Incentive Regulation of Multinational Enterprises*

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Abstract

Sectors with a long regulatory tradition have recently experienced intense activity by multinationals whose international operations and relocation threats represent a new cause for concern for regulators. The present paper analyses a multinational serving two countries and being regulated by two uninformed national authorities. The firm is shown to favor, or cross-subsidize, the country with a larger stake in the firm's profit and the linkage among national regulations may induce the output in a country to increase in the firm's inefficiency parameter. This paper also analyzes multinational's lobbying decisions for the two countries and its effects on national regulations. Finally, free to choose its location, the firm could credibly threaten to "fly" away from tough regulators and this is shown to let the firm obtain larger profits.

Keywords: Multinational Enterprises, Regulation, Asymmetric Information, Multiprincipals, Lobbying.

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1 Introduction

Multinational enterprises (henceforth MNEs) play a major role in the economies of many countries. World sales of all multinational foreign affiliates equalled 99 per cent of total world exports in 1985, and this figure rose to 122 per cent in 1991. Thus, from 1991 onwards international production has surpassed export as the principal means of delivering goods and services to foreign markets (UNCTAD 1998). Recently, even utility sectors have faced substantial activity by multinationals. Internationalization of sectors with a long regulatory tradition such as energy, telecommunications, banking and insurance is mainly taking place through foreign located subsidiaries. EDF-GDF, the former French energy monopolist, recently acquired London Electricity, an important energy provider in the U.K., and is planning expansion into the German electricity market. Similarly, ENDESA, the Spanish national energy group, acquired a 29.2% majority stake in the Chilean ENERSIS Group in 1997, becoming the largest electricity provider in the region. In 1993 the Aguas Argentinas group led by the French multinational Vivendi, received a 30-year regulated concession to provide water and wastewater services to the 9 million inhabitants of metropolitan Buenos Aires. The UK firm Cable & Wireless had a majority stake in Hong Kong Telecom, the main local telecom services provider, until 1997, and still provides regulated services in Australia, Russia, the Caribbean and Sweden.

These developments raise interesting research issues for the economics of regulation. The "New Regulatory Economics" (see Laffont and Tirole 1993) has produced a range of tools for dealing with the problems faced by regulators in utility sectors. Informational asymmetries between the regulator and the regulated firm are placed at the centre of the regulatory arena. However, this tools cannot be directly utilized when dealing with the problem of regulating multinational enterprises, since multinationals are subject to regulation by several independent regulators. The rules imposed by a regulator in country A often affect the behavior of the multinational in country B. Moreover, multinationals take advantage of differences in national regulations: they may cross-subsidize production in the countries with more advantageous regulations, and get regulators to compete against each other. Thus, a regulator has to recognize that its optimal policy may both affect and depend on the existing policy in other countries. In other words, regulators face a problem of common agency (see Bernheim and Whinston 1986).

In the present paper I shall analyze a simplified situation, which obviously does not consider some important features of the previous examples. The players are a MNE, which supplies two separate national markets, and two domestic regulators, which independently regulate local production. The firm is a monopolist in both markets, and thus regulation is required to limit the firm's market power. Even if not explicitly modelled, the internal production of intermediate, possibly shared inputs, is a specific feature of the MNEs' activities (e.g. headquarter services, R&D, technological know-how, patents, brand name and company reputation, see Markusen 1995), and this may constitute an important source of asymmetric information within the regulatory process. Thus, regulation is imperfect due to the asymmetric information between the MNE and its regulators. This setting poses several new questions and the presence of MNEs calls for a rethinking of standard results in the economics of regulation. To this end, I am going to compare national regulations with two benchmarks: regulation with full information, and second best regulation obtained when two uninformed national authorities cooperate in regulating the MNE.

The most important features of this model are: (i) complementarity or substitutability in the production of the national outputs, which may be due respectively, to economies or diseconomies of scale / scope; (ii) differences in national demands; (iii) differences in the weights used by regulators to evaluate the MNE's profit against consumer surplus. In a symmetric setting featuring substitutability, interaction between non cooperative national regulations leads to more powerful incentive contracts if profit weights are sufficiently small. With respect to the case of cooperating regulators, the MNE is induced to increase production in all domestic markets. The contrary is true if profits weights are large or if technology exhibits complementarities.

The greater the MNE's ownership share of domestic citizens, the more the regulator values the MNE's profit. Moreover, it is a well documented fact that MNEs exercise considerable bargaining power *vis a vis* host countries, and engage in country-specific lobbying activities to increase governments' stakes in their profits.[1] With substitutes, if the MNE mostly lobbies, and/or is owned by, one country, then the country with the larger profit weight, *ceteris paribus*, is going to be offered a lower price and consume more than the other one does. Hence, the MNE favors that country by cross-subsidizing its local production and 'dumping' on that market. The country with the larger weight is shown to over-consume, and the other to under-consume, with respect to the first best. Similarly, the country with less elastic demand over-consumes while the other under-consumes.

Multinationals are often said to "*... escape the regulatory reach of any national government*" (Caves 1996 page 257). According to this "sovereignty at bay school", MNEs are in a position to play national regulations against each other. I model this possibility by allowing the firm to shut down production in one country. The MNE can then choose to produce in the country with the most advantageous regulations and thus make countries compete for its services. With substitutes, the firm reduces its (marginal) costs by producing for a single market. In this case, the threat to move away and produce for the foreign market is a credible one (while with complements or economies of scale it is not), and I am going to show that competition between countries may leave the firm with unusually large profits.

Profit weights used by regulators importantly condition the regulatory outcome in the two countries, and the MNE may want to influence those weights for its own purposes. Lobbying the two possibly non-benevolent regulators may serve this aim by endogenizing profit weights. I show that in a symmetric world with substitutes the MNE prefers to distribute its lobbying resources equally between the two countries. Interestingly, in this case profit weight equalization is also preferable from the social point of view (considering the sum of national welfare in the two countries). On the contrary, with complements the MNE prefers to concentrate its efforts towards lobbying one single country, but this negatively affects (the sum of national) social welfare(s). The introduction of asymmetries produces more complex results. For example, when market demands are equal, but one country owns a smaller ownership share, the MNE prefers to allocate more lobbying resources to that country with substitutes and to the other with

[1] The firm may bribe national regulators or engage in country specific advertising campaigns to raise citizens' general interests in the firm. See Graham and Krugman [1991].

complements. Lastly, I give an example showing that, if lobbying activity is intense, it may be socially preferable to have two independent (non-benevolent) regulators rather than a single one implementing international cooperation.

Notwithstanding the need for a better understanding of the interaction between national regulations, there are very few theoretical studies of regulation in an international context. Few papers deal with international trade in domestically regulated sectors (see, for example, Combes, Caillaud and Jullien 1997). Two closely related papers are Bond and Gresik [1996] and Calzolari [1998]. However, they analyze intermediate input regulation and study a MNE which only serves a foreign market. Calzolari and Scarpa [1999,b] deal with an MNE that is regulated at home and operates in unregulated foreign markets.

Olsen and Osmundsen [2001] present a similar model in order to address a different question.[2] They discuss fiscal and equity externalities in a strategic tax competition game, and show how national ownership shares may affect a firm's overall tax payments. They formulate this question by using an asymmetric common agency framework similar to the one used in my paper. The application that is discussed is quite different, however, and more importantly, there are several differences between their paper and mine. I employ more general social welfare functions and use a more general model that allows for both strategic complements and substitutes, whereas Olsen and Osmundsen only study the case of substitutes. In this way I can show the key role played by complementarity or substitutability in the interaction between countries' activities. Moreover, I discuss what happens when the agent (the firm) is in a position to threaten to serve only one principal (one country). This introduces differences in the individual rationality constraints, and leads to potentially stronger competition between regulators depending on the complementarity or substitutability relationship. In addition, I study the effects of lobbying by the firm. Finally, I make use of competition in non-linear schedules as opposed to direct mechanisms. This is important, because recent writings on common agency (Martimort and Stole 2002 and Peters 2001) show that the Revelation Principle does not apply in this framework, whereas a

[2]The two papers were written independently.

Taxation Principle justifies the employment of non-linear schedules.

In section 2, I present a model featuring the benchmarks of full information and asymmetric information with cooperating regulators; in section 3, I characterize equilibrium production of the regulation game with uninformed and non cooperating regulators; in section 4, I analyse the effects of profit weights, of the MNE's lobbying activity and ownership patterns, on outputs and welfare; section 5 summarizes and concludes the paper. All the proofs are given in the appendix.

2 The model

A multinational enterprise produces and sells final outputs y_d and y_f in countries d and f ("domestic" and "foreign") respectively. Let $p_i(.)$ and $R_i(y_i)$ denote, respectively, the inverse demand in country i and the firm's revenue. Outputs are non-tradeable and markets are separate with independent demands.[3] A subsidiary located in country i produces and sells output y_i locally. The minimum cost function of the MNE is $C(y_d, y_f, \beta)$, where the smaller the parameter β the more efficient the firm is; i.e. $C_\beta > 0$, $C_{\beta y_i} \geq 0$ where subscripts indicate partial derivatives. The MNE's profit is,

$$\Pi(y_d, y_f, \beta) = \sum_{i=f,d} R_i(y_i) - C(y_d, y_f, \beta) - \sum_{i=f,d} T_i, \tag{1}$$

where T_i is the instrument used by country i to regulate local production. Linkages in production implying $C_{y_i y_j} \neq 0$ may exist given that the firm employs some jointly produced intermediate inputs (e.g. managerial or headquarters activities, joint R&D laboratories, patents, brand name and company reputation), or as a result of economies / diseconomies of scope.[4] When $C_{y_i y_j} > 0$ (< 0), productions are *substitutes* (*complements*) in the MNE's profit function, that is, an increase in y_i raises (reduces) the marginal cost of y_j.

[3] This paper deals with multinational production leaving aside issues related to international trade. Our assumptions are particularly appropriate for regulated services.

[4] A previous version of this paper (Calzolari 1999) explicitly models the MNE's intermediate production. Decreasing (increasing) returns to scale in intermediate input production imply $C_{y_i y_j} > 0 (< 0)$.

The MNE has private information about the efficiency parameter β. Regulators share a common prior[5]: they know that β distributes according to a c.d.f. $G(\beta)$ and a density $g(\beta) > 0$ over a support $B = [\underline{\beta}, \bar{\beta}]$. Function $g(.)$ satisfies the monotone hazard rate property, $d\frac{G(\beta)}{g(\beta)}/d\beta \geq 0$ in B, and both $G(\beta)$ and $g(\beta)$ are continuous and differentiable with bounded derivatives. All the elements of the game (except for β) are common knowledge.

Each national regulator maximizes a utilitarian objective function. Social domestic welfare is a weighted sum of net consumer surplus, tax receipts (or transfers) and the MNE's total profit. Regulators are self-interested, and do not cooperate towards regulating the firm. For the sake of reality I make the following assumption.

Assumption 1 *In any country, consumer surplus is high enough that regulators always prefer to have the MNE producing.*

Let $V_i(y_i) = \int_0^{y_i} p_i(u)du$ denote the gross consumer surplus in country i. The welfare function of country i is:

$$W_i = V_i(y_i) - R_i(y_i) + T_i(y_i) + \alpha_i \Pi, \tag{2}$$

where weight α_i is used in country i to value the MNE's profit. The larger the citizens' share of ownership in country i, the larger α_i will be. Moreover, the MNE may lobby a non-benevolent regulator i, thus increasing weight α_i.[6] To avoid unrealistic solutions to the regulation game, I shall assume that $\alpha_d + \alpha_f$ and α_i $i = d, f$ are always smaller than one.

Each regulator only observes output for the domestic market, so that the regulatory instrument is the non linear (twice continuously differentiable) tariff $T_i(y_i)$. Moreover, the jurisdictional powers

[5]I will not consider asymmetrically uninformed principals. See Bond and Gresik [1997] and Calzolari, Diaw and Pouyet [1999] for an early analysis.

[6]I could have employed different profit weights for domestic and foreign profits as in Calzolari and Scarpa [1999,b]. Such an analysis would have required the establishment of a rule for common cost allocation, and is briefly discussed in the conclusions. For the sake of simplicity the shadow cost of public funds is set at zero for both countries. Shadow costs other than zero would not have altered the results from a qualitative point of view.

of regulating authorities are limited to within national boundaries, and regulators are only allowed to regulate domestic production.

The stages of the game are as follows. The MNE privately learns its type. Regulators simultaneously set regulations. The MNE decides which country to produce in, and how much to produce. Finally, regulations are enforced and payoffs realize.

2.1 Benchmarks

With fully-informed, and cooperating countries, regulations are made to maximize the sum of national welfares with profit weight $\alpha = \alpha_d + \alpha_f$, and regulators appropriate all the firm's profits ($\Pi = 0$). Hence, the first best solution $y_i^{FI}(\beta)$, $i = d, f$ (FI stands for full information) satisfies marginal cost pricing rules,

$$p_i(y_i) = C_{y_i}(y_d, y_f, \beta). \tag{3}$$

Note that y_j enters W_i uniquely *via* the firm's cost (i.e. there are no direct-externalities) and this implies that, given full information, the question of whether regulators cooperate or not is immaterial.[7]

Outputs y_i^{FI} are suboptimal when cooperating regulators are uninformed. The firm would have an incentive to produce as if it were less efficient, thus obtaining additional profits. Uninformed regulators have to leave informational rents to the MNE in order to get the firm to choose the desired production profiles. To this end, they first have to set implementability conditions which guarantee the existence of transfers T_d, T_f, such that the MNE is induced into opting for a certain production plan y_i, $i = d, f$. Then, they maximize aggregated welfare with respect to y_i, $i = d, f$, subject to these implementability conditions. Standard Principal-Agent theory shows that

$$\dot{\Pi}\left(y_d(\beta), y_f(\beta), \beta\right) = -C_\beta\left[y_d(\beta), y_f(\beta), \beta\right] < 0 \tag{4}$$

[7] Non cooperating regulators might however set transfers so high that the firm prefers not to produce at all. I have not considered these uninteresting equilibria. For a common agency model with direct externalities, see Martimort and Stole [1999].

is a necessary condition for implementability, while non-increasing outputs are sufficient. The firm must also be induced into producing, and, given (4), this is always the case if the most inefficient firm is left with zero profit. Maximization with the incentive compatibility constraints (4) gives the optimality conditions for $y_i^{AC}(\beta)$ (AC for asymmetric information and cooperation),

$$p_i\left(y_i\right) = C_{y_i}\left(y_d, y_f; \beta\right) + (1-\alpha)\frac{G\left(\beta\right)}{g\left(\beta\right)} C_{\beta\, y_i}\left(y_d, y_f; \beta\right), \quad i = d, f. \tag{5}$$

As compared with the full information case, the pricing rule is increased by the positive term $(1-\alpha)\frac{G}{g}C_{\beta\, y_i}$. Raising the output of a type β (with mass $g(\beta)$) increases the profits of all types more efficient than β (which amount to $G(\beta)$), according to (4). This profit increase is weighted by $(1-\alpha)$ in welfare and is required for the purposes of incentive compatibility. It is the premium the firm obtains for privately held information.

3 The regulation game

Taking the regulatory instrument of the other country as given, each national regulator acts as if the MNE had already chosen its behavioral response to the output produced in the other country. In this way the original problem is transformed into a simpler Principal-Agent equivalent setting, while at the same time subgame perfection is preserved in the original game. By repeating this procedure for both countries, one obtains a system of optimality conditions whose solutions are candidates for the perfect Bayesian equilibrium of the original game.[8]

Country i chooses the twicely differentiable regulatory mechanism $T_i(y_i)$ to maximize expected national welfare, given the foreign optimal mechanism and the MNE's output strategy (incentive compatibility), and subject to the constraint that the MNE accepts to produce for market i (participation constraint). The firm maximizes (1) w.r.t. y_j obtaining the optimal y_j for given y_i, $\hat{y}_j(y_i;\beta)$. Substituting

[8] In multiple principal games, the standard Revelation Principle (Myerson 1979 among others) does not hold. However, Martimort and Stole [2002] and Peters [2001] show the existence of a taxation principle which justifies the use of our mechanisms in applied games.

$\hat{y}_j$ back into the profit,

$$\Pi(y_i, \hat{y}_j(y_i;\beta);\beta) = R_i\left(y_i\right) - T_i\left(y_i\right) + \widehat{\Pi}\left(y_i;\beta\right), \tag{6}$$

where,

$$\widehat{\Pi}\left(y_i;\beta\right) = R_j\left[\hat{y}_j\left(y_i,\beta\right)\right] - C\left[y_i, \hat{y}_j\left(y_i,\beta\right),\beta\right] - T_j\left[\hat{y}_j\left(y_i,\beta\right)\right]. \tag{7}$$

Incentive compatibility can then be stated as,

$$y_i(\beta) \in \underset{y_i}{ArgMax}\Pi(y_i, \hat{y}_j(y_i;\beta);\beta). \tag{8}$$

In order to prepare for the more general and interesting case in which the MNE can choose to serve two, one or none of the markets, I first present the simple situation whereby the firm cannot decide to produce for just one country.[9] In such a case, which may arise for example when the firm has incurred a large sunk installation cost, the MNE is not in a position to make countries compete against each other for its services. Hence, each regulator has simply to guarantee the firm a non-negative equilibrium profit.

Given the regulation chosen by the other country, the program of regulator i is thus:

$$(P_i)\begin{cases} \underset{T_i(.)}{Max}\int_B \left\{V_i\left(y_i(\beta)\right) - R_i\left(y_i(\beta)\right) + T_i\left(y_i(\beta)\right) + \alpha_i\Pi(\beta)\right\} dG\left(\beta\right) \\ \text{s.t. } (8),\ \Pi(\beta) \geq 0. \end{cases}$$

where $\Pi(\beta) = \underset{y_i}{Max}\Pi(y_i, \hat{y}_j(y_i;\beta);\beta)$.

The following proposition gives the necessary conditions for optimal differentiable outputs in the case of asymmetric information and non-cooperation $y_i^{ANC}(\beta)$.[10]

Proposition 1 *When the MNE can only choose to serve either both or neither of the two countries, there are differentiable equilibrium outputs $y_i^{ANC}(\beta), i, j = d, f,\ i \neq j$ such that*

[9] This corresponds to the *intrinsic common agency* setting in the words of Bernheim and Whinston [1986], and was originally studied by Martimort [1992] and Stole [1992].

[10] I limited my analysis to differentiable equilibria. For a more general treatment see Stole [1997]. An artifact of common agency is multiple equilibria, which also applies to proposition 1.

(a) $p_i(y_i) = C_{y_i}(y_i, y_j, \beta) + (1-\alpha_i)\frac{G(\beta)}{g(\beta)}\left[C_{\beta y_i}(y_i, y_j, \beta) + C_{\beta y_j}(y_i, y_j, \beta)\frac{\partial \hat{y}_j}{\partial y_i}\right]$,

(b) $\frac{\partial \hat{y}_j}{\partial y_i} = C_{yy}\Pi_{y_j y_j}$ *with* $\Pi_{y_j y_j} = \dot{y}_j/(C_{yy}\ \dot{y}_i + C_{\beta y_j}) \leq 0$,

(c) $\Pi(\bar{\beta}) = 0$.

The first term on the r.h.s. of the marginal cost pricing rule (a) is the standard marginal cost. The second term is composed of two elements. The first, $(1-\alpha_i)\,G/gC_{\beta y_i}$, is the direct (marginal) informational cost discussed in the case of cooperation. The second element, $(1-\alpha_i)\,G/gC_{\beta y_j}\frac{\partial \hat{y}_j}{\partial y_i}$, is an indirect informational cost. Increasing output y_i affects the MNE's decision for output y_j (through $C_{yy} \neq 0$), as can be seen from conditions (b). This in turn affects the rent left to the firm. In fact, we can easily show (see the proof) that the firm's profit increases with outputs as well as with cooperation. Hence, conditions (b) show that in the case of complements, there is an additional marginal cost for rising y_i, and a marginal benefit in the case of substitutes. Regulator i internalizes this indirect cost/benefit when he chooses optimal output. This *contractual externality* is the consequence of non-cooperation between the two regulating authorities, and it vanishes when countries cooperate. With complementary outputs the two informational distortions are positive and add up. The overall informational distortion (the second term in (a)) is unambiguously positive and non-cooperation increases the distortion with respect to AC. On the contrary, in the case of substitutes the two distortions have opposite signs. Thus, one can not say, *a priori,* that the sign of the sum is not going to be negative: in such a case, there would be an overall decrease in marginal cost. As usual, both distortions are eliminated in the case of the most efficient MNE (no-distortion at the bottom). Condition (c) shows that the least efficient firm is left with the reservation profit when it cannot make regulators compete against each other.[11]

Interestingly, in the case of substitutes, the reduction of marginal costs due to contract externalities may be so great as to entail equilibrium productions, with one output decreasing and the other increasing in the (in-)efficiency parameter β.

[11] In common agency models, the single crossing condition is endogenous and represents a complex issue for the purposes of the analysis. In the proof of Proposition 1 as it is standard practice in this literature, I focus on those equilibria for which the condition is satisfied.

Proposition 2 *With complements, equilibrium outputs both decrease in β. With substitutes, they cannot both rise in β.*

In the following I will show that this non-standard result is not just a curiosity but applies for reasonable parameter configurations.

As regulators independently set country-specific regulations, the MNE can choose to produce in one, both or neither of the countries. Thus there are two interesting possible scenarios. (i) The regulators are able to observe whether the firm is also producing abroad or not. Regulator i would then offer a menu of regulatory policies $\{T_i^0, T_i\}$, depending on whether the firm only produces domestically (T_i^0) or chooses to be a MNE (T_i). (ii) Even when regulators can identify a firm's location, they may be forced to offer just one regulatory policy (T_i) independently of the firm's location decisions. For example, a European authority would ban the previous discriminatory policies on the basis that the jurisdictional power of regulatory authorities is limited to national boundaries, and regulators are not allowed to condition the firms' decisions regarding production in other countries.

With the discriminatory case (i), regulator i may end up with a firm choosing the policy T_i^0 and producing for the domestic market only. In this event, the most appealing policy T_i^0 is the one which maximizes national welfare.[12] This standard regulation is obtained as described in section 2, by setting $y_j = 0$ and $\alpha = \alpha_i$. Country i then establishes regulation T_i (in force when the firm serves both markets), whereby for any β, the firm does not choose to shut down production in country i

$$\Pi(\beta) \geq \Pi_{\text{-}i}(\beta), \tag{9}$$

where $\Pi_{\text{-}i}(\beta) \equiv \Pi_{\text{-}i}\left(y_j^0(\beta), \beta\right) \geq 0$ with $y_j^0(\beta) = Arg\max \Pi_{\text{-}i}(y_j, \beta)$ and $\Pi_{\text{-}i}(y_j, \beta) = R_j(y_j) -$

[12]Other equilibria exist, because T_i^0 is out of equilibrium. However, our choice for T_i^0 can be justified with refinements where the firm trembles when deciding the country to produce in. Even if I do not explicitly purse this analysis, one could employ the sequential equilibrium concept by Kreps and Wilson [1982]. With a small probability that the firm decides to be active in a single country, T_i^0 must be set to maximize national social welfare. I thank one referee for pointing me out this property of T_i^0.

$C(0, y_j; \beta) - T_j^0(y_j)$. The program of regulator i, then, is as shown in (P_i), with participation constraint (9) instead of $\Pi(\beta) \geq 0$.

In case (ii), when a supra-national authority forbids discrimination between national and foreign firms, regulators find themselves in a much more competitive international setting. In fact, with a unique regulation T_i for each country (instead of the menus $\{T_i^0, T_i\}$) the firm can credibly threaten to quit the country if it is toughly regulated as a MNE. To avoid this, regulators may be obliged to let the firm earn larger profits , given that now: $\Pi_{\_i}(\beta) = Max\{\underset{y_j}{Max}\{R_j(y_j) - C(0, y_j; \beta) - T_j(y_j)\}, 0\}$.

Proposition 3 *Regardless of the possibility to discriminate between domestic and multinational firms, outputs are characterized as in proposition 1 (a)-(b), both in the case of complements and weak substitutability (i.e. if $y_j^0(\beta) - y_j(\beta)$ is small). When regulators can discriminate, the least efficient multinational achieves zero profit ($\Pi(\bar{\beta}) = 0$). If they cannot discriminate, the least efficient firm obtains zero profit with complements but may obtain positive profit with substitutes.*

With complements, national regulations are not affected by the possibility that the firm may have to choose the country to produce in. This is also true for equilibrium production with substitutes, as long as substitutability is not too strong, implying that the difference $y_j^0(\beta) - y_j(\beta)(\geq 0)$ is small, where $y_j^0(\beta)$ is the optimal output of a domestic firm in country j. Note that when, for example, $C(y_i, y_j; \beta) = C(y_i + y_j; \beta)$, the total quantity of outputs produced when the firm serves both markets simply needs to be larger than the quantity produced when serving a single market ($y_j^0(\beta) - y_j(\beta) \leq y_i(\beta)$). If regulators can design a menu of regulations for domestic and multinational firms (i.e. case (i)), then the least efficient firm is left with zero profit even if it may threaten to "flee" abroad. When countries cannot discriminate between domestic and multinational firms (case (ii)), the constraint on regulatory policies may be to the firm's advantage. In fact, with substitutes the MNE faces additional costs in producing for both countries, and the threat to move away ought to be taken seriously. Competition to attract the firm may then lead to an increase in $\Pi(\bar{\beta})$, and all the firms (i.e. all types of firm) will end up with larger profits. However, in the case of complements, by producing in both countries the firm saves on (marginal) costs and the threat to move away is no longer a credible one. Competition between regulators is weakened, while firms maintain the same profits the MNE obtains when it can only decide to produce in both countries or in neither of them (intrinsic common agency).[13]

3.1 A linear-quadratic model

I now analyse an explicitly solvable linear-quadratic model. Let the cost function be $\beta Y + \frac{\delta}{2}Y^2$ with $Y = y_h + y_f$ and $\delta > 0$ (< 0) with substitutes (complements). Inverse demands are linear, $p_i(y_i) = a - b_i y_i$, $i = f, d$. Priors are distributed over $B = [0, 1]$ according to a c.d.f. with hazard rate $G(\beta)/g(\beta)$ approximated by a linear function.[14]

In the case of cooperation, full information and asymmetric information solutions are unique, linear and defined by, $y_i^h = k_i + \beta\, s_i^h$, $h = FI, AC$, where $k_i = \frac{ab_j}{\Gamma}$ is an intercept, $s_i^{FI} = -\frac{b_j}{\Gamma} < 0$ and $s_i^{AC} = -\frac{(2-\alpha)b_j}{\Gamma} < 0$ are the slopes and $\Gamma \equiv \delta(b_f + b_d) + b_f b_d > 0$ (from the second order conditions of the full information program).

With asymmetric information and non cooperation, system (b) in proposition 1 admits linear solutions of the type $y_i(\beta) = k_i + s_i\,\beta$.[15] Note that the most efficient type ($\underline{\beta}$) is not distorted, and the constant terms k_i are the same in the three cases FI, AC and ANC. Comparing equilibrium schedules thus amounts to comparing the slopes.

Proposition 4 *Given the presence of substitutes, if $s_i < 0$ for any i, then $\frac{\partial s_i}{\partial \alpha_i} > 0$, $\frac{\partial s_i}{\partial \alpha_j} < 0$, $\frac{\partial s_i}{\partial b_i} > 0$, $\frac{\partial s_i}{\partial b_j} < 0$. If $b_i \neq b_j$, the demand slope is sufficiently low (high) and profit weight small (large) in country*

[13] Interestingly, the larger profit which has to be left to the MNE may induce one (or both) regulator(s) to shut down local production. This possibility is ruled out here by assumption 1. Asymmetric equilibria, whereby the MNE prefers to produce for a single country, are discussed in Calzolari, Diaw and Pouyet [1999].

[14] The uniform and arbitrarily close approximations of any exponential distribution have linear hazard rates. When explicitly needed, I will employ the uniform distribution. Similar linear quadratic common agency models are also studied in Stole [1992], [1997], Biglaiser and Mezzetti [1993], Martimort [1996 a] and Olsen and Osmundsen [2001].

[15] As is often the case in the literature on linear-quadratic common agency games, we are looking for linear solutions. This choice is justified by Martimort [1992], [1996 a] and Martimort and Stole [1999], when showing that linear solutions are the only ones surviving the extension of the types' support B.

i (j), then $s_i < 0$ and $s_j > 0$ and, in this case, $\frac{\partial s_j}{\partial \alpha_j} < 0$, $\frac{\partial s_j}{\partial b_j} < 0$. Under complements, it is always $s_i < 0$ for any i, and $\frac{\partial s_i}{\partial \alpha_i} > 0$, $\frac{\partial s_i}{\partial \alpha_j} > 0$, $\frac{\partial s_i}{\partial b_i} > 0$, $\frac{\partial s_i}{\partial b_j} > 0$.

With substitutes, when the demand slopes in the two countries are different, output in one country may *increase* in β as already stated in proposition 2. In this case, the country with a rising output in β over-consumes both with respect to FI and AC (y_i^{FI} and y_i^{AC} are decreasing in β). Interestingly enough, reasonable parameter configurations can be found whereby this over-production effect also holds with decreasing productions in both countries.[16] Contrary to what happens with cooperating regulators or complementarity, with substitutes a rise in the foreign weight increases (the absolute value of) the contract externality at home and reduces domestic output. The effects of demand elasticities (b_d, b_f) are preserved with non cooperation as long as both outputs are decreasing. On the contrary, when output abroad is increasing, then a higher foreign profit weight and/or a lower foreign demand elasticity reduce(s) the foreign slope. This is a consequence of the fact that when foreign output is increasing, the overall distortion is negative, and any increase in foreign profit weight leads to a reduction in the distortion which in turn implies a decrease in output.

3.2 Equilibrium production and MNE's profits

With complements, regulator i knows that a larger y_i implies greater foreign production ($\partial \hat{y}_j / \partial y_i > 0$), and as outputs increase profits, this means leaving firms with larger profits. With asymmetric information, this additional (marginal) cost induces regulator i to further distort production in a downwards direction. The argument is obviously symmetric for regulator j as well, and leads to lower equilibrium production and profits than in the case where the two regulators cooperate and internalize the externality, $y_i^{ANC} \leq y_i^{AC} \leq y_i^{FI}$. Hence, the MNE is not able to take advantage of non-cooperation between regulators. On the contrary, with substitutes, $\partial \hat{y}_j / \partial y_i < 0$, and the contract externality moves in the opposite direction, reducing asymmetric information distortion. The net effect is ambiguous, but the

[16] A similar result was also independently obtained by Olsen and Osmundsen [2001].

following proposition can be formulated.[17]

Proposition 5 *With complements, non-cooperative regulations lead to under production and smaller profits compared with both cooperation and full information. With substitutes, and sufficiently small (large) profit weights, non-cooperation leads to over- (under-) production in both countries and larger (smaller) profits compared with cooperation.*

With substitutes and small profit weights, the firm is able to take advantage of non cooperation. On the contrary, with both complements and substitutes associated with large profit weights, the firm unexpectedly prefers to be regulated by cooperating countries. For intermediate values of profit weights, results are ambiguous and both demand elasticities and the level of returns to scale become relevant. In fact, with regard to total production $Y^h \equiv y_d^h + y_f^h$, the linear quadratic model shows that with high substitutability (large δ) $Y^{ANC} \leq Y^{AC}$, while with low substitutability (δ close to zero) $Y^{AC} < Y^{ANC}$. Intermediate values of δ generate an ambiguous ranking of productions. When output y_i turns out to be increasing in β, the net asymmetric distortion is negative, $y_i^{ANC} \geq y_i^{FI}$ and total production may be, in principle, larger than with full information. However, the linear quadratic model shows this case to be impossible.

4 Profit weights and lobbying

It is interesting to see how the MNE behaves when the two countries value the firm's profits differently. A limit case in which $\alpha_i = 1$ and $\alpha_j < 1$, may be looked at in order to grasp some of the more important results. One should note that results obtained in this case are qualitatively the same if α_i is smaller but sufficiently close to one. A profit weight close to one may apply in country i if citizens have a large share in ownership and/or the MNE successfully lobbies regulator i. Moreover, when the MNE faces perfect

[17] Unlike our choice in this present work, most multiprincipals studies deal with fully symmetric models for simplicity (Stole 1992 and Martimort 1992). Olsen and Osumndsen [2001] and Stole [1997] are exceptions to this rule. With full symmetry, the previous indeterminacy is resolved, so that substitutes and $\alpha_i = 0$ for all i imply $y_i^{AC} \leq y_i^{ANC}$.

competition in country i, it is obliged to implement efficient production in that country, as required by $\alpha_i = 1$. To control the effect of different profit weights on equilibrium production, I assume the cost function here to be symmetric with respect to outputs.

Proposition 6 *Let us consider α_i sufficiently high and $\alpha_i > \alpha_j$. Everything else being symmetric, productions in the two countries are so that $y_i^{ANC} \geq y_j^{ANC}$ and $y_i^{AC} = y_j^{AC}$.*

If national regulators cooperate, different profit weights in the two countries have no effect on national productions. On the contrary, when the two regulators do not cooperate, consumers in country j are penalized, as they end up consuming less than in the other country. For this result note that first, in the case of cooperation, regulated productions are functions of the *sum* of profit weights. Hence, *ceteris paribus*, outputs are equal in the two countries. Second, no cooperation introduces asymmetric distortions because regulators differently averse leaving the multinational with informational rents. The exact entity of the difference of outputs is then driven by the link (or the absence of) among national regulations. Consider equal profit weights, a small increase in α_i has a first order effect in reducing the informational distortion which increases y_i, but an indirect and smaller second order effect on production in country j *via* the contract externality. Proposition 6 shows that the MNE favors the country with the highest profit weight, and provides it with the same good but at a lower price than that applied in the other country. This kind of *favoritism* can naturally be reinterpreted in terms of international *dumping*. The firm sells exactly the same homogenous good at different prices in the two countries where demands and costs are equal. Proposition 4 shows that the result is even more marked with substitutes, where a rise in the profit weight of country i actually *reduces* output in the other country j. In a similar vein, a model with a more detailed description of the MNE's cost function could also show that the subsidiary located in the country with the smallest profit weight *cross-subsidizes* production of the subsidiary located in the other country by reducing its local production costs (see Calzolari 1999). Finally, one has to notice that a larger output induced by a larger profit weight does not imply *per se* that the households in country are better off. In fact, the net effect on national welfare has also to take into account firm's profit and tax revenues, as indicated in (2).[18] However, the solvable model shows that the welfare of each country is always increasing in the local profit weight. The idea is that a larger profit weight makes the informational rent less expensive and this direct effect together with larger output dominate any possible reduction in tax revenues.[19]

4.1 MNE's lobbying activity

I have shown that profit weights play a major role in the determination of equilibrium prices, quantities and profits. For this reason, regulators and the MNE may want to affect weights for their own benefits. The following results analyze the model whereby α_d and α_f are endogenous in the regulation game. I employ menus of regulations $\{T_i^0, T_i\}$, but results also hold with non-discriminating regulations and intrinsic common agency (see the discussion of proposition 3).

MNEs are often said to "capture" regulators and then raise countries' stakes in company's profit. To simplify the lobbying game, I assume that the MNE disposes of a limited amount λ of resources for lobbying activities, and uses a simple one-to-one lobbying technology. The MNE lobbies the two countries under the constraint $\lambda = \lambda_d + \lambda_f$, and a unitary increase in λ_i determines a unitary increase in $\alpha_i = \theta_i + \lambda_i$, where θ_i is country i's ownership share of the firm. Hence, our interpretation of non-benevolent regulators is that the captured regulator in country i maximizes her private objective function (2) with profit weight α_i, while the social welfare function in country i should have a smaller profit weight equal to $\alpha_i - \lambda_i$. The additional term $\lambda_i \Pi$ is determined by the lobbying activity of the MNE (e.g. bribes to regulators) and by the fact that regulators are non-benevolent and accept being lobbied. Even if this simple model of lobbying is rather *ad hoc*, nevertheless it allows to describe the

[18] As it is common in Multiprincipals analysis, cross-country distribution of surpluses and tax revenues are uniquely determined up to a constant. A bargaining game between the two countries would allow to determine the exact distribution.

[19] The presence of a MNE in a country may be a source of benefits for unemployment reduction. Hence, according to proposition 6, the country more concerned with local employment has a larger profit weight and ends up with a larger regulated production.

effects of imperfect delegation to regulators with private agendas.[20]

Let us first consider a completely symmetric model. Deriving equilibrium profit w.r.t. λ_i under the constraint $d\lambda_i = -d\lambda_j$, one obtains $\frac{\partial \Pi}{\partial \lambda_i} = \int_{\underline{\beta}}^{\bar{\beta}} \sum_j C_{\beta y}(.) \frac{\partial y_j}{\partial \lambda_i} du$. By symmetry, $\frac{\partial y_i}{\partial \lambda_i} = -\frac{\partial y_j}{\partial \lambda_i}$ and then $\frac{\partial \Pi}{\partial \lambda_i} = 0$: the net marginal benefit of a shift in lobbying from one country to another is identically zero. However, this result has different consequences in the case of substitutability than it does in that of complementarity.

Proposition 7 *In the symmetric linear quadratic model, the MNE lobbies a single country with complements and lobbies both countries with substitutes to an identical extent. With complements (substitutes) and equal demands, the MNE lobbies the country with the largest (smallest) ownership to a greater extent. With equal ownership, the MNE lobbies the country with the most elastic demand.*

The lobbying-maximization program is concave in the case of substitutes but convex with complements and this explains proposition 7. The reason for the divergence between the two cases can already be found in proposition 4. With substitutes, a rise in α_i at the expenses of α_j increases y_i but lowers y_j, and for intermediate values of α_i the net effect is positive. Whereas with complements, a rise in α_i at the expense of α_j produces counter-balancing effects: y_i rises and y_j decreases, but with complements, an increase in y_i also raises y_j. The net effect is an increase in total output, with the MNE preferring to concentrate all its lobbying resources in one country.

Interestingly, the MNE's lobbying preference described in proposition 7 can be also interpreted in terms of *preferred ownership* shares. To this end, it suffices to substitute λ_i with θ_i in the previous analysis. The firm prefers to be individually owned with complements and jointly and equally owned by the two countries with substitutes. Given this, we are now interested in verifying whether the countries in question and the MNE have aligned preferences with regard to ownership allocation and lobbying activities.

[20]Grossman and Helpman [1994], Feenstra and Lewis [1991] and Martimort [1996 b] use this interpretation for profit weighting in social welfare functions.

Let us consider a change in α_i which is matched by an equal with opposite sign change in α_j, $d\alpha_i = -d\alpha_j$. This kind of variation in profit weights is open to two interesting diverse interpretations. Firstly, it could be due to a change in ownership by the two countries d and f, with a given share of ownership going to other countries. Secondly, it could be the consequence of a reallocation of lobbying activities between the two countries. Let us first consider a fully symmetric model. By plugging the (non-cooperative) equilibrium productions in the aggregated welfare function $W = W_d + W_f$, and deriving with respect to α_i, one gets

$$\frac{dW}{d\alpha_i} = \int_B \sum_h \left[(1 - \alpha_h) \frac{G}{g} \left(C_{\beta y_h} + C_{\beta y_j} \frac{\partial \hat{y}_j}{\partial y_h} \right) \right] \frac{dy_h}{d\alpha_i} dG(\beta)$$

for $h \neq j$ (simply using the results in proposition 1). The effects of a marginal change in α_i are $\frac{dy_i}{d\alpha_i} = \frac{\partial y_i}{\partial \alpha_i} - \frac{\partial y_i}{\partial \alpha_j}$; and likewise for j. With symmetry, the term in square brackets is the same for $h = d, f$ and one finally gets the identity $\frac{\partial W}{\partial \alpha_i} = 0$. In a symmetric world there is no (marginal) gain to be had from increasing α_i (and correspondingly reducing α_j), and symmetric profit weights $\alpha_d = \alpha_f$ maximize aggregated welfare.[21]

A similar analysis in a non-symmetric world is much more complicated. However, numerical simulations in the linear quadratic model show that both for complements and substitutes, the optimal profit weight for a given country decreases (increases) with domestic (foreign) demand elasticity. The following corollary summarizes the previous results.

Corollary 1 *The preferences for profit weights shown by the two countries and the MNE coincide in the case of substitutes, whereas they diverge with complements, in a symmetric linear quadratic model. In the presence of asymmetries, preferences do not generally coincide.*

Lobbying is commonly perceived as a detrimental activity from the point of view of national welfares. It is common wisdom that national non-benevolent regulators independently maximizing their own

[21]This holds assuming second order conditions are verified, as is the case with the linear quadratic model. Clearly, this result does not hold for each country taken individually. Each country always benefits from a larger profit weight because this makes the MNE's informational rents less expensive.

private agendas act worse than a single non-benevolent supra-national regulator. However, I now show that this belief may be mistaken, and that when the process of delegation is subject to the lobbying activity of the MNE, countries may be better off by delegating regulation to non cooperating regulators.[22]

Let us suppose, for the sake of simplicity, that the firm is completely owned by a third country (i.e. $\theta_d = \theta_f = 0$) and lobbies countries equally ($\lambda_i = \lambda/2$). As already stated, regulation is imperfect in that, regardless of the presence of one or more regulators, the latter maximize their private objective function which diverges from national social welfare. With full foreign ownership the social welfare is simply as in (2) with $\alpha_i = 0$. On the contrary, each independent and non-benevolent national regulator sets the regulation in order to maximize her private objective which is as in (2) but with $\alpha_i = \lambda_i$. Similarly, a single supra-national, non-benevolent regulator maximizes $\Sigma_i W_i$ with profit weight $\alpha = \lambda$. Let W_2 be the sum of expected *social* welfares in the two countries when the *two* regulators operate (where then $\alpha_i = 0$ for any i), while W_1 is *social* welfare when regulation is delegated to a single authority (where then $\alpha = 0$). Define $\Delta W = W_2 - W_1$. Figure 1 shows how ΔW modifies with λ in the linear quadratic model with the following parameter configuration $a = 10$, $b_d = b_f = 1$, $\delta = 1$, $\lambda_d = \lambda_f = \lambda/2$.[23]

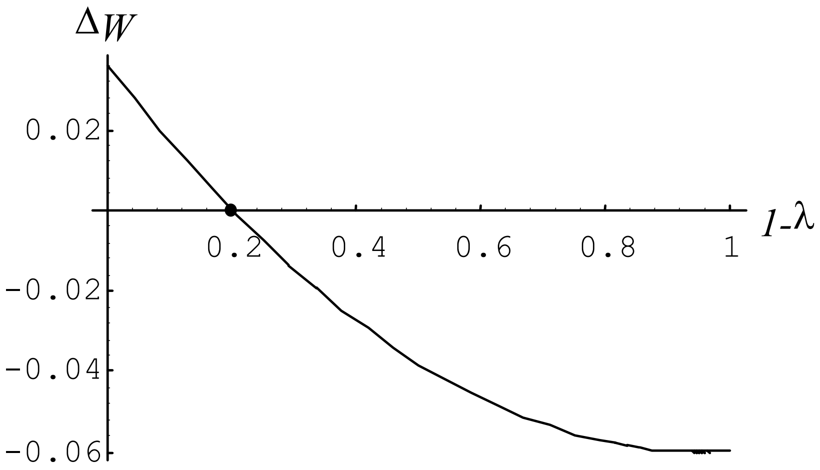
When lobbying resources are limited ($1 - \lambda$ large), centralized regulation dominates independent regulations. However, when the MNE has a sufficiently large amount of resources for lobbying ($1 - \lambda$ small), then the reverse is true.

Proposition 8 *With non-benevolent (national and supra-national) regulators and for a sufficiently high λ, national independent regulation may be preferable to centralized supra-national regulation, from the viewpoint of aggregated national welfares.*

Independent national regulators impose contractual externalities upon each other, and the lack of coordination makes lobbying activity less effective. The net effect is that independent regulators are preferable when the MNE can afford a tough lobbying campaign. In a second best situation, as is the

[22] See also Martimort [1996 b] for an example along these lines involving common agency.

[23] All SOCs are verified for these parameters.



($a=10$, $b_d=b_f=1$, $\delta=1$, $\lambda_d=\lambda_f=\lambda/2$)

Figure 1:

case here with asymmetric information and non-benevolent regulators, an additional distortion (no-cooperation and independent regulators w.r.t. a supra-national regulator, in this case) is not necessarily detrimental to welfare.

5 Summary and Conclusions

Despite its practical importance, the presence of multinational enterprises in regulated industries has received little theoretical attention. In this paper I have analysed this issue by employing a model with one multinational firm and two (uninformed) national independent regulators in which, contrary to most writing on common agency, asymmetries are in fact present. This is a simple framework, which of course does not take account of a number of factors, such as the presence of competing firms. Nevertheless, the model serves to show how utilities regulation is affected by the multinational dimension of firms.

Contractual or regulation externalities arise from non-cooperation between regulators, and as such affect production and equilibrium prices. When national productions are complements, externalities among regulations lead to under production both in the case of full information and asymmetric information with cooperating regulators. The contrary can be true in the case of substitutes, and may be accompanied by unexpected, upward-sloping production in one country with respect to the cost-inefficiency parameter. Competition among national regulators also plays an important role. When a firm is free to choose its location, it may threaten national regulators with moving and producing abroad, and regulators may be obliged, as a consequence, to leave the firm larger profits. Moreover, the MNE is shown to favor and cross-subsidize the country with a larger stake in the firm's profits. Finally, I have analyzed the effects of ownership structure on aggregate welfare, and the way the MNE allocates its lobbying resources to national regulators.

In this paper I have analysed the cases of both complements and substitutes, and showed that the prevailing relationship has important consequences for the regulatory process. Both cases are of empirical importance. In fact, MNEs are often characterized by joint production of intermediate inputs, which may lead to complementarity or substitutability depending on the economies or diseconomies of scale in input production. These firms also use common inputs such as R&D, brand name and firm reputation, which normally result in complementarity. On the other hand, internal competition over a scarce input (e.g. internationally mobile management) may induce substitutability. Moreover, also international regulations for joint-costs sharing among a MNE' subsidiaries may affect the prevailing relationship. Consider, for example, a MNE producing with a joint facility at constant cost, and assume that a "volume-based" cost-sharing rule is in force, so that the joint cost must be shared among subsidiaries in proportion to their respective outputs. Whenever the MNE partially owns one of the two subsidiaries, complementarity (substitutability) will arise if domestic output in equilibrium is smaller (larger) than foreign output.[24] Hence, it generally seems rather difficult arguing that complements are more or less adequate than substitutes for any given sector (e.g. electricity, telecommunication etc.). Given the importance of the relationship between outputs illustrated in previous sections, empirical

[24]If β is the constant cost, and the MNE partially owns the foreign subsidiary, the profit (net of regulatory transfers) is $\Pi = \Pi_d + (1-\rho)\Pi_f$, where ρ is the share of subsidiary f owned by other firms, and $\Pi_i = R_i(y_i) - \beta\ y_i/(y_d + y_f)$. One can show that $\frac{\partial^2 \Pi}{\partial y_d \partial y_f} = -\beta\rho\frac{(y_d - y_f)}{(y_d+y_f)^3}$.

studies may be of some interest with regard to the regulatory process.

The growth and spread of multinationals often accompanies increased competition. Hence, one important extension of the present paper is the introduction of competing firms in one or both of the markets. One interesting step in this direction involves an analysis of how a regulator would react to the regulated firm's expansion into unregulated foreign markets, as made by Calzolari and Scarpa [1999, b]. In such a case, international regulation is confronted with the interesting current issue of allocating common costs to the MNE's subsidiaries. National or international rules on common cost allocation may also induce the MNE to locate intermediate production in one country or another.

Finally, the design of optimal international production in regulated sectors may be of interest, especially in the case of integrated economic areas such as the EU and the USA. Countries may decide to let domestic firms only serve markets or they may also choose to let multinationals in. To compare these two structures one has first to take into account the importance of economies of scale / scope possibly arising from the integrated production of a MNE. A second factor is that, as long as markets are separated, domestic firms, unlike multinationals, do not generate contract externalities. These externalities increase production costs with complements, and reduce them with substitutes, and a trade off exists. The possibility to trading outputs between countries may also be compared whenever feasible.

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6 Appendix

Proof of proposition 1 I first need a preliminary result on the necessary and sufficient conditions for implementability.

Lemma 1 *(Necessary conditions) If the functions* $\{y_i(\beta), \Pi(\beta)\}$ *are implementable for regulator* i *(i.e. there is a transfer schedule whereby this output and profit will be chosen by the MNE), then for all* β *such that* $y_i(\beta)$ *is continuous,* $\dot{y}_i(\beta)$ *exists and is non zero, and* $\frac{\partial \widehat{\Pi}[y_i;\beta]}{\partial \beta}$ *is differentiable in* y_i *at* $y_i(\beta)$*,*

$$\dot{\Pi}(\beta) = \frac{\partial \widehat{\Pi}[y_i(\beta);\beta]}{\partial \beta} = -C_\beta [y_i(\beta), y_j(y_i(\beta), \beta); \beta] \, (< 0) \tag{10}$$

$$\frac{\partial^2 \widehat{\Pi}[y_i(\beta);\beta]}{\partial y_i \partial \beta} \frac{1}{\dot{y}_i} \geq 0. \tag{11}$$

(Sufficient conditions) Under complements if $\dot{y}_i(\beta) \leq 0$*, under substitutes if*

$$\int_{\beta'}^{\beta} \int_{\beta'}^{\beta} \frac{\partial^2 \widehat{\Pi}(y_i(t); s)}{\partial \beta \partial y_i} \dot{y}_i(t) dt ds \geq 0 \qquad \forall \beta, \beta' \in B, \tag{12}$$

then $y_i(\beta)$ *is implementable for regulator* i*.*

Proof of lemma 1 (*Necessary conditions)* (i) The envelope theorem gives $\dot{\Pi}(\beta) = \frac{\partial \widehat{\Pi}(.)}{\partial \beta}$ and, on $\widehat{\Pi}\,(.)$ for output y_j, also $\frac{\partial \widehat{\Pi}(.)}{\partial \beta} = -C_\beta < 0$. To obtain (11) first totally differentiate the FOC for y_i, which gives $T_i'' = R_i'' + \frac{\partial^2 \widehat{\Pi}}{\partial y_i^2} + \frac{\partial^2 \widehat{\Pi}}{\partial y_i \partial \beta}\frac{1}{\dot{y}_i}$, and then substitute $R_i'' + \frac{\partial^2 \widehat{\Pi}}{\partial y_i^2} - T_i'' \leq 0$ into the SOC.

(*Sufficient conditions)* From implementability, the two following conditions hold for any $y_i(\beta)$ and $y_i(\beta')$

$$R_i(y_i(\beta)) + \widehat{\Pi}(y_i(\beta);\beta) - T_i(y_i(\beta)) \geq R_i(y_i(\beta')) + \widehat{\Pi}(y_i(\beta');\beta) - T_i(y_i(\beta')),$$

$$R_i(y_i(\beta')) + \widehat{\Pi}(y_i(\beta');\beta') - T_i(y_i(\beta')) \geq R_i(y_i(\beta)) + \widehat{\Pi}(y_i(\beta);\beta') - T_i(y_i(\beta)).$$

Summing the two one obtains[25] $\int_{\beta'}^{\beta}\int_{y_i(\beta')}^{y_i(\beta)} \frac{\partial^2 \widehat{\Pi}(u;s)}{\partial \beta \partial y_i} duds \geq 0$, and by changing variable with $y_i(t) = u$, one gets (12). Deriving $\frac{\partial \widehat{\Pi}(.)}{\partial \beta}$ with respect to y_i yields $\frac{\partial^2 \widehat{\Pi}(y_i;\beta)}{\partial y_i \partial \beta} = -C_{\beta\, y_i} - C_{\beta\, y_j}\frac{\partial \hat{y}_j}{\partial y_i}$, and, with a slight abuse of notation, $\dfrac{\partial y_j}{\partial y_i} = \frac{C_{yy}}{\Pi_{y_j y_j}}$ (differentiate the FOC for y_j w.r.t. y_j and y_i) where $\Pi_{y_j y_j} \leq 0$ for the SOCs. Substituting, (12) becomes

$$\int_{\acute{\beta}}^{\beta}\int_{\acute{\beta}}^{\beta} [\underset{(+)}{C_{\beta y_i}} + \underset{(+)}{C_{\beta y_j}} \underset{(-)}{C_{yy} (\Pi_{y_j y_j})^{-1}}] \dot{y}_i(t) dtds \leq 0 \tag{13}$$

When $C_{yy} < 0$, the integrand is positive and in this case, for any pair of β, β', $\dot{y}_i(.) \leq 0$ is sufficient for the (12) to be satisfied. On the contrary, when $C_{y_i y_j} > 0$ one can not give a sign to the integrand and no general sufficient conditions can be obtained. ■

Let us now consider a relaxed version of the original program, with constraint (8) replaced by the necessary condition (10). Totally differentiating $\Pi\,(\beta)$ with respect to β shows that $d\Pi\,(\beta)\,/d\beta = -C_\beta < 0$, and by setting $\Pi\left(\bar{\beta}\right) \geq 0$, all the other participation constraints are satisfied. Moreover, as the rent left to the firm is costly for regulators, it is optimal to set $\Pi\left(\bar{\beta}\right) = 0$, result (c). Substitute T_i from (6), integrating by parts the last term in the integrand of program (P_i) and using (10): the relaxed program of country i then becomes,

$$\underset{y_i,}{Max} \int_B \left\{ V_i\,(y_i) + \widehat{\Pi}\,(y_i;\beta) + (1-\alpha_i)\frac{G(\beta)}{g(\beta)}\frac{\partial \widehat{\Pi}\,(y_i;\beta)}{\partial \beta} \right\} dG\,(\beta) - \Pi_{\text{-}i}\left(\bar{\beta}\right).$$

[25] $\frac{\partial \widehat{\Pi}(.)}{\partial \beta}$ has to be absolutely continuous, and this is the case, as is discussed in Stole [1997].

Using $\partial\widehat{\Pi}/\partial y_i = -C_{y_i}$ and $\partial^2\widehat{\Pi}/\partial\beta\partial y_i = -C_{\beta y_i} - C_{\beta y_j}\frac{\partial \hat{y}_j}{\partial y_i}$, point by point maximization gives (a). Differentiating w.r.t. β, the equilibrium FOC for y_j (in equilibrium it is $\hat{y}_j\left(y_i\left(\beta\right),\beta\right) = y_j\left(\beta\right)$) and rearranging terms one obtains $\Pi_{y_j y_j} = (C_{yy}\dot{y}_i + C_{\beta y_j})/\dot{y}_j$. This, together with what has been proved in lemma 1, give (b). Finally, we need to study which conditions the solution to this relaxed program need to satisfy for implementability. Note that the sufficiency condition (12) with substitutes is not the standard monotonicity. The reason is that, in this case the single crossing property, which is here endogenous, does not always hold (the sign of $\frac{\partial^2\widehat{\Pi}}{\partial y_i \partial\beta}$ may not be constant in B).[26] One could put additional structure on the firm's payoff, as done by Martimort [1992] and Stole [1997], such that $\frac{\partial^2\widehat{\Pi}}{\partial y_i \partial\beta}$ with a constant sign along the equilibrium path implies global incentive compatibility. Following Martimort and Stole [1999], I note that the conditions indicated in the text of the proposition are necessary *provided that* the single crossing and monotonicity conditions are verified. Hence, I focus on equilibria where condition (12) emerges for both regulators.

Finally, to validate the current approach the tariffs $T_j(y_j)$ for $j = d, f$ need to be prolonged for out of equilibrium outputs, otherwise a "boundary problem" arises. In fact, T_i may induce the firm to chose output $y_j(\underline{\beta})$ (similarly if it induces output $y_j(\bar{\beta})$) and then, if $T_j(y_j)$ is uniquely defined for equilibrium outputs (i.e. in $\bar{Y}_j \equiv \left[y_j(\bar{\beta}), y_j(\underline{\beta})\right]$), at point $y_j(\underline{\beta})$ the function $\hat{y}_j\left(y_i,\beta\right)$ exhibits a kink and $\partial^2\widehat{\Pi}/\partial\beta\partial y_i$ a discontinuity. However, following Martimort [1992], a sufficient extension of $T_j(y_j)$ for $y_j < y_j(\bar{\beta})$ and $y_j > y_j(\underline{\beta})$ allows to eliminate this issue (see also Stole 1997). ■

Proof of proposition 3

Case (i). Substituting constraint (9) in program (P_i) and totally differentiating the net rent with respect to β,

$$\frac{d\left[\Pi\left(\beta\right) - \Pi_{\text{-}i}\left(\beta\right)\right]}{d\beta} = -\left[C_\beta(y_i(\beta), y_j(\beta);\beta) - C_\beta(0, y_j^0(\beta);\beta)\right]. \tag{14}$$

With complements $y_j(\beta) \geq y_j^0(\beta)$, and given $C_{\beta y_i} > 0$, net rent is decreasing in β. On the contrary, with substitutes we have $y_j(\beta) \leq y_j^0(\beta)$, and the difference on the r.h.s. of (14) can be negative. However,

[26] Adverse selection models with no single crossing property are beyond the scope of this paper. See Araujo and Moreira [1998] for a first analysis in this direction.

when substitutability is weak, the difference $y_j^0(\beta) - y_j(\beta)$ is small, and thus $\left| y_j(\beta) - y_j^0(\beta) \right| \leq |y_i(\beta) - 0|$. Hence, the effect in C_β of a strictly positive y_i more than compensates for the reduction in y_j, implying the net rent is again decreasing in β. Both with complements and not too strong substitutes, therefore, it is optimal to set $\Pi\left(\bar{\beta}\right) - \Pi_{\text{-}i}\left(\bar{\beta}\right) = 0$. Finally, one can easily show that it is never optimal for country j to set a domestic regulation T_j^0 which leaves strictly positive profits to type $\bar{\beta}$ (result (c)). Results (a) and (b) are simply obtained as in the proof of proposition 1. In fact, whether the MNE produces for both countries or one single country, the only difference is in the participation constraint we have analyzed.

Case (ii). Countries cannot discriminate. This proof is based on Ivaldi and Martimort [1994] and Calzolari and Scarpa [1999 a]. As in (i), the only difference with intrinsic common agency is in the participation constraint. Let us first consider complements, and without any loss of generality, let us indicate the non-linear tariff as $T_i(y_i) = t_i + \tau_i(y_i)$, where t_i is a constant term. Here, by simply playing with the constant terms of the non linear tariffs, I can prove that the MNE is left with zero profits. By defining $\hat{\Pi}_{\text{-}i}(\beta) = \underset{y_j}{Max}\left\{R_j\left(y_j\right) - C\left(0, y_j; \beta\right) - T_j\left(y_j\right)\right\}$. I can now prove that $\Pi_{\text{-}i}(\bar{\beta}) = \hat{\Pi}_{\text{-}i}(\bar{\beta}) > 0$ for *both* $i = d, f$ cannot be true, and thus for at least one i, $\Pi\left(\bar{\beta}\right) = \hat{\Pi}_{\text{-}i}(\bar{\beta}) = 0$ must hold. Suppose, on the contrary, that $\Pi_{\text{-}i}(\bar{\beta}) = \hat{\Pi}_{\text{-}i}(\bar{\beta}) > 0$ for $i = d, f$. From $\Pi\left(\bar{\beta}\right) = \hat{\Pi}_{\text{-}i}(\bar{\beta})$ one obtains t_j and similarly also t_i can be obtained. By adding them up, we get

$$\begin{aligned} \Pi(\bar{\beta}) = \quad & \textstyle\sum_{h=i,j} \max_{y_h} \left[R_h(y_h) - C(0, y_h; \bar{\beta}) - \tau_h\left(y_h\right)\right] + \\ & -\max_{y_i, y_j} \left[\textstyle\sum_{h=i,j} R_h(y_h) - C(y_i, y_j; \bar{\beta}) - \tau_h\left(y_h\right)\right] \end{aligned} \tag{15}$$

With complements, $-C(0, y_j; \bar{\beta}) - C(y_i, 0; \bar{\beta}) \leq -C(y_i, y_j; \bar{\beta})$, and the sum of the maximands in the first line is smaller than the maximand in the second line for any y_i, y_j. Thus, *a fortiori*, the first line in (15) is smaller than the second line, giving $\Pi(\bar{\beta}) < 0$, which is a contradiction.

Let us now consider substitutes. I will show that if countries use transfers $T_i(y_i) = t_i + \tau_i(y_i)$ for *any* $y_i \in \Re_+$, the multinational can take advantage of substitutability and earn extra-profits. Calculating t_i and t_j as above, $\hat{\Pi}_{\text{-}i}(\bar{\beta})$ can be written as the expression in (15). Adding $C(y_i, y_j; \bar{\beta}) - C(0, y_j; \bar{\beta}) -$

$C(y_i, 0; \bar{\beta}) \geq 0$ (the sign by substitutes) to the maximand in the second line, one obtains an expression which is larger than the original maximand for any y_i, y_j and is the exact sum of the maximands in the first line. Hence, *a fortiori* considering the max, the first line is always larger than the second. It should be pointed out that an essential ingredient of this proof is the fact that regulators cannot discriminate transfers on the basis of the MNE's location decisions; in fact, we are assuming that transfers are $t_i + \tau_i(y_i)$ for *any* $y_i \in \Re_+$. However, in equilibrium when the firm produces for both countries, output y_i must belong to the set $\bar{Y}_i$. Hence, regulator i could set transfers

$$T_i(y_i) = \begin{cases} t_i + \tau_i(y_i) & \text{if} \quad y_i \in \bar{Y}_i, \\ t_i' + \tau_i(y_i) & \text{otherwise.} \end{cases}$$

without *explicitly* violating the no-discrimination constraint in equilibrium. In such a case, the out-of-equilibrium term t_i' could be set sufficiently high that an MNE producing for country i alone with a quantity $y_i^0 \notin \bar{Y}_i$ obtains very low (possibly negative) profits $\hat{\Pi}_{\text{-}i}$. In such a way, the MNE is discouraged from threatening to produce for the competing regulator j only and ends up again with zero profits. It is clear, however, that those transfers implicitly violate the no-discrimination condition. ■

Proof of proposition 2 With complements, outputs are implementable if, and only if, $\dot{y}_i(\beta) \leq 0$, $i = d, f$. With substitutes, a pair $y_d(\beta), y_f(\beta)$ such that: (i) $\dot{y}_i(\beta) \leq 0$, $i = d, f$, is implementable if $C_{y_i y_j} \dot{y}_i + C_{\beta y_j} \geq 0$ for $i = d, f$ and $C_{yy} \sum_h C_{\beta y_h} \dot{y}_h + C_{\beta y_i} C_{\beta y_j} \geq 0$; (ii) $\dot{y}_i(\beta) > 0$, $i = d, f$, is not implementable; (iii) $\dot{y}_i(\beta) \leq 0$, $\dot{y}_j(\beta) > 0$, $i, j = d, f$, $i \neq j$, is implementable if $C_{y_i y_j} \dot{y}_i + C_{\beta yj} \leq 0$, $C_{y_i y_j} \dot{y}_j + C_{\beta yi} \geq 0$ and $C_{y_i y_j} \sum_h C_{\beta y_h} \dot{y}_h + C_{\beta y_i} C_{\beta y_j} \leq 0$.

In fact, for implementability, the complements case directly follows from lemma 1. For substitutes, proof of proposition 1 allows us to rewrite implementability sufficient conditions (12) for $i = d, f$ as

$$\int_{\hat{\beta}}^{\beta} \int_{\hat{\beta}}^{\beta} \left[\frac{C_{y_i y_j} \left(C_{\beta y_i} \dot{y}_i + C_{\beta y_j} \dot{y}_j \right) + C_{\beta y_j} C_{\beta y_i}}{C_{y_i y_j} \dot{y}_i + C_{\beta y_j}} \right] \dot{y}_i(t) dt ds \leq 0. \tag{16}$$

When $\dot{y}_i > 0$ for both $i = d, f$, the square bracket in the integrand must be negative, but this is impossible because it is composed of positive terms, and this proves case (ii). When both outputs are non-increasing, the SOC on y_j implies the denominator in (16) is positive, and thus, for the bracket to be positive it suffices that $C_{y_iy_j}\sum_h C_{\beta y_h}\dot{y}_h + C_{\beta y_i}C_{\beta y_j} \geq 0$. Finally for (iii), with $\dot{y}_j > 0$ it follows that $C_{yy}\dot{y}_j + C_{\beta y_i} > 0$ (all positive terms): thus taking condition (16) for j, if the numerator is negative, the bracket in (16) is negative and (16) is satisfied for a $\dot{y}_j > 0$. Taking (16) for i, given that the numerator is the same as for j, if $C_{y_iy_j}\dot{y}_i + C_{\beta y_j} < 0$ then the condition is satisfied for $\dot{y}_i \leq 0$. ■

Proof of proposition 4. For future reference, define $\Lambda_i \equiv A_i(B_j - 1) - (A_j + B_j)(B_i - 1)$, $i = d, f$, $i \neq j$ with $A_i \equiv 1 - \alpha_i$ and $B_i \equiv (b_i + \delta)/\delta$. Substituting $y_i(\beta) = k_i + s_i\,\beta$ into the system of optimality conditions and differentiating w.r.t. β,

$$-b_i s_i = 1 + \delta S + (1 - \alpha_i)\,\frac{\delta S + 1}{\delta\ s_i + 1}, \tag{17}$$

for $i = d, f$ where $S = s_d + s_f$. The equations in system (17) are hyperbolas in (s_d, s_f), and the system has four pairs of solutions,

$$\begin{array}{llll} (a) & s_i^a = \frac{H_i + (B_i - 1)\sqrt{\Delta}}{2B_i(B_jB_i - 1)\delta}\ \ i = d, f, & (b) & s_i^b = \frac{H_i - (B_i - 1)\sqrt{\Delta}}{2B_i(B_jB_i - 1)\delta},\ i = d, f, \\ (c) & s_d^c = 0,\ s_f^c = -\frac{2 - \alpha_f}{b_f + \delta}(= -\frac{1}{\delta}), & (d) & s_d^d = -\frac{2 - \alpha_d}{b_d + \delta}(= -\frac{1}{\delta}),\ s_f^d = 0, \end{array}$$

with $H_i \equiv A_i - A_j + B_i(2 + A_i + A_j) - B_iB_j(1 + 2A_i + B_i)$, and $\Delta \equiv A_i^2 - 2A_jA_i + A_j^2 + B_iB_j\,[2\,(A_i + A_j) + 4A_iA_j + B_iB_j]$. Note that solution (c) requires parameters to be such that $\frac{2-\alpha_f}{b_f+\delta} = \frac{1}{\delta}$, likewise for (d). Whenever the constraint is met, any slight change in one parameter upsets this equilibrium if it is not matched by an adequate change in the other parameters designed to keep the constraint satisfied. Hence, we will not consider this equilibrium for comparative statics analysis. Moreover, I will show that solutions (b) are never admissible.

(i-1) Case with $\delta > 0$ and non increasing slopes. We can prove that solutions (a) are equilibrium non-increasing slopes if and only if $\Lambda_i < 0$ $i = d, f$, and solutions (b) are impossible. In fact, given corollary 2, outputs are implementable if $-\frac{1}{\delta} \leq \dot{y}_i \leq 0$ and $-\frac{1}{\delta} \leq \sum_i \dot{y}_i$. Using the definition of s_i^a, one gets $-\frac{1}{\delta} \leq \dot{y}_i$ iff $\Lambda_i \leq 0$. In fact, with manipulations $-\frac{1}{\delta} \leq \dot{y}_i$ iff $L_i + (B_i - 1)\sqrt{\Delta} \geq 0$ where, $L_i \equiv A_i - A_j + A_iB_i - B_iB_j - 2A_iB_iB_j + B_i^2B_j$, or equivalently, $4A_iB_i\Lambda_i(B_jB_i - 1) \leq 0$ which holds iff $\Lambda_i \leq 0$ (as $B_jB_i - 1 > 0$). Similarly, one can prove that $\dot{y}_i \leq 0$ iff $\Lambda_j \leq 0$. We are then left to show that if $-\frac{1}{\delta} \leq \dot{y}_i \leq 0$ for $i = d, f$, then also $-\frac{1}{\delta} \leq \sum_h \dot{y}_h$. Take (17) and solve for s_j^a given s_i^a, then substitute to obtain $\sum_h s_h^a + \frac{1}{\delta} = s_i^a \delta (1 - B_i)(1 + s_i^a \delta) / [\delta(1 + A_i + s_i^a \delta)] \geq 0$. Finally, following the previous analysis, $s_i^b \leq -\frac{1}{\delta}$ iff $\Lambda_i < 0$ $i = d, f$. Hence, if $-\frac{1}{\delta} \leq s_i^a \leq 0$ then $s_i^b \leq -\frac{1}{\delta}$ and slopes (b) are non implementable.

For the comparative statics of solutions (a), first note that,

$$\frac{\partial s_i^a}{\partial \alpha_j} = \frac{(1-B_i)+(B_i-1)(-A_i+A_j-B_iB_j(1+2Aj))\sqrt{\Delta}}{2B_i(B_iB_j-1)\delta} < 0.$$

In fact, the numerator is negative ($(B_i - 1) > 0$, and $(-A_i + A_j - B_iB_j(1 + 2Aj)) < 0$ because $\alpha_j - \alpha_i \in [0, 1]$ and $B_iB_j(1 + 2Aj) > 1$) and the denominator is positive. Then, by differentiating the system of optimality conditions, one obtains

$$\frac{\partial s_i^a}{\partial A_i} = \frac{\overset{(+)}{\frac{\delta S+1}{\delta\ s_i^a+1}}\overset{(-)}{\left[-B_j+A_j\frac{\delta\ s_i^a}{\left(\delta\ s_j^a+1\right)^2}\right]}}{\delta\Psi} < 0 \quad \frac{\partial s_i^a}{\partial A_j} = \frac{\overset{(+)}{\frac{\delta S+1}{\delta\ s_j^a+1}}\overset{(+)}{\left[1+A_j\left(\delta\ s_i^a+1\right)^{-1}\right]}}{\delta\Psi} > 0$$

$$\frac{\partial s_i^a}{\partial B_i} = \frac{\overset{(-)}{\delta\ s_i^a}\overset{(-)}{\left[-B_j+A_j\frac{\delta\ s_i^a}{\left(\delta\ s_j^a+1\right)^2}\right]}}{\delta\Psi} > 0 \quad \frac{\partial s_i^a}{\partial B_j} = \frac{\overset{(-)}{\delta\ s_j^a}\overset{(+)}{\left[1+A_j\left(\delta\ s_i^a+1\right)^{-1}\right]}}{\delta\Psi} < 0$$

with $\Psi \equiv \left[-B_j + \frac{A_j\delta\ s_i^a}{\left(\delta\ s_j^a+1\right)^2}\right]\left[-B_i + \frac{A_i\delta\ s_j^a}{\left(\delta\ s_i^a+1\right)^2}\right] - \left[1 + \frac{A_j}{\delta\ s_i^a+1}\right]\left[1 + \frac{A_i}{\delta\ s_j^a+1}\right]$, the signs are given by implementability conditions in proposition 2, and $\Psi > 0$ comes from $\frac{\partial s_i}{\partial \alpha_j} < 0$.

(i-2) Case with $\delta > 0$ and slopes $s_i \leq 0,\ s_j > 0$. Proposition 2 shows that for implementability $s_i \leq -1/\delta$, and $\sum_h s_h \leq -1/\delta$. From (i-1) $(0 >) - \frac{1}{\delta} \geq s_i$ iff $\Lambda_i > 0$ (similarly $s_j > 0$ iff $\Lambda_i > 0$) and also $0 \geq s_i$ iff $\Lambda_j < 0$. Moreover, following case (i-1), when $-\frac{1}{\delta} \geq s_i$ and $s_j \geq 0$ then it is always the case that $0 \geq \sum_h s_h + \frac{1}{\delta}$. I can now prove that when $\Lambda_i > 0$, $\Lambda_j < 0$, (b) is impossible. By definition, $s_h^a > s_h^b$ for $h = d, f$, and thus if $-\frac{1}{\delta} \geq \dot{y}_i^a$, it must be true that $-\frac{1}{\delta} \geq s_i^b$. Moreover, in (i-1) it has been proven that $-\frac{1}{\delta} \geq s_i^b$ iff $\Lambda_i < 0$, thus the two are not compatible. Similarly, it can also be proven for the other asymmetric equilibrium. As for the Hessian of the MNE's problem, we have $\Pi_{y_iy_i} \leq 0$ iff $(1 + \delta s_j)/s_i \leq 0$ and $\Pi_{y_iy_i}\Pi_{y_jy_j} - C_{y_iy_j}^2 \geq 0$ iff $(1 + \delta s_j)/s_i (1 + \delta s_i)/s_j - \delta^2 \geq 0$. In the current case $(s_i \leq 0,\ s_j > 0)$ these conditions become $s_i \leq -1/\delta$, $s_j \geq -1/\delta$, $1 + \delta \sum_h s_h \leq 0$ and are satisfied as we have previously shown. For the comparative statics, use the same method employed in (i-1), taking into account that now $\delta S + 1 \leq 0$, $\delta\ s_i + 1 < 0$, $\delta\ s_j + 1 > 0$ and $\delta\ s_i + 1 < \delta\ s_j/(\delta\ s_i + 1) < 0$. Finally, when $b_i = b_j$, it is always the case that $\Lambda_i < 0$ and $\Lambda_j < 0$.

In order to understand when asymmetric equilibrium with an increasing output may arise, note that if b_i decreases then Λ_i rises and Λ_j falls, and equilibrium can shift from one with both falling outputs to another with y_j rising. Moreover, for the same profit weight, $b_i < b_j$ is necessary. Furthermore $\frac{\partial \Lambda_i}{\partial \alpha_i} < 0$, $\frac{\partial \Lambda_i}{\partial \alpha_j} > 0$.

(ii) Case with $\delta < 0$. It is quite clear that (c) and (d) are not admissible by proof of proposition 2. With regard to solutions (a) and (b), note that $B_i = -\left[p_i'(y_i) - C_{y_i y_i}\right]/\delta < 0$ (the numerator must be negative for FI second order conditions) and $(B_j B_i - 1) = \left[b_i b_j + \delta\left(b_i + b_j\right)\right]/\delta^2 > 0$, because the numerator must be positive for FI outputs to be decreasing in β. Moreover, $s_i^a < 0$ iff $H_i + (B_i - 1)\sqrt{\Delta} < 0$ for $i = d, f$. Proceeding as above, $s_i^a < 0$ iff $\Lambda_j < 0$, or $H_i < 0$ and $\Lambda_j > 0$. On the contrary, $s_i^b < 0$ iff $H_i - (B_i - 1)\sqrt{\Delta} < 0$ for $i = d, f$ and, similarly, $s_i^b < 0$ iff $\Lambda_i > 0$. However, $\Lambda_i > 0$ and $\Lambda_j > 0$ are impossible and slopes (b) are never an equilibrium. As for the comparative statics, the same reasoning used in case (i) applies, although in this case $\frac{\partial s_i}{\partial \alpha_j} > 0$ and $-B_j + A_j \delta\ s_i / \left(\delta\ s_j + 1\right)^2 > 0$. ■

Proof of proposition 5.

In case of complements, the asymmetric information distortions with and without cooperation among regulators rank in the following way (respectively the l.h.s. and the r.h.s. in (18))

$$\left(1 - \sum_{j=d,f} \alpha_j\right) \frac{G(\beta)}{g(\beta)} C_{\beta y_i} \leq \frac{G(\beta)}{g(\beta)} \left(C_{\beta y_i} + C_{\beta y_j} \frac{\partial \hat{y}_j}{\partial y_i}\right) \tag{18}$$

In fact, the r.h.s. has an additional positive term $C_{\beta y_j} \frac{\partial \hat{y}_j}{\partial y_i}$, and $\alpha_i \leq \sum_{j=d,f} \alpha_j$. Hence, with complements $y_i^{ANC} \leq y_i^{AC} (\leq y_i^{FI})$. Furthermore, as the multinational's profit increase in output, the firm obtains smaller profits with non cooperation than with cooperation.

On the contrary, with substitutes, the term $C_{\beta y_j} \frac{\partial \hat{y}_j}{\partial y_i}$ is negative and the comparison between distortions is in principle ambiguous. However, with $\alpha_d = 0$ and $\alpha_f = 0$, we have $\frac{G(\beta)}{g(\beta)} C_{\beta y_i} \geq \frac{G(\beta)}{g(\beta)} \left(C_{\beta y_i} + C_{\beta y_j} \frac{\partial \hat{y}_j}{\partial y_i}\right)$, and thus, everything being symmetric, we have that $y^{AC} \leq y^{ANC} \leq y^{FI}$. In this case the profits are larger with non cooperation than with cooperation.

Finally, when profit weights are such that $\sum_{i=d,f} \alpha_i \simeq 1$, the distortion in case of cooperation vanishes while the one with no cooperation remains positive. Hence, the ranking in profits and production is as with complements. ■

Proof of proposition 6. Deriving the necessary condition for country i w.r.t. β, one obtains $(p_i' - C_{y_iy_i})\dot{y}_i = C_{y_iy_j}\dot{y}_j + C_{y_i\beta}$. Substituting this expression into the necessary condition for output y_j, one gets

$$p_j(y_j) = C_{y_j} + (1-\alpha_j)\frac{G(\beta)}{g(\beta)}\left(C_{\beta y_j} + \frac{C_{y_iy_j}C_{\beta y_i}}{p_i' - C_{y_iy_i}}\right)$$

With complements the term $\left(C_{\beta y_j} + \frac{C_{yy}C_{\beta y_i}}{p_i' - C_{y_iy_i}}\right)$ is positive (in fact, $p_i' - C_{y_iy_i} \leq 0$ is the SOC for y_i) and output y_j is downward distorted with respect to FI. Moreover, given that the necessary condition for y_i being $p_i(y_i) = C_{y_i}(y_i, y_j, \beta)$, we have $y_i^{ANC} \geq y_j^{ANC}$. With substitutes, when the technology is symmetric $C_{\beta y_j} = C_{\beta y} = C_{\beta y_i}$, the term $\left(C_{\beta y_j} + \frac{C_{yy}C_{\beta y_i}}{p_i' - C_{y_iy_i}}\right)$ becomes $C_{\beta y}\frac{p_i'}{p_i' - C_{y_iy_i}} > 0$, and the same result with complements holds. ■

Proof of proposition 7. First note that $\Pi(\beta) = \int_{\underline{\beta}}^{\bar{\beta}} Y^{ANC}(u, \alpha_i, \alpha_j)du$. Moreover, $\left.\frac{\partial^2 Y^{ANC}}{\partial \alpha_i^2}\right|_{d\alpha_i = -d\alpha_j} = 2\frac{[3(B_i+B_j) - 6B_iB_j + B_i^2B_j + B_iB_j^2 - 2B_iB_j]}{\delta\sqrt{\Delta}}$, where Δ is defined in the proof of proposition 4. For any admissible δ the numerator is non-positive, and thus $\left.\frac{\partial^2 Y^{ANC}}{\partial \alpha_i^2}\right|_{d\alpha_i = -d\alpha_j} \leq 0$, the MNE's program is concave with $\delta > 0$ and convex with $\delta < 0$. With equal demands ($b_i = b_j = b$), $\left.\frac{\partial Y^{ANC}}{\partial \alpha_i}\right|_{d\alpha_i = -d\alpha_j} = 2b\frac{1-2\theta_i}{\delta(b+\delta)\sqrt{\Delta}}$. On the contrary, assuming equal ownership shares ($\theta_j = \theta_i = 1/2$) but differing demands, $\left.\frac{\partial Y^{ANC}}{\partial \alpha_i}\right|_{d\alpha_i = -d\alpha_j} = \frac{b_j - b_i}{(b_i+\delta)(b_j+\delta)}$. ■