where demands are asymmetric. Let

$$p_i = d_i - Q_i \tag{27}$$

where $i$ denotes the country, $i = 1, 2$. In order to make meaningful comparisons, we keep in this extension the total size of the market constant compared to our base case, i.e.:

$$d = \frac{d_1 + d_2}{2}$$

Moreover, to ensure interior solutions, we make the following assumption.

(A0bis) $\quad min\{d_1, d_2\} > \overline{\theta}.$

Under autarky, the results are the same as in the base case, with $d$ replaced by $d_i$, $i = 1, 2$. In the integrated market, total demand is as in equation (2): $p = d - \frac{Q}{2}$ with $Q = q_1 + q_2$.

## Full integration

In the case of full integration, we first determine the optimal consumption sharing rule maximizing $S_1(Q_1) + S_2(Q_2)$ under the constraint that $Q_1 + Q_2 = Q$. Since $S_i(Q_i) = d_iQ_i - \frac{Q_i^2}{2}$, we deduce that $Q_i = \frac{Q_1+Q_2}{2} + \frac{d_i-d_j}{2}$. Computing total consumer surplus $S_1(Q_1) + S_2(Q_2)$, we now obtain that $S_1(Q_1) + S_2(Q_2) = \frac{(d_1-d_2)^2}{4} + \frac{d_1+d_2}{2}(Q_1 + Q_2) - \frac{1}{4}(Q_1 + Q_2)^2$. Substituting this expression in the total welfare function (9), the maximisation problem of the supranational regulator is the same as in the base case plus a constant term $\frac{(d_1-d_2)^2}{4}$. Then, the optimal quantities are the same as in (11).
Replacing these optimal quantities in the welfare functions (9) and the autarky quantities from equation (8) evaluated at $d_i$ in the welfare function (6), we compute the welfare gains from integration $W^*_{asy} - W^C_{asy}$ and compare them with the ones obtained in the base case of symmetric demand.

$$W^*_{asy} - W^C_{asy} = W^* - W^C + \frac{(d_2 - d_1)\left((d_2 - d_1)\left(2\gamma(1 - \Lambda) - 2\Lambda^2 + 1\right) + 2\Delta\right)}{4(1 - \Lambda)(\gamma + \Lambda + 1)} \geq 0 \quad (28)$$

The additional term in the welfare gains can be positive or negative. Is is positive when $d_2 - d_1$ is positive and $\Delta = \theta_2 - \theta_1$ is relatively large, and when $d_2 - d_1$ is negative and $\Delta$ is relatively small. Indeed demand asymmetry plays a similar role than cost asymmetry. To see this point consider the limit case where $\Delta = 0$ (i.e., generation costs are identical). It implies that $W^* - W^C = \frac{1+\Lambda}{4\gamma(1-\Lambda)(1+\gamma+\Lambda)}\Delta^2 = 0$ and that $W^*_{asy} - W^C_{asy} = \frac{2\gamma(1-\Lambda)-2\Lambda^2+1}{4(1-\Lambda)(1+\gamma+\Lambda)}(d_2 - d_1)^2$. Due to the quadratic shape of the transportation cost function, the smaller country has a lower marginal cost. So when the smaller country is also the most efficient one, integration allows the regulator to expand its market share to exploit the low generation and transportation costs. Reallocating production towards the producer with the smaller national market increases productive efficiency and the total welfare gains from trade.

## Sectorial integration with asymmetric regulation

Consumer surplus writes: $S_i(Q_i) = d_iQ_i - \frac{Q_i^2}{2}$ and $Q_i = \frac{Q}{2} + \frac{d_i-d_j}{2}$, where $Q = Q_1 + Q_2 = q_1 + q_2$ and $i, j = 1, 2$ $i \neq j$. Substituting this expression in (6) yields the national welfare function. The regulator of Country i chooses $q_i$ as to maximize this function, given the quantity $q_j$ chosen by the regulator of Country j. At the non cooperative equilibrium we have:

$$q_i^O = 4\frac{d - \frac{\theta_1+\theta_2}{2}}{2(1 + \gamma) + \Lambda} + \frac{\theta_j - \theta_i}{1 + 2\gamma} + \frac{(1 - \Lambda)(d_i - d_j)}{2 + 4\gamma} \quad (29)$$

The last term, which cancels out when $d_1 = d_2$, is the additional term due to the asymmetry of demand. Replacing these quantities in the social welfare function (6) we can compute the welfare gains. As in the Appendix C we focus without loss of generality on country 1. The results for country 2 are symmetrical. The welfare gain of country 1, $W^O_{1,asy} - W^C_{1,asy}$, is equal to the gain obtained in the symmetric case plus an additional term $\zeta(d_2 - d_1, \Delta, \Lambda, \gamma, \theta_1)$:

$$W^O_{1,asy} - W^C_{1,asy} = W^O_1 - W^C_1 + \zeta(d_2 - d_1, \Delta, \Lambda, \gamma, \theta_1)$$

where:

$$\zeta(d_2-d_1,\Delta,\Lambda,\gamma,\theta_1)=\frac{1}{8}\Big((d_2-d_1)\Delta\phi_1(\gamma,\Lambda)+(d_2-d_1)^2\phi_2(\gamma,\Lambda)+(d_2-d_1)(d_1-\theta_1)\phi_3(\gamma,\Lambda)\Big)$$

and:

$$\begin{aligned}
\phi_1(\gamma,\Lambda) &= \frac{4\gamma(3+4\gamma+\Lambda)}{(1+2\gamma)^2(2+2\gamma+\Lambda)}\geq 0\\
\phi_2(\gamma,\Lambda) &= \frac{8\gamma^4(1-\Lambda)+2\gamma^3((4-7\Lambda)\Lambda+7)+\gamma^2(6+\Lambda(19+(2-7\Lambda)\Lambda)+6)+\Lambda\gamma(3-\Lambda)(2+\Lambda(4+\Lambda))+\Lambda^2(2+\Lambda)}{(1+2\gamma)^2(1-\Lambda)(1+\gamma+\Lambda)(2+2\gamma+\Lambda)}\geq 0\\
\phi_3(\gamma,\Lambda) &= \frac{4\Lambda\left(4\gamma^2+\gamma(3+5\Lambda)+\Lambda(2+\Lambda)\right)}{(1+2\gamma)(1-\Lambda)(1+\gamma+\Lambda)(2+2\gamma+\Lambda)}\geq 0
\end{aligned}$$

The additional effect $\zeta$ is decomposed into three terms. The first term, which is identical for both countries, has the sign of $(d_2-d_1)\Delta$: it is positive whenever $(d_2-d_1)$ and $\Delta=\theta_2-\theta_1$ have the same sign. This happens when either country 1 is small and it possess the most efficient technology, or large and endowed with the less efficient technology.

The second term is always positive and increases with the absolute value of $(d_2-d_1)$. It is also identical for both country. This term captures the efficiency gains related to production reallocation in the presence of a positive quadratic transportation cost.

Finally, since $(d_i-\theta_i)$ is always positive by assumption A0bis, the third term has the sign of $(d_j-d_i)$ for country $i$. It means that it is positive for the smallest country and negative for the largest one.

Since the first and second terms are identical for both countries, while the third one is positive for the small country and negative for the large country, we deduce that, everything else being equal, *the smaller country always wins more from integration than the larger one*.

Regarding the net effect of $\zeta$, it depends on the opportunity cost of public funds. When $\Lambda$ is relatively small, the first term in $\zeta$ is the largest. Compared to the base case, the welfare gains increase when the smallest country is also the most efficient. By contrast the two effects (i.e., generation and transportation costs) contradict each other when the large country is the most efficient so that the welfare gains are lower than in the base case. Now for large values of $\Lambda$, the third term in $\zeta$ tends to be the largest, unless $\gamma$ is also very large. Thus, for $\Lambda$ sufficiently large, the additional welfare gains obtained with asymmetric demand tend to be positive for the smaller country and negative for the larger one.

We next want to check that the result in section 3.3, namely that market integration is welfare degrading when countries are too similar and fiscal issues are important, is robust to asymmetric demand. Let $\Delta=0$. The welfare gains then write:

$$W^O_{1,asy}-W^C_{1,asy}=\Gamma_1(\Lambda,\gamma)(d-\theta_1)^2+\frac{1}{8}\Big((d_2-d_1)^2\phi_2(\gamma,\Lambda)+(d_2-d_1)(d_1-\theta_1)\phi_3(\gamma,\Lambda)\Big)$$

where $\Gamma_1(\Lambda,\gamma)=-\frac{1}{4}\frac{\Lambda^2}{(1-\Lambda)(1+\gamma+\Lambda)(2+2\gamma+\Lambda)^2}<0$. For $d_2=d_1$ the term $\Gamma_1(\Lambda,\gamma)(d-\theta_1)^2$ corresponds to the welfare gains in the base model (see Appendix C when $\Delta=0$). If $\Lambda>0$ then the welfare gains are always negative for $d_1=d_2$ and $\Delta=0$. By continuity, this net welfare loss result holds true for strictly positive values of $|d_2-d_1|$ as illustrated

Figure 6: The welfare gains $W^O_{1,asy} - W^C_{1,asy}$, $\Delta = 0$, $\Lambda = 1/3$, $\gamma = 10$

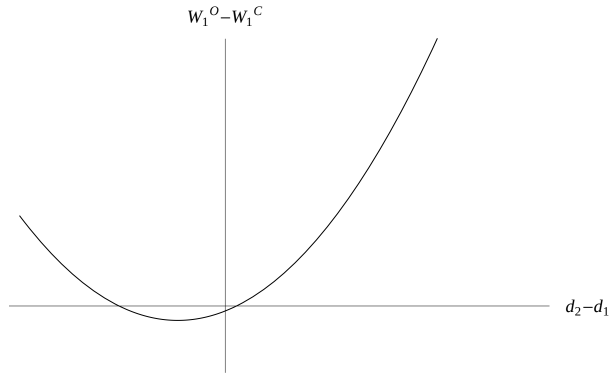



Figure 7: The welfare gains $W^O_{1,asy} - W^C_{1,asy}$, $\Delta = 0$, $\Lambda = 1/3$, $\gamma = 1$

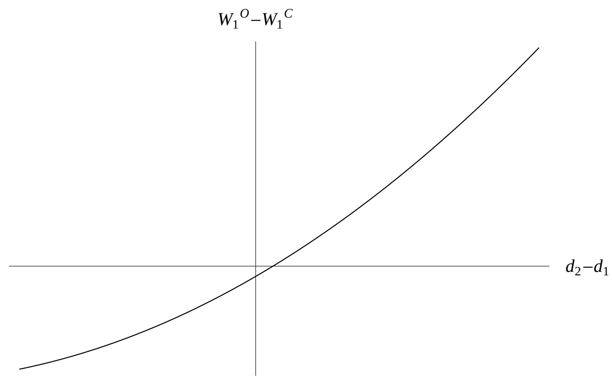



figure 6 and 7. They show that both countries loose from integration if they are too similar (i.e., the engine of integration is cost complementarities).

The welfare gain is a convex function of $d_2 - d_1$ when $\Delta = 0$. The function is increasing for $d_2 - d_1 \geq 0$ (i.e. for the smaller country) and, depending on the value of $\gamma$, it is U-shaped or decreasing for $d_2 - d_1 \leq 0$ (i.e. for the larger country). The U-shaped result is similar to the result illustrated in figure 1 because when $\gamma$ is large $d_2 - d_1$ plays the same role as $\Delta$. When transportation costs are very large, both countries gain from integration (one through export profits, the other through a reduction in the price).