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Lobbying and the Power of Multinational Firms

Andreas Polk, Armin Schmutzler and Adrian Muller*

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Abstract: Are national or multinational firms better lobbyists? This paper analyzes the extent of national environmental regulation when policy is determined in a lobbying game between a government and firm. We compare the resulting regulation levels for national and multinational firms. We identify three countervailing forces, the *easier-to-shut-down effect*, the *easier-to-curb-exports effect* and the *multiple-plant effect.* The interplay of these three forces determines whether national or multinational firms produce more, depending on such parameters as the potential environmental damages, transportation costs and the influence of the firm. We also show that welfare levels are higher with multinational firms than with national firms when there is no lobbying, but that lobbying can reverse the welfare ordering.

Keywords: Multinational enterprises, regulation, policy formation, lobbying, interest groups, foreign direct investment.

JEL: D72, F23, L51.

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1 Introduction

Even though global foreign direct investment (FDI) has faced two major negative shocks since the turn of the century, the stock of foreign capital in most countries is much higher than several decades ago. Some authors argue that the economic influence of firms on the political process has grown due to this aspect of globalization. This perception sometimes culminates in the notion of the "loss of sovereignty" of the nation state. According to this view, national governments lose their discretion to set policy, e.g. environmental regulation, because multinational enterprises have a better bargaining position vis-a-vis the government than national firms: the former can relocate in response to unwanted policies, and governments that want to avoid such relocation must succumb to the wishes of the multinationals. According to this view, a "race to the bottom" ensues when multinational firms are important. Regulation becomes excessively lax so as to attract multinational firms. Contrasting this view is the "Not in my backyard" (NIMBY) story, according to which governments set inefficiently high pollution standards to deter polluting multinational firms.

This paper deals with a single government that regulates a polluting monopolist. In a setting closely related to Motta and Thisse (1994), we first focus on the interaction between location patterns, transportation costs and the choice of regulation in a simple parameterized game, and we determine all equilibria of the game. We then show that important insights still hold in a reduced form approach where we relax assumptions on specific functional forms and on the particular type of product market interaction.

Specifically, we compare the regulation of a national firm which, by definition, can only produce in the home country with the regulation of a multinational firm which can relocate its production to a foreign country. Relocation can either be partial (in which case only the foreign market is served from the foreign plant) or complete (in which case the home market is served from the foreign plant, too). Our modelling approach allows both for the case that regulators maximize welfare and the alternative that they take private benefits into account, which makes them susceptible to influence activities.

We derive regulation levels for arbitrary parameters of the game for national and multinational firms. We then ask under which circumstances national and multinational firms face stronger regulation. As a benchmark, we consider the case that regulators maximize consumer surplus, that is, completely ignore the effects of regulation on producer surplus.

We identify several countervailing effects. First, there is the *easier-to-shut-down effect*. Compared to national firms, the government can induce zero production of the multinational without foregoing consumer surplus altogether. This can lead to situations where the multinational is induced to relocate completely, whereas the national firm still produces. Second, there is the *easier-to-curb-exports effect*. A government that wants the firm to stop its polluting exports needs lower regulation for the multinational than for the national firm, so that the multinational produces more. Finally, there is the *multiple-plant effect*. For parameters such that the government allows the national firm to export, but the multinational exercises the option of partial relocation, the multinational produces less at home (and hence pollutes less) even when both firms face the same level of regulation.

For the case of pure consumer surplus maximization, we show that, as a result of these effects, multinational firms tend to be more regulated (produce lower outputs and emissions) than national firms when transportation costs are low, whereas the converse effect may arise for high transportation costs, provided the environmental damage parameter is high enough. We then analyze how an increase of political influence affects the choice of regulation, and to which extent the effects differ for national or multinational firms. There are countervailing effects which result in a shift of the region where multinationals produce less than national firms towards higher damage levels. Finally, we consider welfare. In the case of pure consumer surplus maximization, welfare always is higher for multinational firms than for national firms. With lobbying, the result is reversed for some parameter regions.

Several theoretical and empirical contributions analyze whether the ability of multinationals to relocate production leads to "pollution havens" which have low regulation in order to attract foreign capital.[1] Even though early empirical research found it hard to confirm this effect, recent contributions provide evidence that regulation has an impact on relocation of firms.[2] The theoretical literature on the regulation of multinational firms has usually taken the perspective that governments maximize national welfare. For instance, Rauscher (1995) considers a game between several governments whose pollution taxes determine the location of a monopolist who, contrary to our

[1]The approaches differ concerning the modeling of competition, relocation, transportation costs and government behavior. Important contributions are Conrad (2005), Eerola (2004), Markusen et. al. (1993), Hoel (1997), Rauscher (1995), Motta and Thisse (1994). Conrad (2005: 275-277) provides a rough overview.

[2]Brunnermeier and Levinson (2004) survey the empirical literature, which consists of two branches. Authors such as Condliffe (2009), List and Co (2000) or Zugravu and Ben Kheder (2008) directly measure the effect of environmental regulation on location decisions. Others analyse the link between trade and regulation (Levinson and Taylor (2008), Ederington, Levinson and Minier (2005)). In sum, these studies provide evidence that there is an effect of environmental regulation on location decisions. The impact differs and depends on factors like the industry's ability to relocate, the role of abatements costs and other aspects of productivity.

model, can only be active in at most one country. He finds that, for local pollutants, the race to the bottom outcome is observed for relatively low environmental damages, whereas the NIMBY case arises for higher damages.

Our approach is closely related to Markusen, Morey and Olewiler (1993, 1995) and Motta and Thisse (1994). In these papers, a multinational firm chooses its location structure as a function of home country policy. The firm can either partially or completely relocate as a reaction to unwanted regulation. In doing so it faces a trade-off which depends on the fixed costs of relocation, transportation costs and the cost of regulation.[3]

However, the question how lobbying influences regulation if firms can relocate production has hardly been addressed in the literature so far.[4] Most closely related to our paper, Cole, Elliott and Fredriksson (2006) analyze lobbying activities of multinational and national firms against environmental regulation if local production causes pollution damages. Contrary to our paper, the authors assume that the market structure is exogenous and focus on the question how the number of foreign plants affects the outcome. Belletini and Kempf (2008) analyze a setup where a government decides about the spatial allocation of production plants, which serve as a public good or bad (like an airport or a waste disposal plant). They analyze how lobbying influences the allocation decision and show that under certain conditions lobbying may lead to over- or underprovision of the public good. Fredriksson (2000) analyzes the allocation of a plant which exerts negative externalities in a NIMBY setting, where each region lobbies against the location of the plant at its own site but benefits from its existence somewhere else.

We proceed as follows. Section 2 describes the model. Section 3 derives the locational choices of firms for given regulation levels. In Section 4, we characterize the regulation for national and multinational firms, respectively. Section 5 compares regulation levels in the two cases, and it shows how lobbying affects the comparison. Section 6 deals with welfare issues. Section 7 generalizes the approach in a reduced form model. Section 8 concludes.

[3] The approaches differ according to the exact modeling of product market interaction (duopoly vs. monopoly), the type of firms that can relocate (only domestic firms or foreign firms as well), the effect of damages on welfare (linear or convex) and the type of policy instruments.

[4] Most papers dealing with lobbying of multinational firms focus on their influence on trade policy. Several authors analyze incentives to lobby for protection if FDI puts a potential threat on domestic firms, i.e. Grossman and Helpman 1996, Ellingson and Warneryd 1999, Konishi, Saggi and Weber 1999.

2 Assumptions

We consider a multi-stage game. There are two countries, $i = 1$ (home) and $i = 2$ (foreign). There is one firm that initially only has one plant in the home country. This firm can be national or multinational. A multinational firm is defined by the option to build another plant in the foreign country.

We assume that a politician in country 1 maximizes a "welfare function" (W), a weighted sum of consumer surplus in the home country (K), total firm profits (Π) and the costs of environmental damage in the home country (D):

$$W = K + \gamma\Pi - D,$$

where $\gamma \geq 0$. The game has the following stages:

1. The politician chooses the regulation level r so as to maximize W.
2. If the firm is multinational, it decides whether to build an additional plant in the foreign location at fixed cost F; a national firm is defined by the absence of this option.
3. The profit-maximizing firm chooses x_j^i, $i, j = 1, 2$, which denote the output levels produced in country i for country j.

We write $x^i = (x_1^i + x_2^i)$ for total output produced in country i, and $x_j = \left(x_j^1 + x_j^2\right)$ for total output produced for country j. Further, we write $x = (x_1^1, x_2^1, x_1^2, x_2^2)$. *Partial relocation* (P) occurs if $x^1 > 0$ and $x^2 > 0$, that is, production takes place in both countries. There is *complete relocation* (C) if $x^1 = 0$, $x^2 > 0$, that is, all production takes place in country 2. If $x^2 = 0$, we say that there is *no relocation* (N).

We assume that the firm is a monopolist on both markets who faces linear demand $p_i = a - x_i$ in country $i = 1, 2$. We assume constant marginal production costs, which we set to 0 for simplicity. If a market is served from another country, the firm incurs transportation costs $t > 0$ per unit output. Regulation is assumed to lead to additional costs r that are proportional to output. Profits are thus

$$\sum_{j=1}^{2} p_j(x_j)x_j - rx^1 - t\left(x_2^1 + x_1^2\right) - \delta F \tag{1}$$

where $\delta = 1$ if there is complete or partial relocation, $\delta = 0$ otherwise, that is, for a national firm or a multinational firm that does not relocate. Environmental damages are given as $b\left(x^1\right)^2$, where $b > 0$. In the foreign country, there is no regulation. The model thus has the exogenous parameters a, F, b, t, γ. The regulation level r is endogenous, as is the location choice and more generally the output vector x.

2.1 Lobbying interpretation

The welfare function can account for the cases that the politician is either benevolent or influenced by lobbying of firms. In the former case γ reflects the weight that the benevolent politician gives to producer surplus.[5] In the latter case, a standard lobbying game (similar to Grossman and Helpman 1994) maps directly into our simpler framework. To this end, we add a first stage in which the firm offers a contribution schedule $C(r)$ to the politician, which maps a particular level of regulation to a contribution that the firm pays to the politician. The firm's objective function thus becomes $\pi(r) = \Pi(r) - C(r)$, that is, profits minus contributions. Next the politician sets regulation levels so as to maximize $U(r) = \widehat{W}(r) + \beta C(r)$, where $\beta \geq 0$ and $\widehat{W}(r) = K + \widehat{\gamma}\Pi - D$ is the "true" welfare function where the weight parameter $\widehat{\gamma}$ reflects normative considerations.

In Appendix A, we show that the regulation level resulting from this more complex game maximizes a weighted sum of welfare and profits. The weight γ of profits is the sum of the true weight $\widehat{\gamma}$ and the politicians concern for private benefits (β). Thus, our simpler game can be regarded as a reduced form of the more complex lobying game. We also show that, if the politician cares much about welfare, β is small, and the firm must offer high compensation payments to induce a policy deviation of a given size.[6]

3 Firm behavior

We first describe the behavior of a multinational firm for given regulation; the case of national firms is trivial because the locational structure is fixed as N. Intuitively, firms face simple trade-offs between locational choices. Compared to complete relocation, no relocation means saving fixed costs, but incurring the costs of regulation. Compared to partial relocation, no relocation means saving fixed costs, but incurring transportation costs and regulation costs.

[5] Typically $\gamma \leq 1$ would be assumed, reflecting either distributional preferences for consumers or foreign ownership of assets.

[6] The politician's payoff is independent of β because he is exactly compensated for the equilibrium policy deviation and his marginal benefit of contribution payments (captured by β) is small.

Compared to complete relocation, partial relocation involves saving transportation costs, but incurring regulation costs.

The following assumptions guarantee that (i) it is possible to earn positive profits in a country that is served from abroad and (ii) the profits that can be obtained in the unregulated foreign country from serving this country locally outweigh the fixed costs.

Assumption 1 *(i) $t < a$, (ii) $a^2 > 4F$.*

In Appendix B.1, we show that, for optimal output choices, profits in the different locational regimes are:

$$\begin{aligned}
\Pi^N(r) &= \begin{cases} \frac{1}{4}\left[2a^2 - 2a(t+2r) + (t+r)^2 + r^2\right] & \text{if} \quad r \leq a - t \\ \frac{1}{4}\left[a^2 - 2ar + r^2\right] & \text{if} \quad a - t < r \leq a \\ 0 & \text{if} \quad a < r \end{cases} \\
\Pi^P(r) &= \frac{1}{4}\left[2a^2 - 2ar + r^2 - 4F\right] \quad \text{if} \quad r \leq a \\
\Pi^C(r) &= \frac{1}{4}\left[2a^2 - 2at + t^2 - 4F\right] \qquad (2)
\end{aligned}$$

$\Pi^N(r)$ can also be interpreted as the profit of a national firm. The case $r \leq a - t$ is relevant when both markets are served: The joint costs of transportation and regulation are not too high to prevent exports. If $a - t < r \leq a$, no profits can be earned from serving the foreign country because combined transportation costs and regulation are too high, whereas regulation is not too costly to stop production altogether. For $a < r$ regulation alone suffices to choke production even for the home-country market.

The multinational will choose the location $l(r) \in \{C, N, P\}$ that maximizes $\Pi^l(r)$. Straightforward calculations (see Appendix B.2) show that there are critical levels of regulation, $r_1 = r_1(a, t, F)$ and $r_2 = r_2(a, t, F)$ and $r_3 = t$ such that location choice is given as[7]

$$l(r) = \begin{cases} N & \text{if} \quad r \leq \min\{r_1, r_2\} \\ P & \text{if} \quad r_1 < r < r_3 \\ C & \text{if} \quad r \geq \max\{r_3, r_2\} \end{cases} \qquad (3)$$

Figure 1 illustrates how the location decisions depend on the parameters of the game.

Increases in a and decreases in F reduce the no-relocation region, because lower relocation costs F promote relocation, and higher demand a makes it more worthwhile to incur the fixed cost of relocation.[8]

[7] To see this, one has to identify where $\Pi^N = \Pi^P$, $\Pi^P = \Pi^C$ and $\Pi^N = \Pi^C$ and which location choice yields higher profits on which side of these lines of equal profits.

[8] This result can be derived by straightforward calculation based on the functions describing the boundaries between the three regions, i.e. on the equations (3) describing the location choice $l(r)$.

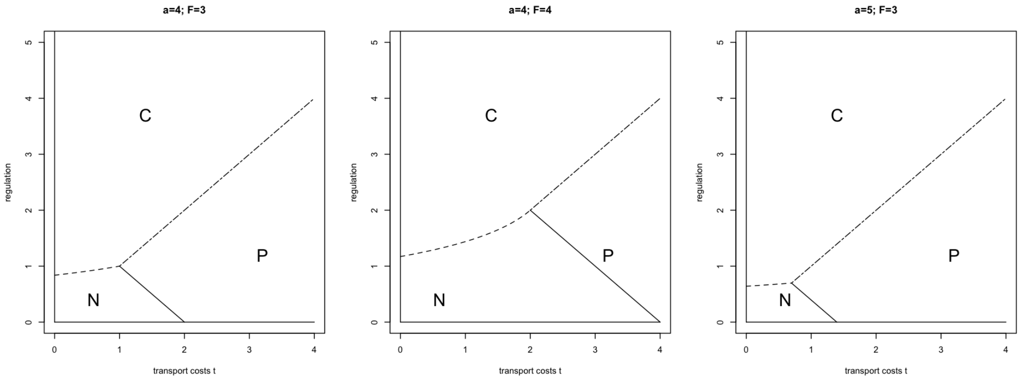

Figure 1: Location decisions of the multinational.

For later purposes, we highlight the role of transportation costs.

Lemma 1: *There exist values* $t^1 = t^1(a, F)$, $t^2 = t^2(a, F)$ *such that*

(i) For $t \leq t^1$*, the firm chooses no relocation for low values of regulation and complete relocation for high levels. Partial relocation never arises. (NC)*

(ii) For $t \geq t^2$*, the firm chooses partial relocation even for zero regulation and relocates completely for high levels of regulation (PC).*

(iii) For $t^1 \leq t \leq t^2$*, the firm chooses no relocation for low values of* r*, partial relocation for intermediate values and complete relocation for high values. (NPC)*

The proof is straightforward (see Appendix B.3).[9] The intuition is simple: (i) When t is low, it is never worthwhile to build a plant in the other country to serve only this country. However, it can be worthwhile to avoid high regulation costs by relocating completely. (ii) When t is very high, the firm will always serve the other country locally even when there is no regulation. (iii) For intermediate cases all locational patterns emerge for suitable r.

4 Determining regulation

In Section 4.1 we consider the optimal regulation for a national firm; we move to multinational firms in Section 4.2.

[9] t^1 corresponds to the intersection of all three regimes N, P and C, and t^2 corresponds to the value where the "$\Pi^N = \Pi^P$"-line intersects with the x-axis.

4.1 National Firms

In Appendix C we derive the expressions for welfare when the firm serves both markets ($r \leq a - t$) and when it produces only for the national market ($a - t < r \leq a$)[10] and use them to characterize the optimal regulation.

Proposition 1 *For* $\gamma^1 \equiv b - \frac{1}{2} \leq \gamma^2 \equiv 2b - \frac{1}{2} \leq \gamma^3 \equiv 2b - \frac{a}{2(2a-t)}$*, we have:*
(i) If $\gamma \leq \gamma^1$*, regulation is so high* ($r = a$) *that there is no production.*
(ii) If $\gamma^1 < \gamma \leq \gamma^2$*, regulation is just high enough that production only occurs for the home country* ($r = a - t$)*.*
(iii) If $\gamma > \gamma^2$*, there is production for both countries. If* $\gamma < \gamma^3$*,* r *lies strictly between* 0 *and* $a - t$*, and it is decreasing in* γ *and* t*, increasing in* a *and* b*. If* $\gamma \geq \gamma^3$*,* $r = 0$*.*

Proof: See Appendix D.

The result is intuitive: If the environmental problem is important and firms do not have much weight, then production may be shut down completely. As the influence of firms increases, regulation will be softened to allow production for the home country. Eventually, regulation becomes so soft that the firm will produce for both countries, and there will be no regulation if the weight of the firm is sufficiently strong.[11] The critical values $\gamma^1, \gamma^2, \gamma^3$ are increasing in b, because regulation levels depends on the trade-off between damages and concern for producer rents. For very low b, there is no regulation (even γ^3 is negative). As the environmental problem becomes more severe (b increases), regulation increases gradually until the firm no longer exports to the foreign country. Finally r becomes so high that production is shut down altogether.

Appendix D contains a formula for r when there is an interior solution in the regime where both markets are served. We will use this solution when we compare national and multinational firms in Section 5.

[10] This also contains the case where the firm closes down production completely ($r = a$). We do not discuss the possibility that $r > a$ explicitly, because it is equivalent to $r = a$. That the firm produces only for the home market if $a - t < r$ can be seen directly from the values for the optimal output for N (equations (7) in Appendix B.1).

[11] The result that there never is a solution in the interior of the regime with only home country production should not be overemphasized: It comes from the fact that, in this case, because of the specific functional forms we are employing, environmental damages and consumer surplus are proportional to the square of local output.

4.2 Regulation of Multinational Firms

We now characterize regulation of multinational firms:

Proposition 2 *There exist γ^{C1}, γ^{C2}, γ^{C3}, γ^{P2} such that the following statements hold :*[12]
(i) For $t \leq t^1$, complete relocation arises if and only if $\gamma \leq \gamma^{C1}$; there is no relocation for $\gamma > \gamma^{C1}$.
(ii) For $t^1 \leq t \leq t^2$, there is complete relocation if and only if $\gamma \leq \gamma^{C2}$. There is partial relocation if and only if $\gamma^{C2} < \gamma \leq \gamma^{P2}$. There is no relocation if and only if $\gamma > \gamma^{P2}$.
(iii) For $t > t^2$, there is complete relocation if and only if $\gamma \leq \gamma^{C3}$. There is partial relocation if and only if $\gamma^{C3} < \gamma$.

Proof: See Appendix E.

To prove this result, one has to take the effects of regulation on location decisions into account. Appendix C gives the corresponding welfare levels as $W^N(r)$, $W^P(r)$ and $W^C(r)$, respectively. $W^N(r)$, the welfare in regime N, is the same as for the national firm.

In Appendix E, we specify Proposition 2 by calculating the regulation levels for arbitrary parameterizations (Proposition 6), which will be useful when we compare the regulation of national and multinational firms in the next section. These calculations will show that higher b works in favor of relocation, whereas increasing γ works against it. Furthermore, Proposition 6 shows that partial relocation only arises for sufficiently high transportation costs ($t > t^1$).

5 National vs. Multinational Firms

We now ask under which circumstances multinationals face stronger or weaker regulation than national firms, respectively, first for $\gamma = 0$ and then for $\gamma > 0$. Rather than comparing regulation levels directly, we take output levels, which are essentially in a one-to-one relation.[13]

[12] t^1 and t^2 are defined in Lemma 1 above. The quantities for the γ's are defined in Appendix E.

[13] An exception arises for the case of complete relocation, where the local output is 0, but the regulation level is not well defined: Any regulation level that is is high enough to induce complete relocation is equivalent.

5.1 Pure Consumer Surplus Maximization

Suppose $\gamma = 0$. Fixing $a = 4$ and $F = 3$, we have the free parameters t, b. The left panel of Figure 2 captures the relocation patterns for the multinational (N,P or C), and it shows for which combinations of t and b the multinational has higher domestic output than the national firm.

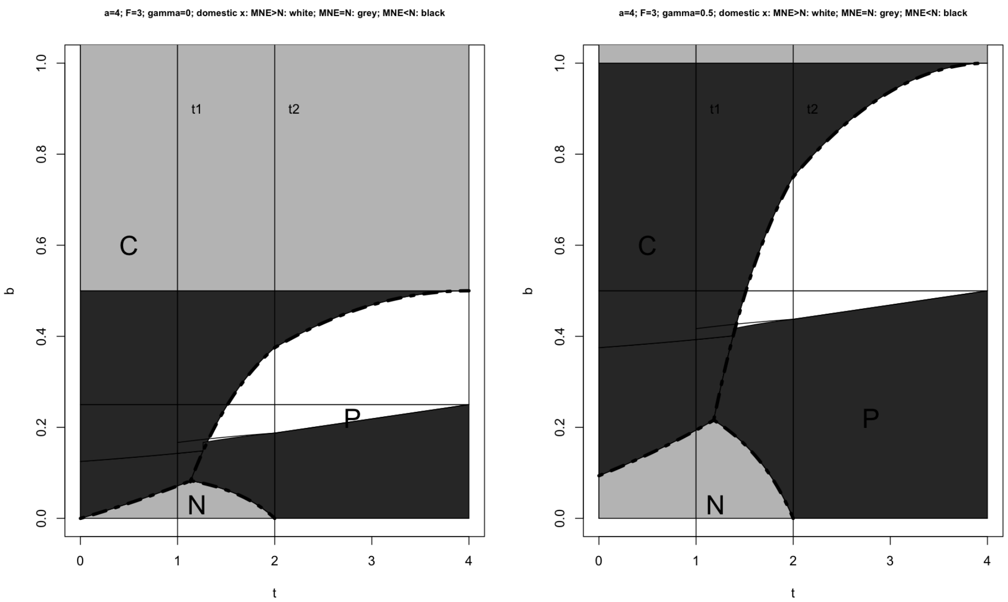

Figure 2: Left: $\gamma = 0$; right: $\gamma = 0.5$

Relocation regimes in the (t, b)-diagram are similar to those in the (t, r)-diagram because more damaging pollutants induce more regulation:[14]

i) For $t < t^1$, an increase in b leads from N to C.

ii) For $t^1 < t < t^2$, an increase in b leads from N to P to C.

iii) For $t > t^2$, an increase in b leads from P to C.

[14] We emphasize that the boundaries for the three ranges of t with N and C; N,P and C; and P and C; are however somewhat different, as the boundaries in the (t, r)-plane are determined by the profits of the multinational alone, while the boundaries in the (t, b)-plane are determined by welfare. There is a region (t^1, t^{1*}) where each of the location choices N,P and C would be chosen by the multinational for certain combinations of t and r. In this region, however, due to welfare considerations, the government never chooses values of r that would induce the multinational to choose P.

As to the comparison between multinational and national firms, we find:

Result 1 *a) The output of national and multinational firms is identical when the damage parameter b is high or when b is low and t is intermediate (the areas shaded grey in the left panel of Figure 2).*
b) Multinational firms produce less than national firms (i) for intermediate values of b and low t and (ii) for low b and high t.
c) Multinational firms produce more than national firms for intermediate values of b and high t.

In the remainder of this subsection, we provide the intuition for these observations, which should also clarify that the results are not an artefact of the particular parameterization used in Figure 2.

To understand the intuition for a), note that for $b \geq 0.5$ ((the upper grey area) the multinational firm relocates completely (no domestic output) and the national firm is driven out of the market (no output at all). Measured in domestic output, the firms thus face equal regulation. For very low b and intermediate t (the lower grey area), the outputs are the same because neither firm is regulated. t has to be intermediate because (i) for very low t the multinational firm would relocate even for low regulation and the government would not prevent this because the resulting reduction in consumer surplus is low, and (ii) for very high t, export is too costly for the firm, so that it would choose partial relocation even for zero regulation.

As to b(i), in the part of C where the national firm produces (intermediate b, low t), the multinational firm trivially has lower domestic output than the national firm. The environmental benefits from shutting down the multinational firm's production are high, and for low transportation costs t, the reduction in consumer surplus is low. With a national firm, the environmental benefits from shutting down would come at the costs of losing consumer surplus altogether. This *easier-to-shut-down effect* implies that the regulator is less reluctant to close down multinational firms.

As to b(ii), for high t, there is partial relocation of the multinational. The left panel of figure 2 shows that there is a critical level of b, which is increasing in t, below which the multinational produces a lower domestic output than the national firm in regime P. To understand this, we focus on the case $t > t^2$, so that there is partial relocation even for $b = 0$.[15]

[15]For $t^{1*} < t < t^2$, the argument is similar. The multinational is still regulated minimally, subject to the constraint that it relocates partially. However, this regulation level now depends negatively on transportation costs (the downward-sloping part of the lower boundary of P), so that the multinational firm's output will increase with transportation costs. With this exception, the intuition for the observed patterns is similar than with

For $b < \frac{1}{8}$ neither firm is regulated.[16] Even though both firms face the same regulation, the national firm which serves both markets produces more output and thus more pollution than the multinational. This *multiple-plant effect* is still present beyond $b = \frac{1}{8}$. While there still is no regulation of the multinational firm, the national firm is regulated: This reflects the greater benefits of regulating national firms which produce all their output in the home country. With convex damages, the marginal damage for the partially relocated firm is thus lower than for the national firm. The national firm is regulated more and more as b increases. Nevertheless, the output of the multinational firm in the home country is lower than for the national firm for small b.

c) As b increases within regime P, the regulation of the national firm eventually becomes so strong that it produces less output than the multinational firm which is still not regulated. This result can be explained as follows: As environmental damages are large enough, the government wants the national firm to produce only for the home country. Whereas the multinational firm does this even for $r = 0$ (because it has the alternative of production abroad), the national firm only does it for $r \geq a - t$. This is the *easier-to-curb-exports* effect: To get rid of the multinational firm's export production, less regulation is needed and the output is correspondingly higher.

5.2 Increasing Influence of the Firm

We now assess the effects of a positive weight on the firm's profit ($\gamma > 0$), reflecting greater weight of producer surplus or greater importance of private benefits in the regulator's objective function. Clearly, regulation becomes weaker for both firms as γ increases. The more interesting question is whether it becomes more likely that the multinational faces less regulation than the national firm or, conversely, that the national firm becomes regulated less, that is which type of firms are better lobbyists. We will show that both results can arise.

The right panel of figure 2 shows that an increase in γ has the following effects:[17]

i) The complete relocation regime shifts upwards (both the lower and the

large t. For low b the government regulates neither firm. Beyond the level of b where partial relocation is induced, the multinational firm is initially regulated more than the national firm. As b increases, the regulator aims at choking off export production of the national firm which requires stronger regulation than for the multinational.

[16]Use Proposition 1: For $\gamma = 0$ and $b < \frac{1}{8}$, $\gamma^3 = 2b - \frac{1}{4} < 0$ and hence $r = 0$.

[17]Note that as the critical value t^2 is independent of γ, and t^{1*} only changes slowly with γ, the parameter regimes change mainly along the b-dimension.

upper boundary). The upward shift of the lower boundary says that there are parameter values without domestic production of the multinational for low γ, but with domestic production for high γ. Specifically, for $t < t^{1*}$, the region where multinational firms produce the same output as the national firm grows. The increasing weight of the multinational firm reduces the relevance of the *easier-to-shut-down effect* in these regions, with the result that the multinational no longer produces less than the national firm. The upward shift of the upper boundary of the complete relocation regime arises because the increasing influence of the national firm reduces the area where its production is shut down.
For sufficiently high t and points just inside C, the increase in γ leads into the part of P where multinational firms are regulated less than the national firm and produce higher outputs; the *easier-to-curb-exports* effect kicks in. Hence again lobbying reverses the ordering of the output levels in favor of the multinational firms.

ii) The second effect arises only in P. As for $\gamma = 0$ there is a critical level of b above which the multinational firm produces higher domestic output than the national firm. This critical level increases in γ. Thus there is a parameter region where a switch from multinational firms having higher domestic output to national firms having higher domestic output arises as γ increases. Intuitively, in the regime P, the regulation of the multinational firm is independent of b. It is always as low as possible to just induce partial relocation or it is at $r = 0$. For the national firm regulation is increasing (and hence output is decreasing) in b. As γ increases, there is no effect on the regulation of the multinational firm. However, the regulation of the national firm becomes less stringent, so that the *easier-to-curb-exports* becomes less relevant. Expressed more generally, the increasing influence of the firms has a stronger impact on the regulation of the national firm, because this firm obtains all of its profits in the home country, whereas the multinational firm obtains a substantial part in the foreign country which is unaffected by regulation.

6 Welfare

The results in the previous section strongly suggest that the welfare comparison between national and multinational firms is ambiguous. On the one hand, where the multinational is induced to relocate, local pollution will decline. On the other hand, relocation may lead to reductions in consumer surplus. Of course, by choosing regulation accordingly, the government can avoid relocation if desired. At first glance, it might therefore seem that a country is always better off with a multinational firm, because this adds the option of inducing exit of an undesired firm without losing consumer surplus completely. However, an option that the government loses with a multinational firm is to regulate the firm heavily and nevertheless have local production – the firm will vote with the feet when regulation gets too stringent.

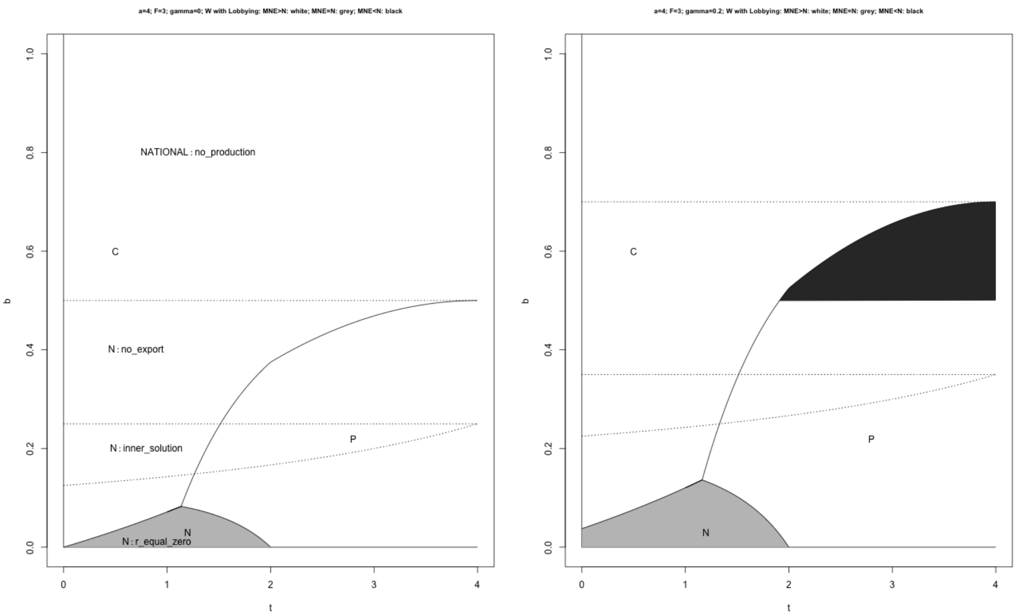

Figure 3: Left: $\gamma = 0$; right: $\gamma = 0.2$

In spite of these potential ambiguities, our model yields a very clear result: For $\gamma = 0$, a country that faces a multinational firm is always better off than with the national firm, except for a small region where regulation and welfare are identical for both types of firms (grey area in the left panel in Figure 3). The intuition can be obtained from this figure, which is closely related to Figure 2. First, consider regime C: When the environmental damage is so substantial that the production of the national firm is choked off entirely, welfare is clearly higher with the multinational, because the multinational still generates consumer surplus for the home country. As the environmental damage parameter declines, the national firm is regulated less, so that it at least produces for the local market: Contrary to the multinational firm, the national firm therefore generates environmental damage, but because transportation costs are fairly small, so are the losses in consumer surplus from having a multinational rather than a local firm. In regime P, first consider low damage parameters. Then, contrary to the multinational firm, the national firm produces for both countries, thereby creating more pollution than the multinational without generating more consumer surplus. As the pollution parameter increases, so that the government wants to curb exports of the national firm, excessive regulation is necessary to induce this, so that the multinational firm generates higher consumer surplus without substantially more pollution.

The picture changes dramatically when lobbying is taken into account. The right panel in Figure 3, which corresponds to the right panel in Figure 2, compares welfare (defined as pure consumer surplus minus damages) for national and multinational firms when regulation is determined with $\gamma = 0.5$. The picture shows that there now is a region where welfare with multinational firms is lower than with national firms (shaded dark). In this region, there is partial relocation, and the multinational firm produces more than the national firm. Because of the *easier-to-curb-export effects*, the multinational firm is regulated less than the national firm. This increases environmental damages and reduces welfare compared to the national firm.

Figure 3 nicely illustrates the effects of lobbying on welfare: Even though our setting is biased in the sense that a consumer-surplus maximizing government is always better off with multinationals, this changes with lobbying: There are parameter regions (with fairly high environmental damage parameter) where the increasing influence activities reverse the welfare comparison.

We want to point out the the clear result for $\gamma = 0$ is due to the model specification where both the consumer surplus and the damage function are quadratic in output. For differing functional forms of these terms, the area where welfare with multinational firms is lower than with national firms will already emerge for $\gamma = 0$ or only for γ strictly positive, depending on the specific characteristics of each of these terms.

7 Generalizations

We now show that the main insights of our analysis hold much more generally. We work with assumptions on the demand structure, the nature of regulation and the damage function which are compatible with our specific example. As before, we suppose there are two countries $i = 1, 2$ and one firm, which originally has a plant in country 1. However, regulation in country 2 can be positive as well. We denote regulation levels as r_i. There are parameters capturing market demand $a > 0$, transportation costs $t \geq 0$, relocation costs $F \geq 0$ and environmental damages $b \geq 0$. Let $\theta = (a, b, t, F)$. The firm has three options for location decisions, namely "no relocation" ("N"), i.e. it produces in country 1 only, "complete relocation" ("C"), i.e. it produces in country 2 only, and "partial relocation" ("P"), where production for country 1 takes place in country 1, production for country 2 takes place in country two. We use the notation $l(r_1, r_2; \theta)$ to denote locational decisions N,P or C.

7.1 Profits and Locational Choices

We let $\pi_{ij}(r_i; a, t)$ denote the optimal profits of a firm that serves country j from country i (gross of relocation costs); total gross profits of a firm having taken the locational decision l are thus $\pi_l(r_i, r_j; a, t) \equiv \pi_{i1}(r_i; a, t) + \pi_{j2}(r_j; a, t)$, with $i = 1 = j$ for l =N, $i = 2 = j$ for l =C, and $i = 1$, $j = 2$ for l =P. We let $x_{ij}(r_i; a, t)$, $x_l(r_i, r_j; a, t)$ denote the corresponding outputs. $\Pi_l(r_i, r_j; a, t) = \pi_l(r_i, r_j; a, t) - F$ denotes net profits.

Assumption 2 *Let $i = 1, 2$.*
(a) For $i, j = 1, 2$ and all $a > 0$; $t > 0$, there exists an $r^{\max} = r^{\max}(a, t)$ such that $x_{ij}(r_i; a, t) \equiv 0$ and $\pi_{ij}(r_i; a, t) \equiv 0$ for $r_i \geq r^{\max}$.
(b) For $r_i \leq r^{\max}$, π_{ij} and x_{ij} are (i) decreasing in r_i and (ii) increasing in a; (iii) decreasing in t for $i \neq j$ and independent of t for $i = j$. As long as $x_{ij} > 0$, the statements can be replaced with "strictly increasing" and "strictly decreasing", respectively.
(c) (i) $x_{ij}(r_i; a, t) \equiv x_{ji}(r_j; a, t)$ and $\pi_{ij}(r_i; a, t) \equiv \pi_{ji}(r_j; a, t)$
(ii) $x_{1j}(r_1; a, 0) \equiv x_{2j}(r_2; a, 0)$ and $\pi_{1j}(r_1; a, 0) \equiv \pi_{2j}(r_2; a, 0)$ for $r_1 = r_2$,
(d) x_{ij} and π_{ij} are continuous in all arguments.
(e) $\lim_{t\to\infty} \pi_{ij}(r_i; a, t) = \pi_{ji}(r_j; a, t) = 0$ (for $i \neq j$),
$\lim_{a\to 0} \pi_{ij}(r_i; a, t) = 0$ *for $j = 1, 2$.*
(f) $x_{ii}(0; a, t) > 0$ and $\pi_{ii}(0; a, t) > 0$.

These assumptions are fairly general. (a) states that there is a prohibitive level of regulation. (b) stipulates that outputs and profits react to changes of regulation and to market parameters in the expected way. (c) requires that countries and firms are symmetric and differ only according to the type of regulation. Assumptions (d) and (e) are innocuous regularity properties; (f) states that outputs and profits are positive without regulation.

We show that the qualitative properties of Figure 1 hold if Assumption 2 does.

Proposition 3 *(i) For all $r_2 \geq 0$ and all θ, $l(0, r_2; \theta) \neq C$.*
(ii) For all $(r_2; \theta)$ there exists $r_1^* > 0$ and $t^* > 0$ such that $\forall r_1 < r_1^*$ and $\forall t < t^*$, $l(r_1, r_2; \theta) = N$.
(iii) For all $(r_2; \theta)$ such that $\pi_{22}(r_2; a, t) \geq F$ there exists $r^* = r^*(r_2; \theta) > 0$

such that $l(r_1, r_2; \theta) = C$ *for* $r_1 > r^*$.
(iv) For all (r_1, r_2, a, F) *there exists a* $t^* > 0$ *such that* $l(r_1, r_2; \theta) \neq P$ *for* $t < t^*$. *If* $\pi_{22}(r_2; a, t) \geq F$, *then there is a* t^{**} *such that* $l(r_1, r_2; \theta) \neq N$ *for* $t > t^{**}$.

Proof: See Appendix F

The proposition reflects the relocation structure of our specific model in a more general context. First, complete relocation does not occur when there is no regulation in the home country.[18] Second, if regulation and transportation costs are small, no relocation occurs. Third, provided that foreign country regulation is not too high to prevent positive profits net of relocation costs, complete relocation occurs for sufficiently high regulation in the home country. Fourth, whether relocation is partial or complete depends on the interaction between regulation and transportation costs: For low transportation costs, partial relocation is never optimal, while for higher transportation costs partial relocation can be optimal and no relocation is never chosen.

7.2 The Choice of Regulation

We now introduce additional assumptions so that we can address the choice of regulation.

Assumption 3 *(a) The regulator maximizes a weighted sum of consumer surplus (minus damages) and profits.*
(b) Consumer surplus is a strictly increasing function of x_i.
(c) Damages are continuous, weakly increasing functions of x_i *and* b. *For* $b > 0$, *they are strictly increasing in* x_i; *for positive* x_i, *they are strictly increasing in* b. *For* $b = 0$, *damages are* 0 *for all* x_i *and hence the optimal regulation is* 0.
(d) For national and multinational firms, the optimal regulation is a continuous function of all parameters as long as no change of location is induced. As $b \to \infty$, *the optimal regulation involves* $x_i = 0$.

We now ask to which extent the comparative analysis (Result 1) for the pure consumer surplus case generalizes.

Proposition 4 *Suppose* $\gamma = 0$.
a) Fix a, F *and* r_2.
(i) For every level of transportation costs, there exists a value of $\overline{b}$ *such that neither the national nor the multinational firm produces any output for* $b > \overline{b}$.

[18] Note that in this case partial relocation may occur due to high transportation costs.

(ii) If t is sufficiently small, but positive, there exists $\underline{b} > 0$ such that both firms produce the same output level for $b < \underline{b}$.
b) Fix a and F. Suppose r_2 is sufficiently small. (i) If t is sufficiently small, there exist b_* and b^* such that $b_* < b^*$ and multinational firms produce less home-country output than national firms for $b \in (b_*, b^*)$. (ii) If t is sufficiently large, there exist $\widetilde{b}$ such that multinational firms produce less home-country output than national firms for $b < \widetilde{b}$.

Proof: See Appendix F

Result a) identifies the conditions under which both firms are regulated so that they choose the same output levels. In qualitative terms, the regions where this is the case correspond to those shaded grey in Figure 2. Result b) uncovers the two forces because of which the multinational firm might produce less than the national firm: Result (i) reflects the *easier-to-shut-down effect* that arises for low transportation costs and intermediate values of damages. Result (ii) generalizes the *multiple-plant effect* that arises for large transportation costs and low damages.
However, note that we have not included a generalization of the result that, for large transportation costs and intermediate values of the damage parameter, the multinational firm produces more output. While the logic of the *easier-to-curb-emissions effect* is quite general, it merely implies that, *if* there are some points in the partial relocation regime where it is optimal to prevent exports of the national firm, then the multinational firm will be regulated less for these values and produce larger outputs. While there are large parameter regions where this logic is confirmed, there are also parameter regions where this is not the case.

8 Conclusions

In a simple monopoly model, we investigated whether national or multinational firms face stronger regulation. For low transportation costs, multinationals exercise the option of relocation when environmental damages are high (and hence regulation becomes stricter); national firms then produce at least as much as multinationals. As transportation costs increase, the situation is more complex. There is a large range of parameters for which multinational firms relocate partly. In this parameter regime, the multinational firm typically produces lower outputs than the national firm when environmental damages are low. For intermediate transportation costs, these lower outputs reflect more stringent regulation; for higher transportation costs they simply result from the fact that the multinational firm produces a large part of its output abroad. As environmental damages increase, the multinational tends to face less regulation than the national firm and thus produces a higher output. In this case, the government uses regulation policy to render national production for export unprofitable, because it decreases aggregate welfare.

In our simple model, consumer surplus net of environmental damages is always higher for multinational firms than the national firm when the government cares only about consumers. When the government also takes the producer surplus into account, consumers may be better off with national than with multinational firms.

Appendices

A The lobbying game

We first show that the regulation level resulting from the game described in Section 2.1 maximizes a weighted sum of welfare and profits.

Proposition 5 *There is a subgame perfect equilibrium $r^*, C^{r^*}(r)$ of the lobbying game such that*

$$r^* = argmax_r \, \Pi(r) - \frac{1}{\beta}\left[\widehat{W}(r^0) - \widehat{W}(r)\right].$$

and

$$C^{r^*}(r) = \begin{cases} \frac{1}{\beta}\left[\widehat{W}(r^0) - \widehat{W}(r)\right] & if \;\; r = r^*. \\ \frac{1}{\beta}\left[\widehat{W}(r^0) - \widehat{W}(r)\right] - \varepsilon(r) & if \;\; r \neq r^* \end{cases} .$$

ε is differentiable and has the following properties:

$$\varepsilon(r^*) = 0 = \varepsilon(r^0); \varepsilon(r) > 0 \;\forall\; r \neq r^*, r^0; \varepsilon(r) \leq \frac{1}{\beta}\left[\widehat{W}(r^0) - \widehat{W}(r)\right]. \quad (4)$$

Proof: In the second stage, for any contribution schedule $C(.)$, the politician chooses a policy r that maximizes $\widehat{W}(r) + \beta C(r)$. By choosing r^0, the politician can obtain $\widehat{W}(r^0) + \beta C(r^0)$. Here, $C(r^0) = 0$, as the regulation level r^0 is by definition chosen as being welfare-maximizing without lobbying payments. Thus, if a regulation $\widetilde{r} \neq r^0$ is to be induced, it is necessary that

$$C(\widetilde{r}) \geq \frac{1}{\beta}\left(\widehat{W}(r^0) - \widehat{W}(\widetilde{r})\right).$$

Thus, any desired location $\widetilde{r}$ can be induced with the following scheme:

$$C^{\widetilde{r}}\left(r\right)=\begin{cases}\frac{1}{\beta}\left[\widehat{W}\left(r^{0}\right)-\widehat{W}\left(r\right)\right] & \text{if } r=\widetilde{r}\\ \frac{1}{\beta}\left[\widehat{W}(r^{0})-\widehat{W}(r)\right]-\varepsilon(r) & \text{otherwise.}\end{cases}$$

with $\varepsilon(\widetilde{r})=0=\varepsilon(r^{0});\varepsilon(r)>0\ \forall\ r\neq\widetilde{r},r^{0};\varepsilon(r)\leq\frac{1}{\beta}\left[\widehat{W}(r^{0})-\widehat{W}(r)\right].$

Facing $C^{\widetilde{r}}\left(r\right)$, the politician obtains utility levels $\widehat{W}\left(r^{0}\right)$ for r^{0} and $\widetilde{r}$ and lower utility levels for all other values of r. Any desired regulation level $\widetilde{r}$ can be induced at minimal costs $\frac{1}{\beta}\left[\widehat{W}\left(r^{0}\right)-\widehat{W}\left(\widetilde{r}\right)\right]$. Thus, the firm effectively chooses r as

$$r^{*}=\arg\max_{r}\Pi\left(r\right)-\frac{1}{\beta}\left[\widehat{W}\left(r^{0}\right)-\widehat{W}\left(r\right)\right].$$

The corresponding contribution schedule is $C^{r^{*}}$. ■

The proposition has an intuitive implication.

Result 2 *The regulation level chosen in the lobbying game is*

$$\arg\max_{r}\widehat{W}\left(r\right)+\beta\Pi\left(r\right)$$

Proof: By Proposition 5,

$$r^{*}=argmax_{r}\ \Pi(r)-\frac{1}{\beta}\left[\widehat{W}(r^{0})-\widehat{W}(r)\right].$$

Thus

$$r^{*}=argmax_{r}\ \Pi(r)+\frac{1}{\beta}\widehat{W}(r)=argmax_{r}\ \beta\Pi(r)+\widehat{W}(r).$$

■

Thus, regulation maximizes a weighted sum of welfare and firm profits.

B The location decisions of the multinational

B.1 Deriving Equation (2)

Using (1), profits in the different locations are

$$\begin{aligned}\Pi^{N} &= p_{1}x_{1}^{1}+p_{2}x_{2}^{1}-r\left(x_{1}^{1}+x_{2}^{1}\right)-tx_{2}^{1} && (5)\\ \Pi^{P} &= p_{1}x_{1}^{1}+p_{2}x_{2}^{2}-rx_{1}^{1}-F && (6)\\ \Pi^{C} &= p_{1}x_{1}^{2}+p_{2}x_{2}^{2}-tx_{1}^{2}-F.\end{aligned}$$

Simple calculations show that the optimal output levels are

$$\begin{aligned}
x_1^1 &= \max\left(\frac{a-r}{2},0\right),\ x_2^1 = \max\left(\frac{a-r-t}{2},0\right) \text{ in regime } N \\
x_1^1 &= \frac{a-r}{2},\ x_2^2 = \frac{a}{2} \text{ in regime } P \\
x_1^2 &= \frac{a-t}{2},\ x_2^2 = \frac{a}{2} \text{ in regime } C.
\end{aligned} \tag{7}$$

Inserting these choices into (5), we obtain (2).

B.2 Locational Choices

We now derive locational choices (3). Using (2), we first make pairwise comparisons of profits in the different regimes:

$$\Pi^N > \Pi^P \quad \Rightarrow \quad \begin{cases} r^2+t^2+2rt-2ar-2at+4F>0 & \text{if } \ r \le a-t \\ -a^2+4F>0 & \text{if } \ a-t<r \end{cases}$$

$$\Pi^P > \Pi^C \quad \Rightarrow \quad \begin{cases} t>r & \text{if } \ r\le a \\ \textit{never} & \text{if } \ a<r \end{cases}$$

$$\Pi^N > \Pi^C \quad \Rightarrow \quad \begin{cases} r^2+rt-2ar+2F>0 & \text{if } \ r\le a-t \\ r^2-t^2-a^2+2at-2ar+4F>0 & \text{if } \ a-t<r\le a \\ 0>2a^2-2at+t^2-4F & \text{if } \ a<r \end{cases}$$

For regime N to be chosen, we need $\Pi^N > \Pi^P \wedge \Pi^N > \Pi^C$. For $r \le a-t$ we therefore need :

$$r^2+t^2+2rt-2ar-2at+4F>0 \wedge r^2+rt-2ar+2F>0.$$

For $a-t<r\le a$, N is optimal if

$$-a^2+4F>0 \ \wedge \ r^2-t^2-a^2+2at-2ar+4F>0.$$

For $r>a$, the condition becomes

$$-\mathrm{a}^2+4\mathrm{F}>0 \ \wedge \ 0>(\mathrm{a}-\mathrm{t})^2+\mathrm{a}^2-4\mathrm{F}.$$

Due to assumption 1*(ii)*, $a^2>4F$, the second and the third case cannot occur. For the first case, simple derivations show that the two conditions can be written as follows:

$$\text{for } r\le a-t \ : \ r<\min\left\{a-t-\sqrt{a^2-4F},\, a-\frac{t}{2}-\frac{1}{2}\sqrt{(t-2a)^2-8F}\right\}$$

Defining

$$r_1 \equiv a - t - \sqrt{a^2 - 4F} \text{ and } r_2 \equiv a - \frac{t}{2} - \frac{1}{2}\sqrt{(t-2a)^2 - 8F}, \tag{8}$$

the first statement in (3) follows.
For regime P to be chosen, we need $\Pi^P > \Pi^N \wedge \Pi^P > \Pi^C$. For $r \leq a - t$, we thus require

$$r^2 + t^2 + 2rt - 2ar - 2at + 4F < 0 \wedge t > r.$$

For $r > a - t$, the condition for P to be optimal is

$$-a^2 + 4F < 0 \wedge t > r.$$

Again, straightforward calculations show that location P is chosen in the following cases:

$$\begin{array}{lcl} \text{for } r \leq a - t & : & a - t - \sqrt{a^2 - 4F} < r < t \\ \text{for } r > a - t & : & -a^2 + 4F < 0 \wedge r < t \end{array}$$

Using $a^2 - 4F > 0$ and the fact that C is chosen in the remaining cases, where neither N nor P will be chosen, leads to the equations (3) for $l(r)$.

B.3 Proof of Lemma 1

Define $t^1 = \frac{a-\sqrt{a^2-4F}}{2}$ and $t^2 = a - \sqrt{a^2 - 4F}$. Using (3) and (8): regimes N, P and C intersect at t^1, and t^2 corresponds to the value where the "$\Pi^N = \Pi^P$"-line intersects with the x-axis.

C The Expressions for Welfare

Simple calculations show:

$$\begin{aligned} K^N &= \int_0^{x_1^1} (a-q)\mathbf{d}q - (a - x_1^1)x_1^1 = \frac{(x_1^1)^2}{2} \\ K^P &= \int_0^{x_1^1} (a-q)\mathbf{d}q - (a - x_1^1)x_1^1 = \frac{(x_1^1)^2}{2} \\ K^C &= \int_0^{x_1^2} (a-q)\mathbf{d}q - (a - x_1^2)x_1^2 = \frac{(x_1^2)^2}{2} \end{aligned} \tag{9}$$

$$
\begin{aligned}
D^N &= b(x_1^1 + x_2^1)^2 \\
D^P &= b(x_1^1)^2 \\
D^C &= 0 \qquad (10)
\end{aligned}
$$

The welfare levels in the different locational regimes are then (taking Π from (5)):

$$
\begin{aligned}
W^N &= \frac{(x_1^1)^2}{2} + \gamma[(a - x_1^1)x_1^1 + (a - x_2^1)x_2^1 - r(x_1^1 + x_2^1) - tx_2^1] \\
&\qquad -b(x_1^1 + x_2^1)^2 \\
W^P &= \frac{(x_1^1)^2}{2} + \gamma[(a - x_1^1)x_1^1 + (a - x_2^2)x_2^2 - r(x_1^1) - F] - b(x_1^1)^2 \\
W^C &= \frac{(x_1^2)^2}{2} + \gamma[(a - x_1^2)x_1^2 + (a - x_2^2)x_2^2 - t(x_1^2) - F] \qquad (11)
\end{aligned}
$$

Inserting the values for the output from above (equation (7)) and discerning the cases as above gives [19]:

$$
\begin{aligned}
W^N(r) &= \begin{cases} \text{if } r \le a - t: & \frac{\gamma}{4}\left[2a^2 + 2r^2 + t^2 + 2rt - 4ar - 2at\right] \\ & \quad +\frac{1}{8}(a-r)^2 - \frac{b}{4}\left(2a - 2r - t\right)^2 \\ \text{if } a - t < r \le a: & \frac{\gamma}{4}(a-r)^2 + \frac{1}{8}(a-r)^2 - \frac{b}{4}\left(a-r\right)^2 \\ \text{if } a < r: & 0 \end{cases} \\
W^P(r) &= \begin{cases} \text{if } r \le a: & \frac{\gamma}{4}\left[2a^2 + r^2 - 2ar - 4F\right] + \frac{1}{8}(a-r)^2 \\ & \quad -\frac{b}{4}\left(a-r\right)^2 \end{cases} \\
W^C(r) &= \frac{\gamma}{4}\left[2a^2 + t^2 - 2at - 4F\right] + \frac{1}{8}\left(a-t\right)^2. \qquad (12)
\end{aligned}
$$

D Regulation of national firms

Proof of Proposition 1

(a) The welfare levels corresponding to $r \geq a$ (No Production), $r \leq a - t$ (Full Production) and $a - t \leq r \leq a$ (No Exports) are given in equation (12). We first show that the optimal r and the corresponding welfare levels correspond to the values shown inTable 1.

(a1) Clearly, for $r \geq a$, welfare is 0, independent of r.

[19] In regime P, we ignore the case $r > a$: In this case, the home market would not be served, so that complete relocation is always preferred.

(a2) For $r \leq a-t$, firms produce both for both markets. Using the F.O.C for unconstrained maximization of $W^N(r)$,

$$r = \frac{a(-4\gamma - 1 + 8b) + t(-4b + 2\gamma)}{-4\gamma - 1 + 8b}$$

is a candidate interior solution. However, this candidate is only in $[0, a-t]$ if $2b - \frac{1}{2} \leq \gamma < 2b - \frac{a}{2(2a-t)}$. For $\gamma < 2b - \frac{1}{2}$, $W^N(r)$ is increasing in r on $[0, a-t]$, so that the optimum is $r = a - t$. For $\gamma > 2b - \frac{a}{2(2a-t)}$, $W^N(r)$ is decreasing in r, so the optimum is $r = 0$. Table 1 also contains the resulting welfare levels.

(a3) For $a - t \leq r \leq a$, it turns out that $W^N(r)$ is always monotone, resulting in an optimum $r = a$ if $\gamma < b - \frac{1}{2}$ and $r = a - t$ if $\gamma > b - \frac{1}{2}$.

(b) Next, we compare welfare in the candidate solutions. (b1) If $\gamma < \gamma^1 \equiv b - \frac{1}{2}$, the optimal solution is $r = a - t$ in the full production regime and it is $r = a$ in the no exports regime. Comparing the expressions for welfare, we obtain that $r = a$ and $W = 0$. Hence, part (i) of the result follows.

(b2) If $b - \frac{1}{2} < \gamma < \gamma^2 \equiv 2b - \frac{1}{2}$, the candidate optimum in both regimes is $r = a - t$. Hence, part (ii) of the result follows.

(b3) If $2b - \frac{1}{2} \leq \gamma < \gamma^3 \equiv 2b - \frac{a}{2(2a-t)}$, the optimum in the full production regime is given by the interior solution. It has to be compared with the optimum in the No Exports regime ($r = a - t$). Using the corresponding expressions in Table 1, it turns out that the full production optimum is superior.

(b4) If $\gamma > \gamma^3$, the optimum in the full production regime is $r = 0$, the optimum in the No Exports regime is $r = a - t$. Using the corresponding expressions for welfare in Table 1, it follows that full production is superior. Together with (b3), this implies Part (iii) of the result.

range of γ	$r =$	$W^N =$
$\gamma < b - \frac{1}{2}$	a	0
$b - \frac{1}{2} < \gamma < 2b - \frac{1}{2}$	$a - t$	$t^2(\frac{\gamma}{4} + \frac{1}{8} - \frac{b}{4})$
$2b - \frac{1}{2} \leq \gamma < 2b - \frac{a}{2(2a-t)}$	$\frac{a(-4\gamma-1+8b)+t(-4b+2\gamma)}{-4\gamma-1+8b}$	$\frac{t^1}{(1+2\omega)^2}\left[\frac{\gamma}{4}(2\omega^2 + 2\omega + 1) + \frac{\omega^2}{8} - \frac{b}{4}\right]$
$2b - \frac{a}{2(2a-t)} < \gamma$	0	$(2a^2 + t(t-2a))\frac{\gamma}{4} + a^2\frac{1}{8} - \frac{b}{4}(t-2a)^2$

Table 1: Optimal values for the regulation r and corresponding welfare levels for the national firm ($\omega := -4b + 2\gamma$)

E Regulation of multinational firms

We specify Proposition 2 by including regulation levels.

Proposition 6 *There exist γ^{C1}, γ^{C2}, γ^{C3}, γ^{P2} such that:*[20]
(i) For $t \leq t^1$, complete relocation arises if and only if $\gamma \leq \gamma^{C1}$; there is no relocation for $\gamma > \gamma^{C1}$. We obtain $r^C = a - \frac{t}{2} - \frac{1}{2}\sqrt{-8F - 4at + 4a^2 + t^2}$ or $r^N = 0$.
(ii) For $t^1 \leq t \leq t^2$, there is complete relocation if and only if $\gamma \leq \gamma^{C2}$. There is partial relocation if and only if $\gamma^{C2} < \gamma \leq \gamma^{P2}$. There is no relocation if and only if $\gamma > \gamma^{P2}$. We obtain $r^C = t$, $r^P = a - t - \sqrt{a^2 - 4F}$ or $r^N = 0$.
(iii) For $t > t^2$, there is complete relocation if and only if $\gamma \leq \gamma^{C3}$. There is partial relocation if and only if $\gamma^{C3} < \gamma$. We obtain $r^C = t$ or $r^P = 0$.

We will require several preliminary results.
Lemma 2: *Welfare under complete relocation is*

$$W^C = \left(\frac{\gamma}{4} + \frac{1}{8}\right)(a - t)^2 + \frac{\gamma}{4}\left(a^2 - 4F\right).$$

The corresponding minimal regulation is $r^C = a - \frac{t}{2} - \frac{1}{2}\sqrt{-8F - 4at + 4a^2 + t^2}$ or $r^C = t$.

The result follows directly from (12). Intuitively, as the firm serves both countries from abroad, there is no home country pollution. The home country consumer surplus has to be calculated taking into account the transportation costs t, and similarly for total profits. As W^C is independent of regulation, any value of r inducing complete relocation can be chosen. A natural candidate is the lowest possible value that induces C, thus the lower boundary of the complete relocation region in the (t, r)-graph. These values for r can be taken from Appendix B.

Lemma 3: (i) *If $\gamma < b - \frac{1}{2}$ the constrained optimal choice of r in P lies on the upper boundary of P ($r = t$). The resulting welfare level is*

$$W^P = \left(\frac{\gamma}{4} + \frac{1}{8}\right)(a - t)^2 + \frac{\gamma}{4}\left(a^2 - 4F\right) - \frac{b}{4}(a - t)^2$$

(ii) If $\gamma > b - \frac{1}{2}$ the constrained optimal choice of r in P lies on the lower boundary of P, which is $r = a - t - \sqrt{a^2 - 4F}$ in NPC and $r = 0$ in

[20]These quantities are defined in Appendix E.

PC. The corresponding welfare levels are

$$W^{P-NPC} = \left(\frac{\gamma}{4}+\frac{1}{8}-\frac{b}{4}\right)\left(t+\sqrt{a^2-4F}\right)^2+\frac{\gamma}{4}\left(a^2-4F\right) \quad (13)$$

$$W^{P-PC} = \left(\frac{\gamma}{4}+\frac{1}{8}-\frac{b}{4}\right)a^2+\frac{\gamma}{4}\left(a^2-4F\right) \quad (14)$$

Proof of Lemma 3: The derivative of $W^P(r)$ is $\frac{1}{4}(r-a)(2\gamma-2b+1)$. In regime P, $r \leq a$. Therefore, W^P is monotone increasing in r for $\gamma < b-\frac{1}{2}$ and decreasing for $\gamma > b-\frac{1}{2}$. Thus in the former case the constrained optimum in P lies on the upper boundary of P, in the latter case it lies on the lower boundary (which is at $a-t-\sqrt{a^2-4F}$ or at 0).

We use these results and Proposition 1 to prove Proposition 6.

Proof of Proposition 6**:**
We define the critical levels of γ as follows:

$$\gamma^{C1} \equiv \max\left\{\frac{-a+8ab-4bt}{4a-2t}, \frac{(t-2a)(t+2b(t-2a))}{8F}\right\}$$

$$\gamma^{C2} \equiv \max\left\{\begin{array}{c} b-\frac{1}{2} \\ \min\left(\frac{b\left(t+\sqrt{a^2-4F}\right)^2}{t\sqrt{a^2-4F}-2F+at}-\frac{1}{2}, 2b-\frac{a}{2(a-t)}\right) \\ \min\left(\frac{b\left(t+\sqrt{a^2-4F}\right)^2}{t\sqrt{a^2-4F}-2F+at}-\frac{1}{2}, \frac{2b(2a-t)^2-t(2a-t)}{8F}\right)\end{array}\right\}$$

$$\gamma^{P2} \equiv \max\left\{\begin{array}{c} 2b-\frac{a}{2(a-t)}, \\ \frac{2b\left(2t\sqrt{a^2-4F}+4at-3a^2-4F\right)-\left(t^2+2t\sqrt{a^2-4F}-4F\right)}{2\left(2t\sqrt{a^2-4F}+2at-8F\right)}\end{array}\right\}$$

$$\gamma^{C3} \equiv \frac{ba^2}{t(2a-t)}-\frac{1}{2}$$

(i) We show that for $t < t^1$ complete relocation arises if and only if $\gamma < \max\left\{\frac{-a+8ab-4bt}{4a-2t}, \frac{(t-2a)(t+2b(t-2a))}{8F}\right\}$. We distinguish four cases:

(a) Let $\gamma < b-\frac{1}{2}$. In this case, $\mathrm{W}^N = 0$ according to Proposition 1, so that $W^C > W^N$ and complete relocation is optimal.

(b) Let $b-\frac{1}{2} < \gamma < 2b-\frac{1}{2}$: The optimality condition for the national firm involves $r = a-t$ and the resulting welfare level is given by $t^2\left(\frac{\gamma}{4}+\frac{1}{8}-\frac{b}{4}\right)$. The resulting condition for $W^C > W^N$ is

$$-\frac{\mathrm{bt}^2}{4} < (\mathrm{a}^2-2\mathrm{at})(\frac{\gamma}{4}+\frac{1}{8})+\frac{\gamma}{4}(\mathrm{a}^2-4\mathrm{F}).$$

Using $t < \frac{a-\sqrt{a^2-4F}}{2}$ and thus $a^2 - 2at > 0$, we derive that the inequality always holds.

(c) For $2b - \frac{1}{2} < \gamma < \frac{-a+8ab-4bt}{4a-2t}$, the national firm is optimally regulated so that it produces for both countries. Again, we have $W^C > W^N$ and optimality of C.

(d) Finally, for $\frac{-a+8ab-4bt}{4a-2t} < \gamma$, the optimal regulation of the national firm is $r = 0$. It turns out that $W^C > W^N$ and complete relocation is optimal in case $\gamma < \frac{(t-2a)(t+2b(t-2a))}{8F}$, otherwise no relocation N is optimal, i.e. $W^N > W^C$.

(ii) We have to show that for $t^1 < t < t^2$ the location choice is made as described in the proposition. We distinguish three cases:

(a) For $\gamma < b - \frac{1}{2}$, comparing W^P and W^C from Lemma 2 above and W^N from table 1 shows that C is optimal.

(b) For $b - \frac{1}{2} < \gamma < 2b - \frac{a}{2(2a-t)}$, comparison of the relevant expressions for W^N and W^P from above shows that always $W^P > W^N$ and that thus N is never chosen. Comparing W^P and W^C leads to C being optimal for $\gamma < \frac{b(t+\sqrt{a^2-4F})^2}{2at+2t\sqrt{a^2-4F}-4F} - \frac{1}{2}$ and P for the opposite (calculations are straightforward but tedious; cf. notes p22-25).

(c) For $2b - \frac{a}{2(2a-t)} < \gamma$, comparison of all three location choices is necessary. Pairwise comparison of the relevant expressions for welfare yields $W^C > W^P \Leftrightarrow \gamma < \frac{b(t+\sqrt{a^2-4F})^2}{4a-2t} - \frac{1}{2}$, $W^C > W^N \Leftrightarrow \gamma < \frac{2b(2a-t)^2-t(2a-t)}{8F}$, and $W^P > W^N \Leftrightarrow \gamma < \frac{2b(2t\sqrt{a^2-4F}+4at-3a^2-4F)}{2(2t\sqrt{a^2-4F}+2at-8F)} - \frac{(t^2+2t\sqrt{a^2-4F}-4F)}{2(2t\sqrt{a^2-4F}+2at-8F)}$.

Combining all these conditions for optimality of a certain regime yields part (ii) of the proposition.

(iii) We have to show that, for $t > t^2$, there is complete relocation if and only if $\gamma \leq \gamma^{C3} \equiv \frac{ba^2}{t(2a-t)} - \frac{1}{2}$.

(a) For $\gamma < b - \frac{1}{2}$, Lemma 3(i) shows that the optimum in P is on the upper boundary of P and the welfare level is given by the expression for W^P given there. Comparison with the expression for W^C from Lemma 2 above shows that $W^C > W^P$.

(b) For $\gamma > b - \frac{1}{2}$, welfare under partial relocation is given by equation (14). It follows that $W^C > W^P$ for $b > \frac{(2\gamma+1)t(2a-t)}{2a^2}$ (as $a^2 > 2at - t^2$, this is compatible with the first condition on γ: $\gamma > b - \frac{1}{2}$). Rearranging terms, this translates into C for $b - \frac{1}{2} < \gamma < \frac{ba^2}{t(2a-t)} - \frac{1}{2}$ and P for $\frac{ba^2}{t(2a-t)} - \frac{1}{2} < \gamma$ (as $(a-t)^2 > 0$ we have $b - \frac{1}{2} < \frac{ba^2}{t(2a-t)} - \frac{1}{2}$ and these ranges are possible).

F The General Model

Proof of Proposition 3

(i) We have to show that serving country 1 from country 2 is never worthwhile for $r_1 = 0$, i.e. $\pi_{11}(0; a, t) \geq \pi_{21}(r_2; a, t)$ for all r_2. By Assumption 2c(ii) $\pi_{11}(0; a, 0) = \pi_{21}(0; a, 0)$. By b(i) $\pi_{21}(r_2; a, 0) \leq \pi_{21}(0; a, 0)$ for all $r_2 \geq 0$. Thus $\pi_{11}(0; a, 0) \geq \pi_{21}(r_2; a, 0)$. By b(iii) $\pi_{11}(0; a, 0) = \pi_{11}(0; a, t)$ and $\pi_{21}(r_2; a, 0) \geq \pi_{21}(r_2; a, t)$. Hence $\pi_{11}(0; a, t) \geq \pi_{21}(r_2; a, t)$.
(ii) By (cii) $\pi_{11}(0; a, 0) = \pi_{21}(0; a, 0)$, therefore by Assumption (bi), $\pi_{11}(0; a, 0) \geq \pi_{21}(r_2; a, 0)$ for all r_2. Similarly, $\pi_{12}(0; a, 0) \geq \pi_{22}(r_2; a, 0)$. Because $F > 0$, therefore, relocation is never worthwhile for $r_1 = t = 0$. By continuity (d), the result also holds if r_1 and t are sufficiently small.
(iii) By Assumption 2(a), $\pi_{1j}(r_1; a, t) = 0$ for $r_1 \geq r^{\max}$ and $j = 1, 2$, so that production in country 1 is not worthwhile. However, as $\pi_{22}(r_2; a, t) \geq F$ by assumption, a firm that relocates complete obtains a positive profit. Thus, complete relocation is worthwhile for $r_1 \geq r^{\max}$.
(iv) First, we show that, if partial relocation is better than no relocation and $t = 0$, then complete relocation is better than partial relocation: Partial relocation necessarily requires $\pi_{12}(r_1; a, 0) < \pi_{22}(r_2; a, 0)$. By Assumption 2(c) and (biii), $\pi_{12}(r_1; a, 0) = \pi_{11}(r_1; a, 0)$ and $\pi_{22}(r_2; a, 0) = \pi_{21}(r_2; a, 0)$. Therefore $\pi_{11}(r_1; a, 0) < \pi_{21}(r_2; a, 0)$, so that serving country 1 from abroad is more profitable than serving it from home. By continuity (assumption 2d), there then exists a $t^* > 0$ such that complete relocation is optimal for $t < t^*$. Fix r_2, a, F and t. By Assumption 2(e), $\lim_{t\to\infty} \pi_{12}(r_1; a, t) = 0$. Because $\pi_{22}(r_2; a, t) \geq F$, partial or complete relocation is optimal for sufficiently high t and no relocation is never chosen.

Proof of Proposition 4

a) (i) is just a restatement of Assumption 3(d): As $b \to \infty$, r_i becomes so high for both firms that there is no output. (ii) First consider the multinational firm. Assume it has completely relocated. Fix $t > 0$, so that the output of the multinational firm is smaller than if there is no relocation by Assumption 2(biii) and hence complete relocation involves a loss in consumer surplus which is independent of b. By continuity of damages in b and in outputs (Assumption 3(d)), the damage reduction from relocation approaches 0 as b does. Thus, for every $t > 0$ there is a critical value of b below which complete relocation is not optimal.

Moreover, for any given level of a, F and r_2, if b is sufficiently small, the environmental gains from regulation are small by Assumption 3(c). By Assumption 2(b) and 3(b), the costs of regulation in terms of reduced consumer surplus are positive and independent of t. Hence r_1 becomes arbitrarily small as b does. If t is also sufficiently small, the multinational firm's gains from reduced transportation costs and regulation under partial relocation are small by continuity of profits in r_i and t (Assumption 2(d)), so that partial relocation is not worthwhile (due to the fixed, positive relocation costs involved). Thus, there is no relocation.

For the national firm, for sufficiently small b, r_i also becomes arbitrarily small. By Assumption 2(f), home-country profits are positive. If t is also sufficiently small, continuity of profits (Assumption 2(d)) and symmetry (Assumption 2(c)) imply that it is worthwhile to serve the foreign market as well. Thus, both firms are serving both markets and face the same regulation to which they react in the same way.

b) (i) Fix all parameters except b. By Assumption 3(d), regulation optimally reduces outputs to zero as $b \to \infty$. For $b = 0$, there is no regulation and the firm has a positive home country output by Assumption 2(f). By continuity of optimal regulation in b and continuity of outputs in r_i, the intermediate value theorem implies that there exists a minimal $\bar{b} \geq 0$ such that the production of the national firm is optimally reduced to 0. By continuity of x_{ji} the optimal regulation of the multinational firm at $\bar{b}$ involves complete relocation with positive imports of country i if t and r_j are sufficiently small: While the advantage from reducing pollution by constraining either firm to producing for the home country is the same, the multinational firm still generates a positive consumer surplus whereas the national firm does not.

(ii) Let b be sufficiently small. By continuity of damages in outputs and b, the benefits from regulation become arbitrarily small. Therefore the optimal regulation level r_1 is small for both the national and the multinational firm. According to Assumption 2(e), for any r_1 there exists a critical value of t such that there is partial relocation of the multinational above this critical level. The regulation of the national firm is also close to zero. However, the multinational firm produces for both countries. Because outputs are continuous in regulation levels, the multinational firm produces less than the national firm.

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