Optimal Incentive Regulation of Multinational Enterprises*

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First version, February 1998
This version, September 1999

Abstract

Multinational enterprises (MNEs) play a big role in the economy of many countries. Recently even sectors with a long regulatory tradition have faced substantial activity by multinationals. Their interdependent international activities and the credible threats to relocate are new concerns for regulators. I study a multiprincipal model in which a privately informed MNE produces for two countries and is regulated by the two national authorities. I show that standard theory in the economics of regulation must be reconsidered in a world with MNEs and novel results arise. For example, the firm may engage in cross-subsidization activities among the subsidiaries, thus favoring one of the two countries. I then show what regulators loose when they do not adequate national regulations to the international perspective. Finally, I study MNE's incentives to lobby the two non-benevolent regulators and analyze optimal ownership patterns as a substitute for international cooperation in regulation.

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

J.E.L. classification: L51, F23.

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*I am very indebted to Jean Charles Rochet for his research advice. I am specially grateful to Alessandro Lizzeri for his helpful comments and to David Martimort for very helpful discussions on preliminary versions of this paper. I also profited from discussions with Giorgio Basevi, Lars Stole, Petter Osmundsen, Carlo Scarpa, Piero Tedeschi, Jean Jaques Laffont, and seminar participants at the University of Bologna, Bergen and Toulouse. The paper has been presented at the 1998 ASSET, 1999 EEA and 1999 EARIE meetings. The usual disclaimer applies.

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1 Introduction

Multinational enterprises (MNEs henceforth) play a big role in the economy of many countries.[1] Recently even utility sectors have faced substantial activity by multinationals. Moreover, internationalization in sectors with a long regulatory tradition such as telecommunication, banking and insurance, is mainly taking place through foreign located subsidiaries.[2] GDF-EDF, the French former energy monopolist, has recently acquired London Electricity an important energy provider in the U.K. In 1993 the group Aguas Argentinas led by the French multinational Vivendi, received a 30-year regulated concession to serve water and wastewater services to 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. The French insurance firm AXA owns Equitable Life, one of the North America's biggest life insurer and Canada's Boréal Assurances, the country's fourth largest life insurer.

These developments raise interesting research issues for the economics of regulation. The "New Regulatory Economics" (Baron [1989] and Laffont and Tirole [1993]) has generated a well developed tool-box for thinking about the problems faced by regulators. Informational asymmetries between the regulator and the regulated firm were placed at the center of the regulatory arena. However, this tool-box is not directly applicable to the problem of regulating multinational enterprises. This is because multinational firms 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. Thus, each regulator has to recognize that the optimal policy affects and depends on the policy in place in the other countries. In other words, regulators face a problem of common agency.[3] The aim of this paper is to provide a general analysis of this problem.

I model a MNE composed by three departments or subsidiaries. A first department produces an intermediate input specific to the MNE. The other two departments are final stage subsidiaries which are located in different countries and supply local markets by transforming the intermediate input.[4] Each country regulates local output.[5] I discuss two possibilities: I first assume that final stage costs are not observable by regulators. Then I

[1] World sales of all multinationals foreign affiliates were 99 per cent of world exports in 1985 and 122 per cent in 1991. Thus, from 1991, international production has surpassed export as the principal mean to deliver goods and services to foreign markets (UNCTD [1996]).

[2] Another explaination for the diffusion of MNEs is that outputs of several regulated sectors are non-tradeable services, thus the MNE is the only possibility to serve foreign markets.

[3] See Bernheim and Whinston [1986], Martimort [1992] and Stole [1992].

[4] Economic theory shows that MNEs tend to prevail over standard national firms in certain instances. One of the alleged reasons for MNEs' superiority is their ability to exploit internally produced inputs many times for several production facilities (see Markusen [1995]). Examples of these almost public inputs assets are headquarters activities, R&D, technological knowledge, patents, brand name and firm reputation. Interestingly, these assets often characterize regulated sectors and this may explain the diffusion of MNEs in these sectors.

[5] To my knowledge only two papers exist dealing with MNE regulation, Bond and Gresik [1996] and Calzolari [1998]. However, both these papers study a MNE selling output only in the foreign market.

allow for the possibility that this variable becomes observable. These alternative scenarios reflect different characteristics of the inputs (e.g., physical inputs versus managerial effort). With non observability the model parallels the Baron and Myerson [1982] framework with un-observable sub-cost. While the case of input observability follows the tradition on observable sub-costs (see Laffont and Tirole [1986]).

Since the firm is regulated by two national authorities I model the problem as a multiprincipal relationship where the MNE is the privately informed common agent and the regulators are the principals. I show that the use of intermediate inputs generates an important link between national regulations. This environment presents several novel issues and standard results in the economics of regulation must be reconsidered in a world with MNEs.

Under fairly standard circumstances, national regulations affect each other in a non trivial way. Internal production of intermediate inputs is a fundamental and specific component of the activity of MNEs. This characteristic renders very plausible the assumption that regulators are incompletely informed about efficiency in this production phase. An important role is then played by the degree of returns to scale in the production of inputs and the degree of asymmetry between the two countries. (Asymmetries originate from national demands and/or country-specific weights used by regulators to evaluate MNE's profit against consumer surplus.) In a symmetric setting with decreasing returns to scale in producing the inputs (DRS), interaction between national regulations leads to more powerful incentive contracts if profit weights are sufficiently small. The MNE is induced to increase production in all domestic markets as compared with cooperating regulators. The contrary is true if profits weights are large or if technology exhibits increasing returns to scale (IRS).

Profit weights are affected in two ways. The more domestic citizens own the firm, the more the regulator evaluates MNE's profit. On top of that, it is a well documented fact that MNEs have a strong bargaining power *vis a vis* host countries and may engage in country specific lobbing activities to increase governments' interest in MNE's profits.[6] Thus, in the model the MNE lobbies non-benevolent regulators and is able to rise regulators' concern for profits. I then show how asymmetric international ownership and lobbying activities affect domestic regulations and production. With DRS, if the MNE mostly lobbies and/or is owned by one country, then the country with the largest profit weight faces, *ceteris paribus*, a lower price and consumes more than the other. Thus the MNE favors that country cross-subsidizing local production and 'dumping' on that market. Moreover, the country with the largest weight over-consumes and the other under-consumes with respect to first best. Similarly, the country with the least elastic demand over-consumes and the other under-consumes. Interestingly, for some parameter values, an asymmetric equilibrium exists in which one regulator is obliged to offer the same regulation contract for all the possible MNE's types.

In a context like the European Union one could try to implement cooperation between countries delegating all the national powers to a supra-national regulatory body. However,

[6] For example, the firm can bribe national regulators or can engage in country specific advertising campaigns to rise citizens' general interests in the firm (Graham and Krugman [1991]).

at the time being this delegation process seems un-realistic and an alternative is to set an optimal ownership structure letting national authorities to regulate non-cooperatively. I show that in a symmetric world countries prefer to equally share ownership and, whenever there are DRS, the MNE prefers to equally lobby the to regulators. On the contrary, with IRS the MNE prefers to concentrate lobbying towards a single regulator. More complex results arise by introducing asymmetries. For example, when market demands are equal, but one country has a smaller ownership share, the MNE prefers to allocate more lobbying resources to that country with DRS and to the other with IRS. Interestingly, if the lobbying activity is intense, it may be preferable (from the point of view of countries' welfares), to have two independent (non-benevolent) regulators instead of a single one implementing international cooperation.

Multinationals are often said to able 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 each against the others and this becomes an additional constraint for national regulators. In the model I thus allow the firm to shut down production in one country. The MNE can choose to produce in the country with the most favorable regulation and make countries competing for its services. I show that competition between countries for the MNE's production possibly increases firm's profit. Finally, I study the case in which one of the two regulators remains passive and does not realize the international dimension of the firm's activities.

In section 2 I present the model and in section 3 I solve the regulation game. I first address the case with no sub-cost observability providing also the benchmarks with full information and asymmetric information with cooperating countries. I study the effects of international competition and then I introduce sub-cost observability. In section 4 I study equilibrium productions, cross-country subsidization and passive regulation. In section 5 I completely solve a proxy linear-quadratic model. In section 6 I study the effects of ownership patterns and MNE's lobbying activity. Finally, I conclude introducing extensions and ongoing research related to this paper. All the proofs are in the appendix.

2 The model

A multinational produces and sells final outputs y_d and y_f respectively in country d (d for domestic) and f (foreign). The revenue the firm obtains in country i is $R_i(y_i) = y_i\, p_i(y_i)$, where $p_i(.)$ is market i inverse demand. Outputs are non-tradeable and markets are separated with independent demands. Subsidiary located in country i produces output y_i making use of produced input q_i and locally employed labor L_i (wage rate is normalized to one). The final stage production function $y_i = f(q_i, L_i)$ is the same for the two output producing subsidiaries.[7]

Intermediate inputs $Q = q_f + q_d$ are produced by a third unit (whose location is immaterial) at cost $\varphi(Q;\beta)$ where β is an efficiency parameter β : the smaller β the more

[7]The MNE employs the best technology in all subsidiaries. Internal technology transfers within MNEs is an empirically well documented fact. See Blomström [1989].

efficient is the firm, $\varphi_\beta > 0$, $\varphi_{\beta Q} \geq 0$ (subscripts indicate partial derivatives). I will study both the cases of increasing and decreasing returns to scale in producing intermediate inputs, respectively $\varphi_{QQ} < 0$, $\varphi_{QQ} > 0$.[8] Inverting production functions, I obtain the labor demand function $L_i = L(q_i, y_i)$ with the standard properties $L_y > 0$, $L_q < 0$, $L_{yy} > 0$, $L_{qq} > 0$, $L_{qy} < 0$.[9] The MNE's profit then is,

$$\Pi = \sum_{i=f,d} R_i(y_i) - \left[\varphi(Q;\beta) + \sum_{i=f,d} L(q_i, y_i)\right] - \sum_{i=f,d} T_i, \tag{1}$$

where T_i is the instrument used by country i to regulate local production. For the sake of concreteness I make the reasonable assumption that the total quantity of inputs produced when the firm serves two markets is larger than the quantity when it serves only one domestic market (q_i^D).[10]

Assumption 1 $Q \geq q_i^D$, $i = d, f$

The MNE has private information on the efficiency parameter β. Regulators share the common prior that β distributes according to a cumulative distribution function $G(\beta)$ and a density $g(\beta) > 0$ over the support $B = \left[\underline{\beta}, \bar{\beta}\right]$.[11] $g(.)$ satisfies the monotone hazard rate property $G(\beta)/g(\beta) \geq 0$ in B. MNE and regulators have common knowledge on the model.

In each country national regulators maximize an utilitarian objective function. Social domestic welfare is a weighted sum of net consumer surplus, tax recipes (or transfers) and total MNE's profit. Regulators are self-interested and do not cooperate in regulating the firm (cooperation will be considered as a benchmark case). For the sake of concreteness I make the following assumption.

Assumption 2 *In any country consumer surplus is sufficiently high such that it is always preferable to have the MNE producing.*

Let $V_i(y_i) = \int_0^{y_i} p_i(u)du$ be the gross consumer surplus in country i, then 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 α_i is the weight country i uses to evaluate MNE's profit. The more ownership shares citizens in country i own the larger is α_i. Moreover, the MNE may lobby the two non-benevolent regulators thus increasing profit weights. For simplicity I assume that the shadow cost of public funds is zero for both the countries.[12]

[8] The interesting case of a joint (public) intermediate input, $q = q_d = q_f$, can be considered a limit case of decreasing returns to scale.

[9] With convex technologies it is $L_{qy} < 0$ which means that the possibility to substitute labor with the other input, decreases as output increases. Otherway stated, the slope of the isoquants, for a certain quantity of q_i (or L) rises (in absolute value) moving toward higher isoquants.

[10] The main results are however unchanged without this assumption. See later.

[11] I will not consider asymmetrically un-informed principals. See Bond and Gresik [1998] for a first attempt.

[12] Introducing country specific and larger than zero cost of public funds would not alter qualitatively our results.

I consider first the case in which each regulator only observes output for the domestic market such that regulatory instrument is the non linear tariff $T_i(y_i)$.[13] On the contrary when also final stage sub-cost L_i is observable and contractible then the instrument becomes $T_i(y_i, L_i)$. These two cases describe different regulatory instances and correspond respectively to the frameworks employed by Baron and Myerson [1982] and Laffont and Tirole [1986]. Moreover, jurisdictional power of regulating authorities is limited to national boundaries and regulators are thus allowed to regulate only domestic production.[14] It is however reasonable that regulators are able to observe and contract on the fact that the firm is also producing abroad. Then, each country i offers a menu of regulations $\left\{T_i^D, T_i\right\}$ which are respectively in force when the firm produces only domestically (T_i^D) or when it chooses to be a MNE (T_i). I will then compare with the case in which the regulators are constrained to offer a unique regulation contract to the firm.

The timing of the game is the following. The MNE privately learns his type. Regulators simultaneously set regulations. The MNE decides in which country to produce and takes production decisions (intermediate inputs, labors and outputs). Finally, regulations are enforced and payoffs realize. I look for perfect Bayesian equilibria and solve the regulation game in which, given the pair $\{\alpha_d, \alpha_f\}$, regulators set their instruments and the MNE takes production decisions. In section 6 I add another stage at the beginning of this timing. Before setting regulations, countries cooperatively allocate owner shares to maximize the sum of national welfares and the MNE allocate lobbying resources. I thus make weights $\{\alpha_d, \alpha_f\}$ endogenous in the regulation game.

3 The regulation game

Let us first deal with no sub-cost observability. The MNE freely chooses intermediate inputs and labor and the cost function is,

$$C(y_d, y_f, \beta) = \min_{q_d, q_f} \left\{ \varphi(Q; \beta) + \sum_{i=d,f} L(q_i, y_i) \right\}, \tag{3}$$

with $C_\beta = \varphi_\beta > 0$.[15] The profit function then becomes,

$$\Pi(y_d, y_f, \beta) = \sum_{i=f,d} R_i(y_i) - C(y_d, y_f, \beta) - \sum_{i=f,d} T_i(y_i) \tag{4}$$

and profit maximizing productions are,

$$[y_f(\beta),\ y_d(\beta)] \in \underset{y_f, y_d}{ArgMax}\, \Pi(y_f, y_d; \beta). \tag{5}$$

In the case of fully informed and cooperating countries, regulations are set to maximize the sum of the two social welfares thus weighting profit with $\alpha = \alpha_d + \alpha_f$. I avoid

[13] Tariffs are assumed to be twice continuously differentiable.

[14] Moreover, in real world foreign production may not be freely observable.

[15] I will use the notation $\frac{\partial^2 C}{\partial y_i \partial y_j} = C_{yy}$, $\frac{\partial^2 C}{\partial y_i \partial y_i} = C_{y_i y_i}$.

trivial solutions assuming that weights are always smaller than one. Thus, leaving profits to the MNE is costly and with full information regulators leave the firm with $\Pi = 0$. Substituting in the welfare function, the first best solutions $y_i^{FI}(\beta)$, $i = d, f$ (FI stands for full information) satisfy the system,

$$p_i(y_i) = C_{y_i}(y_d, y_f, \beta),\ i = d, f, \tag{6}$$

which are standard marginal cost pricing rules.[16]

With uninformed but cooperating regulators, first best regulations become suboptimal. In fact, a firm with type β would have incentive to produce as if it were a less efficient type $\beta' = \beta + d\beta$ obtaining larger than zero profits. In this case the profit of such a firm would be,

$$\Pi(\beta) = \Pi(\beta') + C[y_d(\beta'), y_f(\beta'), \beta'] - C[y_d(\beta'), y_f(\beta'), \beta],$$

The first term on the r.h.s. is zero (it is the FI profit of a type $\beta + d\beta$) and, with a slight abuse of notation, one obtains $\Pi(\beta) = \int_{\beta}^{\beta'} C_\beta(.,.;u)du > 0$. The MNE then benefits from his private information. Uninformed regulators have to leave informational rents to the MNE in order to make the firm choose the desired (by regulators) production profiles. Regulators have first to set implementability conditions which guarantee there exist transfers T_d, T_f such that the MNE is induced to choose a certain production plan y_i, $i = d, f$.[17] Then they maximize aggregated welfare with respect y_i, $i = d, f$, subject to these implementability conditions. Finally, once the optimal implementable production plan is obtained, the corresponding implementing regulatory mechanism can be recovered.

Standard calculations show that (use the envelope theorem in (5)),

$$\dot{\Pi}(\beta) = -C_\beta[y_d(\beta), y_f(\beta), \beta] < 0 \tag{7}$$

is a necessary condition for implementability, while non-increasing outputs are sufficient.[18] Finally, the firm must be induced to produce and the following incentive rationality constraints have to be satisfied,

$$\Pi(\beta) \geq 0 \qquad \forall \beta \in [\underline{\beta}, \bar{\beta}] \qquad (IR) \tag{8}$$

Substituting the profit, the program of the two cooperating regulators becomes,

$$\begin{cases} \underset{\{y_i\}_{i=f,d}}{Max} \int_B \left\{ \sum_i V_i(y_i) - C(y_d, y_f; \beta) - (1-\alpha)\Pi(\beta) \right\} dG(\beta) \\ s.t.\ \ (7), (8) \end{cases}$$

[16]It is worth noticing with FI it is immaterial whether regulators cooperate or not. The only difference between these two cases is that with non-cooperation no production equilibria also exist in which regulators set high taxes such that the MNE prefers not to produce at all. With cooperation these equilibria are eliminated.

[17]We solve using indirect mechanisms to be consistent with the case of asymmetric information and non cooperation in which the Revelation Principle and direct mechanisms can not be used. See later.

[18]I employ the first order approach (see Guesnerie and Laffont [1984]) and take into account only necessary incentive compatibility constraint (7). Sufficiency implementability conditions can then be verified ex-post.

With (7) the MNE's profit is non increasing in β and then $\Pi(\bar{\beta}) = 0$ is sufficient to have all the rationality constrains satisfied. Integrating by parts the last term in the integrand and using (7), the program becomes,

$$\underset{\{y_i\}_{i=f,d}}{Max} \int_B \left\{ \sum_i V_i(y_i) - C(y_d, y_f; \beta) - (1-\alpha)\frac{G(\beta)}{g(\beta)} C_\beta(y_d, y_f; \beta) \right\} dG(\beta).$$

Maximization point by point gives optimality conditions for outputs $y_i^{AC}(\beta)$ (AC stands for asymmetric information and cooperation),

$$p_i(y_i) = C_{y_i}(y_d, y_f; \beta) + (1-\alpha)\frac{G(\beta)}{g(\beta)} C_{\beta\, y_i}(y_d, y_f; \beta), \quad i = d, f. \tag{9}$$

With respect to first best, marginal cost is increased by the positive term $(1-\alpha)\frac{G}{g}C_{\beta\, y_i}$. Multiplying by $g(\beta)$ both sides of (9), the first term on the r.h.s. represents the marginal cost of a small change in output required to type β while the l.h.s. is the marginal benefits. Gains and benefits are weighted by $g(\beta)$, the mass of type β. The second term on the r.h.s. is an additional marginal cost. Modifying output for type β, the profit of types more efficient than β (which are in number $G(\beta)$) is marginally increased and profits are weighted according to $(1-\alpha)$. This increase in profit is required for incentive compatibility and it is the premium firms obtain for private information.

3.1 Regulation with asymmetric information and non cooperating countries (ANC)

The two output producing subsidiaries are physically (geographically) separated and regulations by non cooperating national authorities may be independent. However, the MNE uses internally produced inputs thus making independence a very special case. We say that there is interaction between regulations if MNE's production in country i affects marginal incentives for production in country j, $\frac{\partial^2 \Pi}{\partial y_i \partial y_j} \neq 0$. The following lemma can then be stated.

Lemma 1 *With asymmetric information and non cooperating regulators, the use of intermediate inputs, the presence of non-constant returns to scale in input production and non perfect substitutability between labor and input ($L_{qy} \neq 0$) are (together) necessary and sufficient conditions for interactions between national regulations. With IRS (DRS) outputs are complements (substitutes).*

Being the two final output producing units physically separated, there can exist regulation interactions only if intermediate inputs are used. A change in production Δy_i implies a change in intermediate input Δq_i. This affects production of the other input Δq_j and, finally, of the other output Δy_j. However, it is straightforward to see that with constant returns to scale in producing intermediate inputs a change in q_i no more affects

q_j and the link vanishes. Similarly, with $L_{qy} = 0$, q and L are perfect substitutes and the effects of regulation in country i on q_j can be eliminated substituting q_j with L_j.[19,20]

In the case the firm produces only for country i, regulation is standard and the mechanism T_i^D is chosen along the lines of the previous sub-section. In the general case one has to look for perfect Bayesian equilibria of the multiprincipal regulation game. For the solution I employ a technique which makes use of indirect profit functions. Taking as given the regulatory instrument imposed to the MNE by the other country, each national regulator acts as if the MNE had already chosen the output produced for the other country. In this way the original problem transforms into a simpler Principal-Agent setting. This procedure has to be repeated also for the other country. Finally, the optimality conditions of these two programs form a system whose solutions are the candidates for the perfect Bayesian equilibrium of the original game.[21]

Country i looks for the regulatory mechanism $T_i(.)$ which maximizes expected national welfare, given the MNE's output decisions (incentive compatibility constraint (5)) and subject to the constraint that the MNE, given the optimal mechanism chosen by the other regulator, must find it profitable to produce for market i (participation constraint). Moreover, country i takes as given the MNE's decisions for country j. The firm maximizes (4) w.r.t. y_j obtaining the optimal y_j for given y_i, $\hat{y}_j(y_i;\beta)$. Substituting back $\hat{y}_j(y_i;\beta)$ into the profit,

$$\Pi(y_i;\beta) = \Pi(y_i, \hat{y}_j(y_i;\beta);\beta) = R_i(y_i) - T_i(y_i) + \widehat{\Pi}(y_i;\beta), \qquad (10)$$

where,

$$\widehat{\Pi}(y_i;\beta) = R_j[\hat{y}_j(y_i,\beta)] - C[y_i, \hat{y}_j(y_i,\beta), \beta] - T_j[\hat{y}_j(y_i,\beta)]. \qquad (11)$$

Incentive compatibility constraint (5) can be then rewritten as,

$$y_i(\beta) \in \underset{y_i}{ArgMax}\, \Pi(y_i;\beta). \qquad (12)$$

Both regulators want the MNE producing for their own markets (assumption 2). Multiprincipal models generally assume that the agent can not decide to participate with

[19] With joint public input only $L_{qy} \neq 0$ is required for interactions.

[20] Interactions can be also generated by exogenous rules. Consider, for example, a firm producing a fixed size common facility at cost βF with no other production costs. International rules generally state fixed costs should be shared by subsidiaries proportionally to productions such that subsidiary i's allocated cost becomes $\beta F\, y_i/(y_d + y_f)$. Now, it suffices the MNE only partially own one of the two subsidiaries to have interdependent productions. In fact, defining $\Pi = \Pi_d + (1-\sigma)\Pi_f$, where $\sigma > 0$ is the share of subsidiary f owned by other firms and $\Pi_i = R_i(y_i) - \beta F\, y_i/(y_d + y_f)$, we then have $\partial^2\Pi/\partial y_d \partial y_f = -\beta F \sigma (y_d - y_f)/(y_d + y_f)^3 \neq 0$ as long as $y_d \neq y_f$.

[21] Employing the Revelation Principle (Myerson (1979), among the others) standard principal-agent models generally employ direct mechanisms (in which the agent announce his type $\hat{\beta}$ and the principal pays a transfer $T(\hat{\beta})$ and orders production $y(\hat{\beta})$) . In this paper I can not use direct mechanisms because in multiprincipal games there exist no such result (see Martimort and Stole [1997]). Thus, I will solve the regulation game using indirect mechanisms of the type $T_i(y_i, L_i)$, $T_i(y_i)$. . Note that with indirect mechanisms I have to justify the choice of the conditioning variables used by the two principals. However applied models, like the one in this paper, allow to individuate "natural" message spaces. In our model observability and limits in countries' jurisdictional power identify message spaces.

only one principal (intrinsic common agency, with the words coined by Bernheim and Whinston [1986]). On the contrary, here I follow a more general and realistic case developed in Calzolari and Scarpa [1999). As regulators independently set country specific regulations, the MNE can decide to produce a non zero output in both, only one or none of the countries. Consequently, in our analysis production for both markets becomes an equilibrium result and not an exogenous hypothesis. Define $\Pi(\beta) = \underset{y_i, y_j}{Max}\ \Pi(y_i, y_j; \beta)$ and $\Pi_{-i}(\beta) = \underset{y_j}{Max} \left\{ R_j(y_j) - C(0, y_j; \beta) - T_j^D(y_j) \right\}$, country i then sets regulation such that for any β the firm does not prefer to shut down production in country i[22]

$$\Pi(\beta) \geq \Pi_{-i}(\beta). \tag{13}$$

Given regulation chosen by the other country, the program (P_i) of regulator i then is,

$$(P_i) \begin{cases} \underset{T_i(.)}{Max} \int_B \{V_i(y_i(\beta)) - R_i(y_i(\beta)) + \alpha_i \Pi(\beta) + T_i(y_i(\beta))\} dG(\beta) \\ \text{s.t. } (13), (12) \end{cases}$$

Similarly to the case AC, regulator i may alternatively solve his program looking for implementability conditions and maximizing with respect to y_i subject to these conditions. To this end, I state the following lemma on implementability conditions.

Lemma 2 *(Necessary) For regulator i, if the functions $\{y_i(\beta), \Pi(\beta)\}$ are implementable (i.e. there exists a transfer schedule such that this output and profit will be chosen by the MNE), then for all β where $y_i(\beta)$ is continuous,*

$$\dot{\Pi}(\beta) = \frac{\partial \widehat{\Pi}[y_i(\beta); \beta]}{\partial \beta} = -C_\beta [y_i(\beta), y_j(y_i(\beta), \beta); \beta] \ (< 0) \tag{14}$$

$$\frac{\partial^2 \widehat{\Pi}[y_i(\beta); \beta]}{\partial y_i \partial \beta} \frac{1}{\dot{y}_i} \geq 0. \tag{15}$$

(Sufficiency) For regulator i with IRS if $\dot{y}_i(\beta) \leq 0$ or, with DRS, if

$$\int_{\beta'}^{\beta} \int_{\beta'}^{\beta} \frac{\partial^2 \widehat{\Pi}(u; s)}{\partial \beta \partial y_i} \dot{y}_i(t) dt ds \geq 0 \qquad \forall \beta, \beta' \in B, \tag{16}$$

then $y_i(\beta)$ is implementable.

Necessary conditions are standard, while sufficiency condition in the case of DRS is not the standard monotonicity condition.[23] From the previous lemma I state a corollary

[22] From standard domestic regulation $\Pi_{-i}(\beta) \geq 0$ for any β.

[23] The reason is that the single crossing property does not always hold. In the proof of the lemma I show that with DRS the sign of $\frac{\partial^2 \widehat{\Pi}}{\partial y_i \partial \beta}$ may not be constant along B. Adverse selection models with no single crossing property are an active area of research in incentive literature and are out of the goal of this paper. Araujo and Moreira (1998) show that when the single crossing condition is not verified, a limited number of changes in the sign of $\frac{\partial^2 \widehat{\Pi}}{\partial y_i \partial \beta}$ is allowed. A new kind of pooling then emerges (discrete pooling) in which the same action is chosen by a finite number of types. Interestingly, in section 5 I show the existence of an equilibrium in which one regulator pools the contracts for all types. This is, to my knowledge, a new result in the multiprincipal literature.

which will be useful in the following.

Corollary 3 *With IRS outputs are implementable if and only if* $\dot{y}_i(\beta) \leq 0$, $i = d, f$. *With DRS a pair* $y_d(\beta), y_f(\beta)$ *such that: (i)* $\dot{y}_i(\beta) \leq 0$, $i = d, f$, *is implementable if* $C_{yy}\dot{y}_i + C_{\beta y_j} \geq 0$ *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* $C_{yy}\dot{y}_i + C_{\beta y_j} \leq 0$, $C_{yy}\dot{y}_j + C_{\beta y_i} \geq 0$ *and* $C_{yy}\sum_h C_{\beta y_h}\dot{y}_h + C_{\beta y_i}C_{\beta y_j} \leq 0$.

The corollary shows it is possible that, given an implementable pair of productions, output for one country is decreasing in β and the other is increasing. An example of this unusual case will be presented in section 6.

As it is usual I employ a relaxed version of the original program (P_i) studying ex-post if and which solutions satisfy implementability conditions. Substituting the instrument T_i from (10), the relaxed program (P_i') then is,

$$(P_i') \quad \begin{cases} \underset{y_i}{Max} \int_B \left\{ V_i(y_i) + \widehat{\Pi}(y_i;\beta) - (1-\alpha_i)\Pi(\beta) \right\} dG(\beta) \\ s.t. \ \Pi(\beta) \geq \Pi_{-i}(\beta), \ \forall \beta \in B \\ \qquad \dot{\Pi}(\beta) = \frac{\partial \widehat{\Pi}(y_i;\beta)}{\partial \beta} (< 0), \ \forall \beta \in B. \end{cases}$$

The multiprincipal game is now transformed into a program similar to a standard Principal-Agent model. However, a main difference still remains for participation constraints. Contrary to standard models, here the reservation utility of the agent is type-dependent. The reason is that each country must leave the MNE with sufficient profits to prefer to produce for that country. The following proposition sates optimality necessary conditions.

Proposition 4 *Equilibrium outputs* $y_d^{ANC}(\beta)$, $y_f^{ANC}(\beta)$ *of the regulation game with non cooperating regulators satisfy the following necessary conditions for* $i, j \in \{f, d\}, j \neq i$,

$$\begin{array}{ll} (i) & p_i(y_i) = C_{y_i}(y_i, y_j, \beta) + (1-\alpha_i)\frac{G(\beta)}{g(\beta)}\left[C_{\beta y_i}(y_i, y_j, \beta) + C_{\beta y_j}(y_i, y_j, \beta)\frac{\partial \hat{y}_j}{\partial y_i}\right] \\ (ii) & \frac{\partial \hat{y}_j}{\partial y_i} = C_{yy}/\Pi_{y_j y_j} \qquad\qquad \Pi_{y_j y_j} = \dot{y}_j/(C_{yy}\ \dot{y}_i + C_{\beta y_j}) \leq 0, \\ (iii) & \Pi(\bar{\beta}) = \Pi_{-i}\left(\bar{\beta}\right) = 0. \end{array}$$

Condition (i) is a marginal cost pricing rule. The first term on the r.h.s. is the standard marginal cost while the second term is composed by two elements. The first, $(1-\alpha_i)\frac{G(\beta)}{g(\beta)}C_{\beta y_i}$, is the direct marginal informational cost. As I already observed with asymmetric information and cooperation, increasing output increases the costly rent left to the MNE. The second element, $(1-\alpha_i)\frac{G(\beta)}{g(\beta)}C_{\beta y_j}\frac{\partial \hat{y}_j}{\partial y_i}$, is an indirect marginal informational cost. Rising output y_i affects the MNE's decision for the other output y_j (through $C_{yy} \neq 0$), this in turn affects the rent which is left to the firm (through $C_{\beta y_j} > 0$). and regulator i internalizes this indirect cost when he chooses optimal output. This contractual externality is a consequence of non cooperation between the two regulating authorities and thus does not exists in the case AC. As usual, for the most efficient MNE (type $\underline{\beta}$) both the distortions vanish ($G(\underline{\beta}) = 0$) and the pricing rule is the first best one (no-distortion at the bottom).

Condition (ii) shows that when there are IRS ($C_{yy} < 0$) then the contractual externality is positive and outputs are complements, $\frac{\partial \hat{y}_j}{\partial y_i} > 0$ (as I already stated in lemma 1). In this case the two informational distortions sum up and the second term in (i) is unambiguously positive. Thus, non-cooperation increases the distortion on productions due to asymmetric information with respect to AC. On the contrary, when there are DRS ($C_{yy} < 0$), the contract externality is negative and outputs are substitutes, $\frac{\partial \hat{y}_j}{\partial y_i} < 0$. In this case the two distortions have opposite signs: the standard asymmetric information distortion increases and the contract externality reduces costs.[24] Thus, *a priori* one can not exclude the sum of the two is negative leading to an overall decrease in the cost of using intermediate inputs. When there are CRS ($C_{yy} = 0$) the contract externality vanishes and intermediate inputs are independent ($\frac{\partial \hat{y}_j}{\partial y_i} = 0$) as well as the regulation programs of the two countries. This confirms lemma 1. In the next session I will deal with the net effect of these distortion on output schedules. Point (ii) also shows that the system of optimality conditions for outputs is a system of differential equations (a common result in multiprincipal). This complicate the solution of the system as I will show in section 5.

Condition (iii) shows that, when regulators can design a menu of regulations for domestic and multinational firms, then the least efficient firm (type $\bar{\beta}$) is left with zero profit even if it can threaten to 'fly' abroad. It is simple to show that the same result holds if the MNE can only decide to produce in both countries or in none of them (intrinsic common agency). When regulators can not discriminate between domestic and multinational firms they are constrained to set a unique regulatory contract. This may be the case, for example, when a supra-national competition policy authority forbids discrimination between national and foreign firms. Being unable to discriminate between firms, national regulators generate a much stronger competitive setting for national regulations.[25] With a unique regulation the firm can credibly threat to quit the country if it is toughly regulated as a MNE. To avoid this possibility regulators may be obliged to leave the firm with larger profits. With DRS productions are substitute and the MNE faces additional costs in producing for both countries. Increased competition between national regulators to attract the firm leads to an increase of $\Pi(\bar{\beta})$ and all the firms (i.e. all the types of firm) end up with larger profits. On the contrary, with IRS the firm profits from producing in both countries and 'flying' away becomes a non credible threat. Competition between regulators is then reduced and firms remain with profits indicated in condition (iii) of

[24] It is interesting to notice that this ambiguity is the same we found for implementability sufficiency conditions.

[25] This analysis is based on related results in Ivaldi and Martimort [1994] and Calzolari and Scarpa [1999].

proposition 4.[26,27] These results are summarized in the following corollary.

Corollary 5 *If countries can only set a unique regulation, then proposition 4 (i)-(ii) hold and (iii) becomes: (iii)' With DRS (IRS)* $\Pi(\bar{\beta}) > (=)0$.

Finally, I conclude the section generalizing optimality conditions to a number $N > 2$ of regulating countries. Assuming full symmetry to save on notation, condition (i) in proposition 4 becomes, $p(y) = C_y + (1-\alpha)\frac{G(\beta)}{g(\beta)}C_{\beta y}\left[1+(N-1)\frac{\partial \hat{y}}{\partial y}\right]$. The distortion due to non-cooperation increases with the number of involved countries. Finally, when the MNE is submitted to the regulation of only one country ($N = 1$) the previous becomes the standard optimality condition with asymmetric information.

3.2 Regulation with sub-cost observability

When the sub-cost L_i of the final producing unit is observable by the local regulator, the regulating instrument of country i becomes $T_i(y_i, L_i)$. Regulator i observes y_i and L_i, then he can also infer q_i and thus one is allowed to use equivalently $T_i(y_i, q_i)$. For the two benchmarks FI and AC I only report the optimality conditions for $i = d, f$,[28]

$$(FI) \quad \begin{cases} p_i(y_i) = L_y(y_i, q_i), \\ \varphi_Q(Q,\beta) = -L_q(y_i, q_i), \end{cases}$$

$$(AC) \quad \begin{cases} p_i(y_i) = L_y(y_i, q_i), \\ \varphi_Q(Q,\beta) + (1-\alpha)\varphi_{\beta Q}(Q,\beta)\frac{G(\beta)}{g(\beta)} = -L_q(y_i, q_i). \end{cases}$$

The first equation in each pair is a marginal cost pricing rule and it is the same with FI and AC. Output is not directly distorted for informational issues, a result which corresponds to what Laffont and Tirole [1993] (page 178) call the *incentive-pricing dichotomy*. The second condition corresponds to the optimal choice of inputs (L_i and q_i). In both cases it states the equality between the ratio of (marginal) input costs (the l.h.s.) and the marginal rate of substitution (the r.h.s.). In AC the marginal cost of intermediate inputs is increased by the informational distortion and becomes the marginal virtual cost.

With non cooperation, calculating optimal input and output for the other country, $y_j(q_j(q_i,\beta))$, $q_j(q_i,\beta)$, one can define an indirect profit $\widehat{\Pi}(q_i,\beta)$. The MNE's profit becomes, $\Pi(y_i, q_i, \beta) = R_i(y_i) - L(q_i, y_i) - T_i(y_i, q_i) + \widehat{\Pi}(q_i,\beta)$. Substituting, the program

[26] In a general multiprincipal setting Calzolari and Scarpa (1999) show that, as long as both equilibrium productions are strictly positive, these are the same in intrinsic common agency, in our more realistic setting whenever regulators can or cannot offer a menu of regulations.

[27] Interestingly the larger profit which has to be left to the MNE may make one (or both) regulator(s) preferring to shut down local production. This possibility is here ruled out by assumptions 1 and 2. Asymmetric equilibria in which the MNE produces in one of the two countries only is an interesting area for future research.

[28] Calculations are standard and omitted. Instead of using profit function (4) it suffices to employ function (1).

of regulator i now is,

$$\begin{cases} \underset{T_i(.)}{Max} \int_B \left\{V_i\left(y_i(\beta)\right) - L\left(q_i(\beta), y_i(\beta)\right) + \widehat{\Pi}\left(q_i(\beta), \beta\right) - (1-\alpha_i)\Pi(\beta)\right\} dG\left(\beta\right) \\ s.t. \qquad \Pi(\beta) \geq \Pi_{\_i}\left(\beta\right) \quad \forall \beta \in B, \\ \qquad\quad \{y_i(\beta), q_i(\beta)\} \in \underset{y_i, q_i}{ArgMax}\, \Pi\left(y_i, q_i, \beta\right) \quad \forall \beta \in B. \end{cases}$$

Necessary and sufficiency conditions for implementability parallel what I stated in lemma 2 and corollary 3 and are not presented. The following proposition summarizes necessary conditions for optimality.

Proposition 6 *With non-cooperation and sub-cost observability equilibrium production plans* $y_i^{ANC}(\beta)$, $q_i^{ANC}(\beta)$ *for* $i = d, f$ *satisfy the following conditions,*

$$\begin{array}{ll} (i) & \begin{cases} p_i(y_i) = L_y(y_i, q_i), \\ \varphi_Q(Q,\beta) + (1-\alpha_i)\frac{G(\beta)}{g(\beta)}\varphi_{\beta Q}\left(Q,\beta\right)\left(1 + \frac{\partial \hat{q}_j}{\partial q_i}\right) = -L_q(y_i, q_i). \end{cases} \\ (ii) & \frac{\partial q_j}{\partial q_i} = \varphi_{QQ}/\Pi_{q_j q_j}, \qquad\qquad \Pi_{q_j q_j} = \ \dot{q}_j/(\varphi_{QQ}\,\dot{q}_i + \varphi_{\beta Q}) \leq 0 \\ (iii) & \Pi(\bar{\beta}) = \Pi_{\_i}\left(\bar{\beta}\right) = 0. \end{array}$$

Proof. The proof is as in proposition 4 and then omitted ■

Outputs are not directly distorted. On the contrary the marginal cost of intermediate inputs takes into account the contract externality $\frac{\partial q_j}{\partial q_i}$. The same considerations stated in proposition 4 hold for the relationship between the sign of this distortion and the returns to scale of input production (similarly also for MNE's participation).

4 Equilibrium productions, cross-country subsidies, and passive regulations

In this section I study equilibrium productions and the possibility the MNE engages in cross-subsidies among the final output subsidiaries. We also study the case in which one regulator remains passive and do not adequate national regulations to the international perspective.

With IRS in producing intermediate inputs (complementarity) and no sub-cost observability, the distortions on outputs in cases AC and ANC are (respectively the l.h.s. and the r.h.s.)

$$\left(1 - \sum_{j=d,f}\alpha_j\right)\frac{G\left(\beta\right)}{g\left(\beta\right)}C_{\beta y_i} < (1-\alpha_i)\frac{G\left(\beta\right)}{g\left(\beta\right)}\left(C_{\beta y_i} + C_{\beta y_j}\frac{\partial \hat{y}_j}{\partial y_i}\right). \tag{17}$$

(the parenthesis on the l.h.s. is smaller than the equivalent on the r.h.s. and on the r.h.s. there is the additional positive term $C_{\beta y_j}\frac{\partial \hat{y}_j}{\partial y_i}$). Thus, with non cooperation production is further downward distorted, $y_i^{ANC} \leq y_i^{AC} \leq y_i^{FI}$ and global under-production applies

$Y^{ANC} \leq Y^{AC}$ with $Y_i^h = \sum_i y_i^h$, h =ANC,AC, [29] Given that intermediate inputs are chosen by the MNE according to the f.o.c. $\varphi_Q(Q,\beta) = -L_q(q,y)$ in all the three cases, I also say that $q_i^{ANC} \leq q_i^{AC} \leq q_i^{FI}$ and proposition 6 shows the same ranking also with sub-cost observability. Moreover, in equilibrium for both cases it is $\dot{\Pi}(\beta) = -\varphi_\beta(Q(\beta);\beta)$ and integrating,

$$\Pi(\beta) = \int_{\beta}^{\bar{\beta}} \varphi_\beta(Q(u);u)\,du. \tag{18}$$

Counter intuitively, with IRS the multinational is not able to take advantage of non cooperation among regulators and prefers to be regulated by two competing countries (in fact $\frac{\partial \Pi(\beta)}{\partial Q} > 0$ by $\varphi_{\beta Q} > 0$).

A different situation applies with DRS (substitutability). In this case $\frac{\partial \hat{y}_j}{\partial y_i} < 0$ and the comparison of distortions in (17) is ambiguous. It is then useful to spend few words on the benchmark of a fully symmetric model.[30] Martimort [1992] and Stole [1992], using a symmetric multiprincipal model, show that with $\alpha_i = 0$ for any i and substitutes, equilibrium activities with cooperation are smaller than with non cooperation. We are now in a position to verify and generalize this result. With $\alpha_i = 0$ for any i condition (17) changes sign and then, everything being symmetric $y^{AC} \leq y^{ANC} \leq y^{FI}$ and $q^{AC} \leq q^{ANC} \leq q^{FI}$. In this case the firm is able to take advantage of non cooperation and, as one would expect, prefers to be regulated by non cooperating countries.

Proposition 7 *With IRS non cooperation always leads to under production in both countries (and global under production) with respect to cooperation (a fortiori w.r.t. FI) and smaller profit left to the MNE. With DRS and sufficiently small (large) profit weights, non cooperation leads to over- (under-) production and larger (smaller) profits than cooperation. When both outputs are non-increasing, non cooperation leads to global under production w.r.t. to first best.*

It is interesting to see how the MNE behaves when the two countries differently evaluate the firm's profit. Given the many effects at play, a general analysis of this issue is a difficult task and I will deal with it employing specific function in section 5 (the linear-quadratic model) Nevertheless a special case can be studied to grasp some of the most important results. It is the one which $\alpha_i = 1$ and $\alpha_j < 1$. Even if this is a limit case one should notice that results obtained are qualitatively the same with α_i smaller but sufficiently close to one. (With $\alpha_i \simeq 1$ the distortionary term in (18) is close to zero and its effect on equilibrium schedules is negligeable.) α_i close to one may apply when citizens in country i have a large owner share and/or the MNE's lobbing towards regulator i is particularly successful. Moreover, if the MNE faced perfect competition in country i it would then be obliged to set efficient production for that country, exactly what $\alpha_i = 1$

[29] Inequalities are strict for any $\beta \in \left]\underline{\beta}, \bar{\beta}\right]$ and are equalities for $\beta = \underline{\beta}$.

[30] Contrary to our paper, most of the multiprincipal literature deals only with fully symmetric models for simplicity . Olsen and Osumndsen (1998) is an exception in a different context of taxation.

implies in propositions 4 and 6. The following proposition shows that the overall asymmetric information distortion (composed by the asymmetric information term and the contract externality) is positive for any return to scale.[31] With DRS distorted production of subsidiary j implies smaller (than first best) output and input. Due to substitutability, subsidiary i produces a larger (than first best) output and uses a larger quantity of intermediate inputs.

Proposition 8 *With DRS, α_i sufficiently high and $\alpha_j < \alpha_i$, inputs and outputs for country j are (non-strictly) smaller in ANC than in FI and the opposite holds for country i. Everything else symmetric, input and output are (non-strictly) larger in country i than in country j. With IRS input and output in country i are always (non-strictly) larger than in country j.*[32]

Consumers in country j are penalized by the link the MNE generates between regulations: they consume, *ceteris paribus,* less than in the other country. The result also holds with IRS case where it is valid for any $\alpha_i < \alpha_j$.[33] In both the cases the MNE favors the country with the highest profit weight and sells the same good at a smaller price than in the other country. This kind of *favoritism* can be also naturally reinterpreted in terms of international *dumping.* In fact the firm sells the same homogenous good at different prices in two countries independently from the local market demands. The specific linear-quadratic model of section 5 will show that the favoritism effect holds in general for any pair of profit weights.

Propositions 8 have also an interesting interpretation in terms of cross-subsidization among the MNE's subsidiaries. Results are more clear-cut with sub-cost observability but they similarly extend to no sub-cost observability. With $\alpha_j < \alpha_i$ subsidiary i uses a larger quantity of intermediate input, $q_j^{ANC}(\beta) \leq q_i^{ANC}(\beta)$ but also produces a larger amount of final output. A meaningful comparison of the two subsidiaries' observable sub-costs, $L_i(q_i, y_i) = \int_0^{y_i} L_y(q_i, u)\, du$, requires to compare the same quantity of output to be produced. It is then evident that $L_y\left(q_i^{ANC}, y\right) \leq L_y\left(q_j^{ANC}, y\right)$ and then the sub-cost of subsidiary j is larger than that of subsidiary $i: L_j > L_i$.[34]

[31] Moreover, for the same reason it is also possible to sign the single crossing condition and non increasing schedules becomes a sufficient condition for implementability.

[32] The non-strictly specification is due to the fact that all production plans are equal at $\underline{\beta}$. Except for that type the results hold with strict inequalities.

[33] Begin with $\alpha_d = \alpha_f$, a small increase in α_i has a first order effect in reducing the distortion in i, then production rises towards first best. However, it has only an indirect and smaller second order effect in rising production in country j *via* the contract externality.

[34] For the case with no sub-cost observability the result holds because it is again $y_i \geq y_j$ and $q_i \geq q_j$. Alternatively cross-subsidies could be studied comparing productions with the ones each country could obtain with a domestic firm. With DRS, producing intermediate inputs for a single market is less expensive and the cross-subsidization effect is stronger. Moreover, the contract externality with a MNE goes in the same direction thus rising intermediate inputs cost for both subsidiaries. With IRS the result is ambiguous. If the returns to scale effect prevails, the cost reduction due to MNE's joint production may be sufficiently large to reduce the cost of the subsidiary using the smaller amount of intermediate input. See also section 7 on this.

Corollary 9 *With both observable and non observable sub-cost, the MNE's subsidiary located in the country with the smaller profit weight cross-subsidizes production of the subsidiary located in the country with the highest profit weight.*

Domestic firms in regulated sectors participate to a complex game of alliances and international cross-ownerships. It may happen that some regulators fail to realize that the firm they regulate produces and is regulated abroad. It is then interesting to study what regulators loose when they do not adequate national regulations to the international perspective. To this end I analyze how consumption, welfares and profit are affected by the presence of a passive regulator which does not internalize the effects of domestic production on foreign activities and firm's profits. Suppose the domestic regulator d believe the firm produces only for the home market, while regulator f knows the firm is a MNE. They then respectively employ regulatory instruments T_d^D, $\left\{T_f^D, T_f\right\}$ and regulator d sets regulation believing that output chosen by the firm will satisfy the following optimality condition

$$p_d(y_d) = C_{y_d}(y_d, \beta) + (1 - \alpha_d)\frac{G}{g}C_{\beta y_d}(y_d, \beta).$$

However interactions between regulations induce a different MNE's behavior. Regulation d remaining unchanged, the firm chooses output y_d according to condition

$$p_d(y_d) = C_{y_d}(y_d, y_f, \beta) + (1 - \alpha_d)\frac{G}{g}C_{\beta y_d}(y_d, y_f, \beta).$$

Firm's decisions are different from what expected by regulator d and two effects are at play. Firstly, with non-CRS y_d affects y_f. Secondly, y_f verifies condition (i) in proposition 4 because regulator f realizes that domestic production affects y_d and distorts his production rising marginal costs by the term $(1-\alpha_f)\frac{G}{g}C_{\beta y_f}\frac{\partial \hat{y}_d}{\partial y_f}$. From the point of view of regulator f nothing changes and implementability (necessary and sufficiency) conditions remain the same. With IRS, $\frac{\partial \hat{y}_f}{\partial y_d} > 0$, marginal cost for y_d is smaller when regulator d remains passive and both y_d and y_f are larger. As a consequence, the MNE benefits (profits positively depends on inputs and outputs from (18)) and prefers to hide its multinational activity to regulator d . On the contrary, the effect on country f's welfare is ambiguous. Consumers' surplus rises but the larger MNE's profit negatively affects welfare. However, if the weight used by country f is sufficiently large then the first effect prevails and country f is better off when the other regulator remains passive. With DRS, $\frac{\partial \hat{y}_f}{\partial y_d} < 0$, y_d and y_f respectively reduces and increases when regulator d remains passive. If the reduction in y_d is larger than the increase in y_f, the firm too may be worse off and would have incentive to make public its multinational nature. For country f the reasoning is the same as with IRS. On the contrary, country d may end up in the worst position with smaller consumer surplus and larger profits left to the MNE. Finally, in both cases the larger is the weight α_d the smaller are all the effects induced by a passive regulator d. More precise characterizations will be provided in the next sections.

5 A linear-quadratic model

Contractual externalities affect productions in a complex way, it is then difficult to deepen the previous analysis. I study the general model of the previous sections with an explicitly solvable linear-quadratic approximation. Let the intermediate input cost function be $\varphi(Q;\beta) = \beta Q + \frac{\delta}{2}Q^2$,with $\delta > 0$ (< 0) for DRS (IRS) and let the final stage technology be $f(q_i, L_i) = \min\{q_i,\ L_i\}$, which implies $q_i = L_i = y_i$ (thus eliminating the distinction on sub-cost observability) and $C_{y\beta} = 1$, $C_{yy} = C_{y_iy_j} = \delta$ (symmetric cost function). Inverse demands are linear, $p_i(y_i) = a - b_i y_i$, $i = f, d$. Finally, priors are distributed according to a probability function $G(.)$ whose hazard rate $G(\beta)/g(\beta)$ can be approximated by a linear function[35] and the types space is $B = [0,1]$. I call this the linear (demand) quadratic (cost) linear (hazard rate) model (LQL).

The FI and AC solutions of this model are unique, linear and respectively defined by,

$$\begin{aligned} y_i^{FI} &= k_i + \beta\ s_i^{FI}, \\ y_i^{AC} &= k_i + \beta\ s_i^{AC}, \end{aligned}$$

where $k_i = \frac{ab_j}{\Gamma}$ is an intercept, $s_i^{FI} = -\frac{b_j}{\Gamma} < 0$ and $s_i^{AC} = -\frac{(2-\alpha)b_j}{\Gamma}$ are respectively the slopes with full information and asymmetric information with cooperation ($\Gamma \equiv \delta(b_f + b_d) + b_f b_d > 0$).[36]

With asymmetric information and non cooperation system (i) in proposition 4 admits linear solutions of the type $y_i(\beta) = k_i + s_i^{ANC}\ \beta$ as proxy of equilibrium schedules.[37] Note that the most efficient type $(\underline{\beta})$ is not distorted and thus the constant terms k_i are the same in the three cases FI, AC and ANC. Comparing equilibrium schedules amounts then to compare the slopes s_i^{FI}, s_i^{AC}, s_i^{ANC}.

Proposition 10 *With asymmetric information and non-cooperation implementable equilibrium outputs are unique. With DRS and both decreasing outputs,* $\frac{\partial s_i^{ANC}}{\partial \alpha_i} > 0$, $\frac{\partial s_i^{ANC}}{\partial \alpha_j} < 0$, $\frac{\partial s_i^{ANC}}{\partial b_i} > 0$, $\frac{\partial s_i^{ANC}}{\partial b_j} < 0$. *When the demand slope is sufficiently low (high) and profit weight is small (large) in country i (j) outputs* y_i *and* y_j *become respectively decreasing and increasing. In this case* $\frac{\partial s_j^{ANC}}{\partial \alpha_j} < 0$, $\frac{\partial s_j^{ANC}}{\partial b_j} < 0$ *and a necessary condition for this asymmetric equilibrium is* $b_i \neq b_j$. *With IRS, equilibrium outputs are always both decreasing and* $\frac{\partial s_i^{ANC}}{\partial \alpha_i} > 0$, $\frac{\partial s_i^{ANC}}{\partial \alpha_j} > 0$, $\frac{\partial s_i^{ANC}}{\partial b_i} > 0$, $\frac{\partial s_i^{ANC}}{\partial b_j} > 0$.

This proposition provide a complete characterization of a non-symmetric equilibrium in a differentiable common agency game. A remarkable fact is that with DRS when demand slopes in the two countries are different, it is possible that output in one country

[35] The uniform distribution has a linear hazard rate and other examples are arbitrarly close approximations of any exponential distribution.

[36] Simple comparative statics shows that $\frac{\partial s_i^h}{\partial b_i} > 0$ $\frac{\partial s_i^h}{\partial b_j} < (>)0$, $h = FI, AC$, with DRS (IRS), $\frac{\partial s_i^{AC}}{\partial \alpha_j} > 0$ $j = d, f$ and $\frac{\partial k_i}{\partial a} > 0$, $\frac{\partial k_i}{\partial b_i} < 0$, $\frac{\partial k_i}{\partial b_j} > (<)0$ with DRS (IRS). Moreover, $b_i + \delta = -(p_i' - C_{yy}) \geq 0$ from the s.o.c. of country i and non-increasing FI outputs require $\Gamma > 0$.

[37] With the LQL model this is without loss of generality. See Stole [1992].

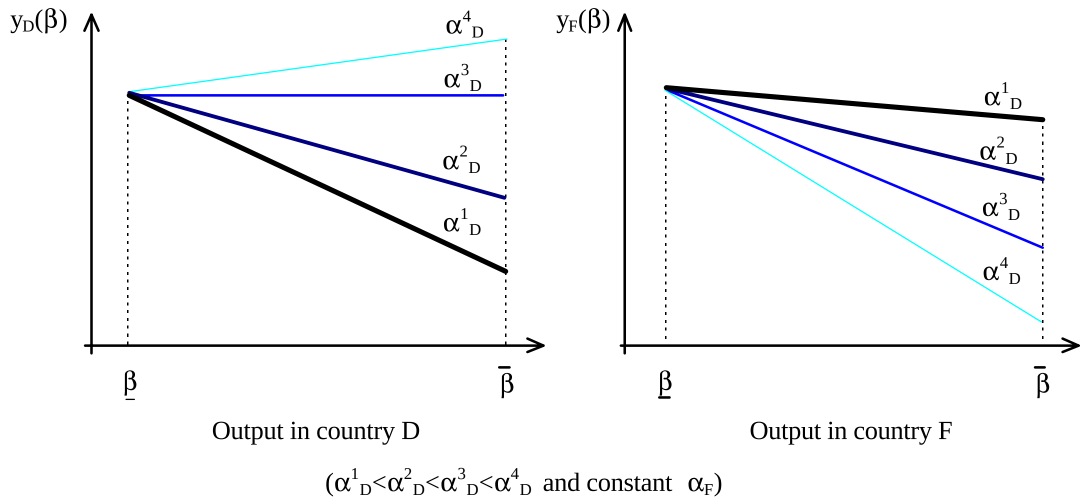

Figure 1:

becomes increasing in cost β. FI outputs are non-increasing and thus the country with output rising in β over-consumes w.r.t. FI and, *a fortiori*, w.r.t. AC (the over-production effect). Interestingly, this effect may hold with both decreasing productions.[38] With co-operating regulators, larger profit weights increase outputs in all the countries. Similarly, with non cooperation and IRS any parameter modification rising output in one country, also rises output in the other country. On the contrary with DRS, if the weight in the foreign country rises, then the negative contract externality due to non cooperation increases at home and output reduces. Less elastic home demand (larger b_d) increases the slopes (and reduces the intercept) of domestic output in all the three cases (FI, AC, ANC) but reduces the slope abroad (where the intercept rises). Thus, the effects of demand elasticities is preserved with non cooperation as long as outputs are both decreasing. On the contrary when output abroad becomes increasing, then an higher foreign profit weight and/or a smaller foreign demand elasticity reduce the foreign slope. This is a consequence of the fact that when foreign output is increasing, the overall distortion is negative. Thus, an increase in foreign profit weight induces a reduction in the (negative) distortion which finally implies a decrease in output. Figure 1 summarizes the effects on equilibrium productions of different α_d. Note that there exists a value (α_d^3) such that regulator j is obliged to the same production for any type β (full bunching): contract externalities are such that regulator d is not able to discriminate with respect to types.

Concerning total production, with non increasing outputs it is $Y^{FI} \geq Y^{ANC}$ for any return to scale (the cost function symmetric, see proposition 7). When one output is

[38]In fact, when the elasticity in market i increases production in market j may become constant (see the appendix). By continuity, for slightly larger b_i both schedules are decreasing and $y_j^{ANC} \geq y_j^{FI}$.

increasing, the distortion for the country with increasing output is negative and total output may be larger than with first best, however the LQL model shows this is impossible and also in this case $Y^{FI} \geq Y^{ANC}$.[39]

Concerning MNE's preference over cooperation and non-cooperation, proposition 7 shows that with IRS $Y^{AC} \geq Y^{ANC}$ and the MNE prefers cooperation. On the contrary with DRS, the MNE prefers non cooperation (cooperation) ($Y^{AC} \leq (\geq) Y^{ANC}$) if profit weights are similar and small (large). For intermediate and asymmetric values of profit weights the difference $Y^{AC} - Y^{ANC}$ may be negative or positive. In this case demand elasticities and the level of returns to scale (δ) become relevant. Simulations shows that with more decreasing returns to scale (large δ), total production tends to be larger in AC than in ANC. Moreover, when there are small decreasing returns to scale (δ close to zero) such that $Y^{AC} < Y^{ANC}$, then reducing both elasticities makes production with cooperation closer to production with non-cooperation. With intermediate values for δ the ranking between productions is again ambiguous. With both intermediate and large δ, if country i has a large elastic demand (small b_i) then reducing elasticity in country j makes $Y^{AC} - Y^{ANC}$ increasing. The contrary is true when the elasticity is small.[40]

With respect to favoritism and cross-subsidies, proposition 10 shows that with DRS a rise of α_i reduces output in country j. Then with non cooperation and DRS in producing intermediate inputs, the MNE always favors and cross-subsidizes production of the country with the largest profit weight. On the contrary, in the case of cooperating countries, there is non favoritism (considering equal demands, the derivatives of outputs with respect to profit weights are the same). With IRS, even if the derivatives of outputs with respect to profit weights have the same sign for both countries, however numerical simulations show that the favoritism result still holds: a rise in α_i increases output in country i more than in country j (the reason here is that in the latter only an indirect effect applies *via* the contract externality). The particular case in which $\alpha_i \simeq 1$ gives simple explicit formulas for equilibrium outputs (see the proof of proposition 10) which confirms all the previous results.[41]

6 Ownership patterns and lobbying

The previous sections show that countries's evaluations of MNE's profit affect production and then national welfares and MNE's profit. As a consequence regulators and the firm may deliberately want to modify profit weights.[42] I single out ownership shares and lobbying activities decomposing profit weights in two parts, $\alpha_i = \theta_i + \lambda_i$, where θ_i is

[39] In fact, from implementability $\delta \dot{Y}^{ANC} \leq -1$ (the non increasing schedule must be sufficiently decreasing) and with FI $\delta \dot{Y}^{FI} = -\delta \left(b_d + b_f \right) / \Gamma > -1$. Thus, finally $\dot{Y}^{FI} > \dot{Y}^{ANC}$

[40] Simulations are available from the author.

[41] Simulations show that, with non increasing outputs and non cooperation, the derivatives of outputs with respect to demand slopes are always larger in absolute values than with FI and AC. The non cooperative behavior thus magnifies the effects of parameter modifications.

[42] Results in this section are derived for the case with menus of regulations. But they also hold with unique regulations and intrinsic common agency. See the discussion of corollary 5.

country i's citizens owner share in the MNE and λ_i is the increase in the profit weight due to lobbying activity addressed to that country. For simplicity I assume regulators equally evaluate repatriated profits and consumer surplus and there are no third owners ($\sum_{i=f,d}\theta_i = 1$). In a first instance I separately study the optimal ownership distribution from countries' and MNE's perspective and assume away the possibility of lobbying ($\lambda_i = 0,\ i = d, f$). Then I analyze, for a given ownership pattern, when and toward which countries the MNE would allocate lobbying resources.

Non cooperation between regulators is sub-optimal and delegating national regulatory powers to a supra-national authority may be beneficial. However, international delegation requires regulators to give up their regulatory powers, something which seems far from realistic. As an alternative, regulators may cooperate in a first stage setting ownership shares to maximize the sum of national welfares, knowing that they will independently regulate the MNE. In this way optimal ownership design may become a substitute for cooperation in regulation.

Let us begin considering a fully symmetric model and, for simplicity, no sub-cost observability. Given optimal non-cooperative regulations, the sum of the two welfare (value) functions becomes

$$W = \int_B \left\{ \sum_h V(y_h(\beta)) - C(y_d(\beta), y_f(\beta), \beta) \right\} dG(\beta). \tag{19}$$

Deriving w.r.t. α_i and using results in proposition 4,

$$\frac{\partial W}{\partial \alpha_i} = \int_B \left\{ \sum_h \left[(1-\alpha_h) \frac{G}{g} \left(C_{\beta y_h} + C_{\beta y_j} \frac{\partial \hat{y}_j}{\partial y_h} \right) \right] \frac{\partial y_h}{\partial \alpha_i} \right\} dG(\beta) \tag{20}$$

for $h \neq j$. The effects of a marginal increase $d\theta_i$ on outputs are $\frac{\partial y_i}{\partial \theta_i} = \frac{\partial y_i}{\partial \alpha_i} - \frac{\partial y_i}{\partial \alpha_j}$ and $\frac{\partial y_j}{\partial \theta_i} = \frac{\partial y_j}{\partial \alpha_i} - \frac{\partial y_j}{\partial \alpha_j}$ (note that $\frac{d\alpha_i}{d\theta_i} = 1, \frac{d\alpha_j}{d\theta_i} = -1$). Moreover, with symmetry the term in square brackets is the same for $h = d, f$ and one finally gets the identity $\frac{\partial W}{\partial \theta_i} = 0$. In a symmetric world there is no (marginal) gain in increasing θ_i (and correspondingly decreasing θ_j) and thus the symmetric ownership $\theta_d = \theta_f$ maximizes aggregated welfare.[43] Clearly this result does not hold for each country singularly taken. Consider country i's interests in increasing domestic ownership at the expenses of foreign ownership ($d\theta_i = -d\theta_j$). Deriving country i's welfare, $\frac{\partial W_i}{\partial \theta_i} = -\int_B \left\{ \frac{\partial \widehat{\Pi}}{\partial \beta} \right\} dG(\beta) = \int_B \{\Pi(\beta)\} dG(\beta) > 0$. Each country always benefits from larger ownership shares (profit weight) because this makes the MNE's informational rents less expensive for the country.

In an asymmetric world the study of optimal ownership shares is much more complicate and I employ the LQL model of section 5. Table 4 reports the optimal θ_i^* which maximize the sum of social surpluses for a given pair of demand slopes.[44] As it has been proved

[43] Assuming second order conditions verified, as it is the case with the LQL model. See later.

[44] Simulations (obtained with Mathematica 3.0) are robust to any parameters configuration and any return to scale but unfortunately we were not able to obtain an analytical proof. Second order conditions have been always checked.

$b_i \backslash b_j$	1	2	3	4	5	6	7	8	9	10
1	0.5	0.64	0.72	0.76	0.80	0.82	0.84	0.85	0.87	0.88
2	0.35	0.5	0.58	0.64	0.68	0.72	0.75	0.77	0.79	0.80
3	0.27	0.41	0.5	0.56	0.61	0.64	0.67	0.70	0.72	0.74
4	0.23	0.35	0.43	0.5	0.54	0.58	0.62	0.65	0.67	0.69
5	0.19	0.31	0.38	0.45	0.5	0.54	0.57	0.60	0.63	0.65
6	0.17	0.27	0.35	0.41	0.45	0.5	0.53	0.56	0.59	0.61
7	0.15	0.24	0.32	0.37	0.42	0.46	0.5	0.53	0.55	0.58
8	0.14	0.22	0.29	0.34	0.39	0.43	0.46	0.5	0.52	0.55
9	0.12	0.20	0.27	0.32	0.36	0.40	0.44	0.47	0.5	0.52
10	0.11	0.19	0.25	0.30	0.34	0.38	0.41	0.44	0.47	0.5

Figure 2: $\theta_i^* = ArgMax \sum_h W_h \quad (a = 10,\ \delta = 1,\ \theta_j = 1 - \theta_i)$

above, when the demand slopes are the same, the optimal ownership is $1/2$ and symmetric. Consider now a reduction in country i elasticity (b_i rises with constant b_j). Country i (j)'s optimal ownership reduces (rises) and, for a sufficiently large elasticity reduction $\theta_i^* = 0$, and $\theta_j^* = 1$ (this case is not represented in the table).

Result 1 *Optimal ownership shares decrease (increase) with domestic (foreign) demand elasticity,* $\partial\theta_i^*(b_i, b_j)/\partial b_i < 0$, $\partial\theta_i^*(b_i, b_j)/\partial b_j > 0$.

To understand the logic of this result first note that a steeper demand in country i implies that, from the point of view of consumer surpluses in (19), it is better to increase consumption in country j. In fact, from proposition 10 outputs respectively increase and decrease with domestic and foreign ownership. A larger b_i means that market i is comparatively smaller that market j, .it is then preferable to make the output of the larger market increase at the expenses of the other one. If b_i is large enough such that $y_i \simeq 0$, then an increase in θ_i has a negligeable effect in increasing domestic output but a large effect in decreasing foreign one. The sum of consumer surpluses then would reduce. Costs (the second part of (19)) increase with total output but the effects on each output go in opposite directions and tend to compensate each other. For this reason the consumer surplus effect always prevails on the cost one.

Non-benevolent regulators may be bribed by the MNE which is then able to rise countries' evaluation for its profit. Even if this simple modelization of lobbying activity is *ad hoc*, it nevertheless allows to describe the effects of imperfections in the delegation of the regulatory authority to regulators with private agendas.[45] To simplify the lobbying game I assume the MNE has at his disposal a limited amount λ of resources for lobbying and that the lobbying technology is one-to-one: a unitary increase in λ_i gives a unitary

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

increase in α_i. The MNE then lobbies the two countries under the constraint $\lambda = \lambda_d + \lambda_f$ or $d\lambda_i = -d\lambda_j$. Consider first a completely symmetric model. Maximizing (18) w.r.t. λ_i under the constraint $d\lambda_i = -d\lambda_j$, one obtains

$$\frac{\partial \Pi}{\partial \lambda_i} = \int_{\beta}^{\bar{\beta}} \varphi_{\beta Q}(.) \frac{\partial Q}{\partial \lambda_i} du.$$

By symmetry, $\frac{\partial q_i}{\partial \lambda_i} = -\frac{\partial q_j}{\partial \lambda_i}, \frac{\partial y_i}{\partial \lambda_i} = -\frac{\partial y_j}{\partial \lambda_i}$ and then $\frac{\partial Q}{\partial \lambda_i} = 0$. Thus the net marginal benefit of a shift in lobbying from one country to another is identically zero.[46] Reintroducing asymmetries, the following proposition can be stated.

Proposition 11 *In the symmetric LQL model, with IRS the MNE lobbies just one country. With DRS the MNE equally lobbies both countries. With IRS (DRS) and equal demands, the MNE lobbies more the country with the largest (smallest) ownership. With different demands, IRS or DRS and equal owner shares, the MNE lobbies the country with the most elastic demand.*

The MNE would allocate more (less) lobbying resources whether this leads to an increase (decrease) in total intermediate input. The MNE's lobbying-maximization problem is concave with DRS but convex with IRS and this explains the particular results in proposition 11. The reason for the divergence between the two cases can already be found in proposition 10. With DRS, a rise in α_i at the expenses of α_j increases y_i but lowers y_j and the net effect is positive for intermediate values of α_i. On the contrary, with IRS, a rise in α_i at the expenses of α_j generates counter balancing effects. y_i rises and y_j decreases but with IRS goods are complements and the increase in y_i also rises y_j. The net effect is an increase in total output (and input) and the MNE concentrate lobbying resources in a single country. From proposition 11 it also follows that with IRS (DRS) the country with the highest (smallest) owner share and the most elastic demand will be mainly lobbied. With DRS, large owner shares and large elasticities have opposite effects with respect to lobbying resources allocation. However, the effects of ownership and elasticities are monotone in all the case and then, for any asymmetry in ownership with $\theta_i < \theta_j$, it always exists a pair of asymmetric demands such that the higher elasticity in country i compensate the ownership effect and the MNE prefers to lobby country i.

The MNE's preference over lobbying described in the proposition can be reinterpreted (substituting λ_i with θ_i) in terms of preferred ownership shares. Moreover, it is interesting to merge the two analysis on optimal ownership and lobbying. Consider for simplicity a symmetric world and suppose regulators cooperatively design the ownership structure in a preliminary stage, knowing that they will not cooperate in regulation and will be non-benevolent. Then with DRS regulators would equally distribute shares in the two countries even knowing that they will be bribed by the MNE. In fact, facing $\theta_d = \theta_f$,

[46] In order to state MNE's incentives to allocate lobbying resources we have to investigate also the second order condition (i.e. sign$\frac{\partial^2 Q}{\partial \lambda_i^2}$). This is done in the next proposition.

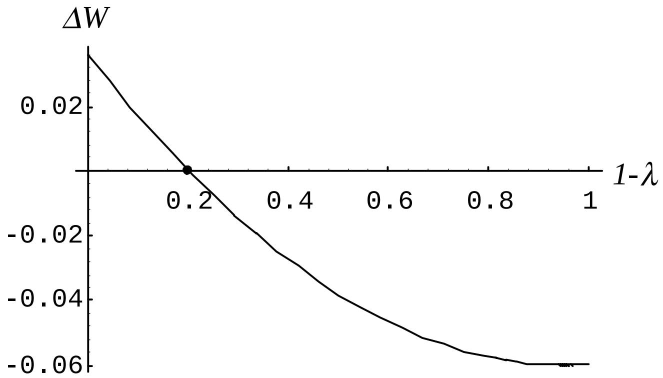

Figure 3:

the MNE would choose equal distribution of lobbying resources such that, at the end, the regulation game takes place with $\alpha_d = \alpha_f$, which is optimal for all the players in a symmetric world. On the contrary with IRS regulators have to anticipate that the MNE will concentrate lobbying resources for a single country and the optimal ownership is no more symmetric.

Lobbying activities are commonly perceived as detrimental from the point of view of national welfares. Moreover, it is a common wisdom that national non benevolent regulators independently maximizing their own private agendas ($W_i^{NB} = W_i + \lambda_i \Pi$) are worse than a single non-benevolent supra-national regulator maximizing his own private agenda ($W^{NB} = W + \lambda \Pi$). I now show, with an example, that this common wisdom may be erroneous. When the process of delegation is subject to the lobbying activity of the MNE, then countries may be better off if they delegate regulation to non cooperating regulators. Suppose for simplicity that the firm is completely foreign owned ($\theta_3 = 1$) and that it equally lobbies countries such that $\lambda_i = \lambda/2$. We now study how the difference between aggregated social welfares with two national regulators and a single regulator is affected by the amount of lobbing resources λ. Let be W_{ANC}^{NB} the sum of expected national welfares when non cooperating regulators independently maximize local welfare and W_{AC}^{NB} the aggregated welfare when regulation is delegated to a single supra-national authority.[47] Then define $\Delta W = W_{ANC}^{NB} - W_{AC}^{NB}$ the difference between the two aggregated welfares. Figure 3 shows how ΔW modifies with λ in the LQL model with parameters $a = 10$, $b_d = b_f = 1$, $\delta = 1$, $\lambda_d = \lambda_f = \lambda/2$. When lobbying resources are small ($1 - \lambda$ large) cooperative centralized regulation dominates independent regulations. However, when the MNE has a large amount of resources for lobbing ($1 - \lambda$ small) then the reverse is true. To understand this result note that a pair of independent national regulators impose each other contractual externalities $\partial \hat{y}_j / \partial y_i$ and this lack of coordination makes

[47] $W_{ANC}^{NB} = \int_B \left\{ \Sigma_i W_i^{ANC} \right\} dG(\beta)$ and $W_{AC}^{NB} = \int_B \left\{ \Sigma_i W_i^{AC} \right\} dG(\beta)$.

less effective the MNE's lobbying activity. Thus, the net effect may make independent regulators preferable when the MNE is ready to a tough lobby campaign. We can then state the following proposition.

Proposition 12 *When the process of regulation is imperfect and it is impossible to avoid (national and supra-national) regulators to be bribed, then national independent regulations may become preferable to centralized supra-national regulation.*

7 Extensions and conclusions

An important issue, specially for integrated economic areas such as EU and US, is the design of production structure in regulated sectors. Before the regulation game takes place, countries may want to coordinate in choosing how markets are served. They could allow only domestic firms or let MNEs to serve all the markets as in the previous analysis. To compare these structures one has to take into account two factors. First, returns to scale matter. When there are IRS (DRS) MNE's joint production costs are smaller (larger) than with two separate firms. Second, contract externalities are not an issue contrary to what happens with MNEs. Moreover, these externalities increase or reduce production costs respectively with IRS or DRS and then a trade off exists. The is also true from the point of view of the involved firm(s). Take the LQL and denote with Y^{MNE}, Y^{SEP} total output respectively produced with a MNE or two independent firms. To simplify the analysis, assume away lobbying issues. And to make the two cases comparable, ownership distribution is the same in the two scenarios and described by the simple limit case in which country i completely owns the firm ($\theta_i = 1$ and $\theta_j = 0$).[48] With algebraic manipulations (see the proof of proposition 10) the difference between total productions is,

$$Y^{SEP} - Y^{MNE} = \frac{b_i b_j + \Gamma}{(b_i + \delta)(b_j + \delta)\Gamma}\delta\left[a - 2\beta\right], \qquad \Gamma > 0$$

When the demand is sufficiently high in the two markets (high value of the intercept a such that the effect of returns to scale prevails), then the square bracket becomes positive and with DRS (IRS) $Y^{SEP} > (<) Y^{MNE}$. This result implies that the profit of a MNE is larger (smaller) than the sum of the profits of the two separate firms when there are DRS (IRS). With DRS a MNE would prefer to split into two independent firms, while with IRS two independent firms would prefer to merge into a single MNE. I am currently working on this issue, also considering the case in which the two independent firms can serve foreign markets with exportations.[49]

Finally, there are some documented cases of services providers in developed countries which are regulated at home and have un-regulated subsidiaries in developing markets.

[48] As we showed previously, results are qualitatively the same when $\theta_i > \theta_j$ and θ_i is sufficiently close to one.

[49] There exist papers studying international trade between domestically regulated firms. See, for example, Brainard and Martimort [1996] and Combes, Caillaud and Jullien [1997].

Intuitively, when a country regulates a firm which is also producing in another country, the former should prefer that the firm is also regulated abroad. The idea is that if this is not the case, then the firm can take advantage of this asymmetry and strategically react in the country in which it has a larger freedom. In an ongoing research I am studying the case in which a MNE produces in several countries but is regulated only by, say, the domestic government. Then, the different types of oligopolistic competition in foreign markets are analyzed.

8 Appendix

Proof of lemma 1. For the complementarity/substitutability relationship, take the optimal intermediate inputs $q_d^*(y_d, y_f)$, $q_f^*(y_d, y_f)$ and, substituting in the profit (use the envelope theorem), $\frac{\partial^2 \Pi}{\partial y_i \partial y_j} = -L_{yq}^i \frac{\partial q_i^*(y_d,y_f)}{\partial y_j}$. Deriving the system of the f.o.c.s for inputs $\frac{\partial q_i^*(y_d,y_f)}{\partial y_j} = \frac{\varphi_{QQ} L_{yq}^j}{\Delta}$, where $\Delta = L_{qq}^f L_{qq}^d + \varphi_{QQ} \times (L_{qq}^f + L_{qq}^d) > 0$ (the sign is due to the s.o.c.s for intermediate inputs). Thus, $\frac{\partial^2 \Pi}{\partial y_i \partial y_j} = -\frac{\varphi_{QQ} L_{yq}^i L_{yq}^j}{\Delta}$ so that if $\varphi_{QQ} > 0$ (DRS), then $\frac{\partial q_i^*(y_d,y_f)}{\partial y_j} < 0$ and $\frac{\partial^2 \Pi}{\partial y_i \partial y_j} < 0$. If $\varphi_{QQ} < 0$ (IRS) then $\frac{\partial q_i^*(y_d,y_f)}{\partial y_j} > 0$ and $\frac{\partial^2 \Pi}{\partial y_i \partial y_j} > 0$.

Necessary conditions. (i) If $y_i(\beta)$ is optimally chosen by the MNE, the envelope theorem gives $\dot{\Pi}(\beta) = \frac{\partial \widehat{\Pi}(.)}{\partial \beta}$. Applying again the envelope theorem on $\widehat{\Pi}(.)$ for production in the other country it also gives $\frac{\partial \widehat{\Pi}(.)}{\partial \beta} = -C_\beta = -\varphi_\beta < 0$. To obtain (ii) take the s.o.c. $R_i'' + \frac{\partial^2 \widehat{\Pi}}{\partial y_i^2} - T_i'' \leq 0$, and, to eliminate T_i'', totally differentiate the f.o.c. getting $T_i'' = R_i'' + \frac{\partial^2 \widehat{\Pi}}{\partial y_i^2} + \frac{\partial^2 \widehat{\Pi}}{\partial y_i \partial \beta} \frac{1}{\dot{y}_i}$. Substituting, this finally gives the (ii).

Sufficiency conditions. From implementability the two following conditions hold for any β and β',

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

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

Summing the two,

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

which transforms into $\int_{\beta'}^{\beta} \int_{y_i(\beta')}^{y_i(\beta)} \frac{\partial^2 \widehat{\Pi}(u;s)}{\partial \beta \partial y_i} duds \geq 0$. Finally, changing variable with $y_i(t) = u$

$$\int_{\beta'}^{\beta} \int_{\beta'}^{\beta} \frac{\partial^2 \widehat{\Pi}(u; s)}{\partial \beta \partial y_i} \dot{y}_i(t) dtds \geq 0.$$

Now, one has to state the sign of $\frac{\partial^2 \widehat{\Pi}(u;s)}{\partial\beta\partial q_i}$. Deriving $\frac{\partial\widehat{\Pi}(.)}{\partial\beta} = -C_\beta\left[y_i, \hat{y}_j\left(y_i, \beta\right); \beta\right]$ with respect to y_i, $\frac{\partial^2\widehat{\Pi}(y_i;\beta)}{\partial y_i \partial\beta} = -C_{\beta\, y_i} - C_{\beta\, y_j}\frac{\partial\hat{y}_j}{\partial y_i}$. Then, to obtain $\frac{\partial\hat{y}_j}{\partial y_i}$ take the f.o.c. for y_j and differentiate w.r.t. y_j and y_i, $\Pi_{y_j y_j} dy_j - C_{yy} dy_i = 0$, from which $\dfrac{dy_j}{dy_i} = \frac{C_{yy}}{\Pi_{y_j y_j}}$ where $\Pi_{y_j y_j} \leq 0$ for the s.o.c.s.. Substituting, the sufficiency condition for implementability becomes,

$$\int_{\acute{\beta}}^{\beta}\int_{\acute{\beta}}^{\beta} [\underset{(+)}{C_{\beta y_i}} + \underset{(+)}{C_{\beta y_j}}\ C_{yy}\ \underset{(-)}{\left(\Pi_{y_j y_j}\right)^{-1}}]\ \dot{y}_i(t) dt ds \leq 0 \tag{21}$$

Then, when $C_{yy} < 0$, the integrand is positive and in this case for any pair β, β', the $\dot{y}_i(.) \leq 0$ is sufficient for the (16) to be satisfied. On the contrary, when $C_{yy} > 0$, one can not sign the integrand and no sufficiency conditions can be given. ■

Proof of corollary 3 Concerning implementability, the IRS case directly follows from lemma 2. For DRS, take $\frac{\partial^2\widehat{\Pi}(y_i;\beta)}{\partial y_i\partial\beta} = -C_{\beta y_i} - C_{\beta y_j} C_{yy}\left(\Pi_{y_j y_j}\right)^{-1}$ obtained in the proof of lemma 2. In equilibrium it is $\hat{y}_j\left(y_i\left(\beta\right), \beta\right) = y_j\left(\beta\right)$ and differentiating w.r.t. β the equilibrium f.o.c. for y_j, $\Pi_{y_j y_j} = C_{yy}\frac{\dot{y}_i}{\dot{y}_j} + C_{\beta y_j}\frac{1}{\dot{y}_j}$. Finally, substituting back, $\frac{\partial^2\widehat{\Pi}}{\partial\beta\partial y_i} = -C_{\beta y_i} - \frac{C_{yy}C_{\beta y_j}\ \dot{y}_j}{C_{yy}\ \dot{y}_i + C_{\beta y_j}}$ and, for future reference, $\frac{\partial y_j}{\partial y_i} = C_{yy}\left(C_{yy}\frac{\dot{y}_i}{\dot{y}_j} + C_{\beta y_j}\frac{1}{\dot{y}_j}\right)^{-1}$. Substitute into (16) and use the two sufficiency conditions for $i = d, f$,

$$\int_{\acute{\beta}}^{\beta}\int_{\acute{\beta}}^{\beta}\left[\frac{\overset{(+)}{C_{yy}}\left(\overset{(+)}{C_{\beta y_i}}\ \dot{y}_i + \overset{(+)}{C_{\beta y_j}}\ \dot{y}_j\right) + \overset{(+)}{C_{\beta y_i}}\overset{(+)}{C_{\beta y_j}}}{\underset{(+)}{C_{yy}}\ \dot{y}_i + \underset{(+)}{C_{\beta y_j}}}\right]\dot{y}_i(t) dt ds \leq 0. \tag{22}$$

When $\dot{y}_i \geq 0$ for both $i = d, f$ the square bracket in the integrand must be negative, but this is impossible because it is composed by positive terms and this proves case (iib). When both outputs are non-increasing, the s.o.c. on y_j implies the denominator in the bracket in (22) is positive and then, for the bracket to be positive, it suffices that $C_{yy}\sum_h C_{\beta y_h}\dot{y}_h + C_{\beta y_i}C_{\beta y_j} \geq 0$. Finally, with $\dot{y}_j > 0$ it follows $C_{yy}\dot{y}_j + C_{\beta y_i} > 0$ (all positive terms), thus if the nominator is negative, then the bracket in (22) is negative and (22) is satisfied for a $\dot{y}_j > 0$. Taking (22) for i, given that the nominator is the same as above, if $C_{yy}\dot{y}_i + C_{\beta y_j} < 0$ then the condition is satisfied for a $\dot{y}_i < 0$. ■

Proof of proposition 4 (iii) Note that $C_{\beta y_i} > 0$. In fact, $C_{\beta y_i} = \varphi_{\beta Q}\left[\frac{\partial q_i}{\partial y_i} + \frac{\partial q_j}{\partial y_i}\right]$ and $\varphi_{\beta Q} > 0$, $\frac{\partial q_i}{\partial y_i} = -\frac{L^i_{qy}(\varphi_{QQ} + L^j_{qq})}{\Delta}$, $\frac{\partial q_j}{\partial y_i} = \frac{L^i_{qy}\varphi_{QQ}}{\Delta}$ and then $\left[\frac{\partial q_i}{\partial y_i} + \frac{\partial q_j}{\partial y_i}\right] = -\frac{L^i_{qy}L^j_{qq}}{\Delta} > 0$. Now take $\Pi\left(\beta\right) - \Pi_{\text{-}i}\left(\beta\right)$ and differentiate with respect to β,

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

where $y_j^D(\beta)$ is the optimal output with a domestic firm in country j. With IRS $y_j(\beta) \geq y_j^D(\beta)$, being $C_{\beta y_i} > 0$, it follows $\frac{d[\Pi(\beta)-\Pi_{\_i}(\beta)]}{d\beta} < 0$, the net rent is decreasing w.r.t. β. Concerning DRS, note that the total derivative of the net rent can be rewritten as $-[\varphi_\beta(Q) - \varphi_\beta(q_j^D)]$, then $\varphi_{\beta q} > 0$ and assumption 1 again imply the result. Thus, when $\Pi\left(\bar{\beta}\right) - \Pi_{\_i}\left(\bar{\beta}\right) \geq 0$, then all the other participation constraints are satisfied. Moreover, as the rent left to the firm is costly, it is optimal to set multinational regulation such that $\Pi\left(\bar{\beta}\right) - \Pi_{\_i}\left(\bar{\beta}\right) = 0$. Finally, standard calculations show that domestic regulation of country j implies $\Pi_{\_i}\left(\bar{\beta}\right) = 0$ and then $\Pi\left(\bar{\beta}\right)$.

(i) Integrating by parts the last term in the integrand and using the condition on $\dot{\Pi}$,

$$-(1-\alpha_i)\int_B \Pi(\beta)\, g(\beta)\, d\beta = (1-\alpha_i)\left\{-\left[\Pi(\beta)\, G(\beta)\right]_{\underline{\beta}}^{\bar{\beta}} + \int_B \frac{\partial\widehat{\Pi}}{\partial\beta} G(\beta)\, d\beta\right\},$$

or

$$-(1-\alpha_i)\int_B \Pi(\beta)\, g(\beta)\, d\beta = -(1-\alpha_i)\,\Pi_{\_i}\left(\bar{\beta}\right) + (1-\alpha_i)\int_B \frac{\partial\widehat{\Pi}}{\partial\beta} G(\beta)\, d\beta.$$

Substituting back, the relaxed program of country i then becomes,

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

Maximization point by point gives the f.o.c. for y_i and similarly for y_j,

$$p_i(y_i)\frac{\partial\widehat{\Pi}(y_i;\beta)}{\partial y_i} + (1-\alpha_i)\frac{G(\beta)}{g(\beta)}\frac{\partial^2\widehat{\Pi}(y_i;\beta)}{\partial\beta\partial y_i} = 0.$$

Deriving (11) w.r.t. y_i gives $\frac{\partial\widehat{\Pi}(y_i;\beta)}{\partial y_i} = -C_{y_i}$. Moreover, taking (14) and deriving w.r.t. y_i gives $\frac{\partial^2\widehat{\Pi}(y_i;\beta)}{\partial\beta\partial y_i} = -C_{\beta y_i}(y_i, y_j, \beta) - C_{\beta y_j}(y_i, y_j, \beta)\frac{\partial\hat{y}_j}{\partial y_i}$.

(ii) See the proof corollary 3. ■

Proof of proposition 7.

When profit weights are such that $\sum_{i=d,f}\alpha_i \simeq 1$, the l.h.s. in (17) is approximately zero while the r.h.s. is positive and the sign is verified. The ranking in production is the same with IRS as well as MNE's preference on cooperation. Similarly can be easily shown for sub-cost observability. Moreover, considerations on asymmetric information distortions (see condition (17)) are with strict inequalities in all the analyzed cases and the over/under production results follow. For the global under production with DRS, corollary 3 shows that distortionary terms in (i) proposition 4 are positive for any non-increasing implementable production plan and, consequently, $Y^{ANC} \leq Y^{FI}$. ■

Proof of corollary 8. We prove for sub-cost observability and similarly can be proved with no sub-cost observability. When $\varphi_{QQ} < 0$ results are standard. With $\varphi_{QQ} > 0$, totally differentiating the necessary condition for input in country i, $\varphi_{QQ}(Q,\beta)(\dot{q}_i+\dot{q}_j)+\varphi_{\beta Q} = L_{qq}\dot{q}_i + L_{qy}\dot{y}_i$, and for output, $\dot{y}_i(p_i' - L_{yy}) = L_{qy}\dot{q}_i$, one gets $\dot{q}_i = -\frac{\varphi_{QQ}\dot{q}_j+\varphi_{\beta Q}}{\Delta}$, $\Delta \equiv \varphi_{QQ} - L_{qq} - \frac{L_{qy}^2}{p_i'-L_{yy}} \leq 0$ (the sign comes from the s.o.c.s on intermediate inputs and outputs). Now substitute this expression in the condition for input j (proposition 6), obtaining,

$$\varphi_Q + (1-\alpha_j)\frac{G}{g}\varphi_{\beta Q}\left[1 - \frac{\varphi_{QQ}\frac{\varphi_{QQ}\dot{q}_j+\varphi_{\beta Q}}{\Delta}}{\varphi_{QQ}\dot{q}_j+\varphi_{\beta Q}}\right] = -L_q.$$

Simplifying, the square bracket becomes $\left[1-\frac{\varphi_{QQ}}{\Delta}\right] = \frac{-L_{qq}-L_{qy}^2\left(p_i'-L_{yy}\right)^{-1}}{\Delta}$. The numerator is equal to $\Delta - \varphi_{QQ}$ and is negative (in fact $\Delta \leq 0$ and $\varphi_{QQ} > 0$). This means that the square bracket is positive as well as the overall distortion. Thus, the ambiguity of the single–crossing condition is resolved and $\dot{q}_j \leq 0$ for implementability. Necessary condition can thus be rewritten as,

$$\begin{aligned}
&p_h(y_h) = L_y\left(q_h, y_h\right) \quad h = d, f,\\
&\varphi_Q(Q,\beta) = -L_q\left(q_i, y_i\right),\\
&\varphi_Q(Q,\beta) + (1-\alpha_j)\tfrac{G(\beta)}{g(\beta)}\varphi_{\beta Q}\left(1+\tfrac{\varphi_{QQ}}{\Delta}\right) = -L_q\left(q_j, y_j\right).
\end{aligned}$$

In the case of non sub-cost observability necessary conditions similarly become,

$$\begin{aligned}
&p_i\left(y_i\right) = C_{y_i}\left(y_i, y_j, \beta\right),\\
&p_j\left(y_j\right) = C_{y_j}\left(y_i, y_j, \beta\right) + (1-\alpha_j)\tfrac{G(\beta)}{g(\beta)}\left(C_{\beta y_j} + \tfrac{C_{yy}C_{\beta y_i}}{p_i' - C_{y_i y_i}}\right).
\end{aligned}$$

Notice that in both the cases the systems are no more differential equations. Moreover, the overall distortionary terms are strictly positive and the ranking on outputs and inputs follows. As already mentioned in the text, these results also hold for α_i sufficiently high but not necessarily equal to one. ■

Proof of corollary 5.[50] Whenever the MNE produces for both countries, the only difference between a unique or a menu of regulations remains in the participation constraint. Transfers can be written w.l.g. as $T_i = t_i + t_i(y_i)$, with $t_i(0) = 0$ and t_i a constant intercept. With DRS (IRS), $C(y_i, y_j; \bar{\beta}) > (<) C(y_i; \bar{\beta}) + C(y_j; \bar{\beta})$. Moreover, with unique regulation $\widehat{\Pi}(0,\beta) = \max\{\Pi_{\text{-}i}(\beta), 0\}$. Consider first DRS. We want then to prove that $\Pi_{\text{-}i}(\bar{\beta}) > 0$. We can write

$$\Pi_{\text{-}i}(\bar{\beta}) = \max_{y_j}\left[R_j(y_j) - C(y_j;\bar{\beta}) - t_j - t_j(y_j)\right] \tag{23}$$

To obtain t_j, consider the following. With respect to regulator j condition (iii) in proposition 4 can be written as

$$\max_{y_i,y_j}\left[\sum_h R_h(y_h) - C(y_i,y_j;\bar{\beta}) - t_j - t_j(y_j) - t_i - t_i(y_i)\right] = \max_{y_i}\left[R_i(y_i) - C(y_i,0;\bar{\beta}) - t_i - t_i(y_i)\right]$$

[50]This proof is based on Ivaldi and Martimort [1994] and Calzolari and Scarpa [1999].

From this one can obtain t_j and, substituting in (23),

$$\Pi_{\_i}(\bar{\beta}) = \max_{y_j} \left[R_j(y_j) - C(0, y_j; \bar{\beta}) - t_j(y_j)\right] + \max_{y_i} \left[R_i(y_i) - C(y_i, 0; \bar{\beta}) - t_i(y_i)\right] - \\ - \max_{y_i, y_j} \left[\sum_h R_h(y_h) - C(y_i, y_j; \bar{\beta}) - t_j(y_j) - t_i(y_i)\right] \tag{24}$$

With DRS it is always true that

$$\max_{y_i, y_j} \left[\sum_{h=i,j} R_h(y_h) - C(y_h, 0; \bar{\beta}) - t_h(y_h)\right] > \\ \max_{y_i, y_j} \left[\sum_{h=i,j} R_h(y_h) - t_h(y_h) - C(y_i, y_j; \bar{\beta})\right] \tag{25}$$

Finally, being the l.h.s.s in (25) equal to the sum of the first two terms in (24), $\Pi_{\_i}(\bar{\beta}) > 0$.

For IRS one has just to prove that at least one of the following two is true $\Pi_{\_i}(\bar{\beta}) < 0$ or $\Pi_{\_j}(\bar{\beta}) < 0$, which implies $\widehat{\Pi}(0, \bar{\beta}) = 0$. Assume on the contrary that $\Pi_{\_i}(\bar{\beta}) > 0$ and $\Pi_{\_j}(\bar{\beta}) > 0$, this leads to a contradiction.. In fact, derive t_j and t_i as above and add them up obtaining

$$-(t_j + t_i) + \max_{y_i, y_j} \left[\sum_h R_h(y_h) - C(y_i, y_j; \bar{\beta}) - t_j(y_j) - t_i(y_i)\right] = \\ \max_{y_j} \left[R_j(y_j) - C(0, y_j; \bar{\beta}) - t_j(y_j)\right] + \max_{y_i} \left[R_i(y_i) - C(y_i, 0; \bar{\beta}) - t_i(y_i)\right] - \\ - \max_{y_i, y_j} \left[\sum_h R_h(y_h) - C(y_i, y_j; \bar{\beta}) - t_j(y_j) - t_i(y_i)\right]$$

Contrary to DRS, the r.h.s. is negative and so is the l.h.s.. But this implies $\Pi(\bar{\beta}) < 0$ which is impossible. ■

Proof of proposition 10. First, 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 $B_i \equiv (b_i + \delta)/\delta$. Then, optimality conditions for the LQL model are, $i = d, f$

$$a - b_i y_i = \beta + \delta Y + (1 - \alpha_i)\, \beta \frac{\delta \dot{Y} + 1}{\delta\ \dot{y}_i + 1}. \tag{26}$$

Substituting $y_i(\beta) = k_i + s_i^{ANC}\ \beta$ into (26) and differentiating w.r.t. β,

$$-b_i s_i^{ANC} = 1 + \delta S + (1 - \alpha_i) \frac{\delta S + 1}{\delta\ s_i^{ANC} + 1}, \tag{27}$$

for $i = d, f$ where $S = s_d^{ANC} + s_f^{ANC}$. System (27) has two sets of solutions,

$$\begin{aligned} (a) \qquad s_i^{ANC} &= \frac{H_i + (B_i - 1)\sqrt{\Delta}}{2B_i(B_j B_i - 1)\delta}, \\ (b) \qquad s_i^{ANC} &= \frac{H_i - (B_i - 1)\sqrt{\Delta}}{2B_i(B_j B_i - 1)\delta}. \end{aligned}$$

with $H_i \equiv A_i - A_j + B_i(2 + A_i + A_j) - B_iB_j(1 + 2A_i + B_i)$, $\Delta \equiv A_i^2 - 2A_jA_i + A_j^2 + B_iB_j\left[2\left(A_i + A_j\right) + 4A_iA_j + B_iB_j\right]$.

(i-1) $\delta > 0$. We now prove that equilibrium (both) non-increasing schedules exists iff $\Lambda_i < 0$ $i = d, f$, they are described by equations (a) and, finally, slopes (b) are impossible (unicity).

Let us start with (a). From corollary 3 outputs are implementable if $-\frac{1}{\delta} \leq \dot{y}_i \leq 0$ and $-\frac{1}{\delta} \leq \sum_i \dot{y}_i$. Using definition of s_i^{ANC} in (a) one obtains that $-\frac{1}{\delta} \leq \dot{y}_i$ 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, $L_i \equiv A_i - A_j + A_iB_i - B_iB_j - 2A_iB_iB_j + B_i^2B_j$ (notice that $B_jB_i - 1 > 0$). This transforms into $L_i^2 - (B_i - 1)^2\Delta \leq 0$ and then $4A_iB_i\Lambda_i(B_jB_i - 1) \leq 0$. Finally this last holds iff $\Lambda_i \leq 0$. Similarly, $\dot{y}_i \leq 0$ iff $\Lambda_j \leq 0$. In fact, with manipulations $\dot{y}_i \leq 0$ iff $H_i + (B_i - 1)\sqrt{\Delta} \leq 0$, which transforms into $4\left(1 + A_i\right)B_i\Lambda_j(1 - B_jB_i) \geq 0$ and this last condition holds 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 it is also $-\frac{1}{\delta} \leq \sum_h \dot{y}_h$. To this end take (27) and solve for s_j^{ANC} obtaining $s_j^{ANC} = -(1 + s_i^{ANC}\delta)(1 + A_i + B_is_i^{ANC}\delta)/\left[\delta(1 + A_i + s_i^{ANC}\delta)\right]$, then substitute getting $\sum_h s_h^{ANC} + \frac{1}{\delta} = s_i^{ANC}\delta(1 - B_i)(1 + s_i^{ANC}\delta)/\left[\delta(1 + A_i + s_i^{ANC}\delta)\right] \geq 0$. Now one must prove that if $-\frac{1}{\delta} \leq s_i^{ANC,a} \leq 0$ then $s_i^{ANC,b} \leq -\frac{1}{\delta}$ and outputs (b) are non implementable. Following the previous analysis one can show that $s_i^b \leq -\frac{1}{\delta}$ iff $L_i^2 - (B_i - 1)^2\Delta < 0$ which again is true iff $\Lambda_i < 0$ $i = d, f$.

For the comparative statics first notice that,

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

In fact, the nominator is negative (the first bracket is negative, $(B_i - 1) > 0$, $(-A_i + A_j - B_iB_j(1 + 2Aj)) < 0$ because $\alpha_j - \alpha_i \in [0, 1]$ and $B_iB_j(1 + 2Aj) > 1$) and the denominator is positive. To obtain the sign of the other derivatives differentiate the system (26) and obtain

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

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

where $\Psi \equiv \left[-B_j + A_j\frac{\delta\ s_i^{ANC}}{\left(\delta\ s_j^{ANC}+1\right)^2}\right]\left[-B_i + A_i\frac{\delta\ s_j^{ANC}}{\left(\delta\ s_i^{ANC}+1\right)^2}\right] - \left[1 + A_j\left(\delta\ s_i^{ANC} + 1\right)^{-1}\right]\left[1 + A_i\left(\delta\ s_j^{AN}\right.\right.$
The signs are given by implementability conditions in corollary 3 and $\Psi > 0$ comes from $\frac{\partial s_i^{ANC}}{\partial A_j} < 0$ as I proved above.

(i-2) $\delta > 0$. Consider first the case with $s_i^{ANC} \leq 0$, $s_j^{ANC} > 0$. Corollary 3 shows that for implementability $s_i^{ANC} \leq -1/\delta$, and $\sum_h s_h \leq -1/\delta$. From above, $(0 >) - \frac{1}{\delta} \geq s_i^{ANC}$ iff $\Lambda_i > 0$ (similarly $s_j^{ANC} > 0$ iff $\Lambda_i > 0$) and also $0 \geq s_i^{ANC}$ iff $\Lambda_j < 0$. Moreover, when $-\frac{1}{\delta} \geq s_i^{ANC}$ and $s_j^{ANC} \geq 0$ then it is always $0 \geq \sum_h s_h + \frac{1}{\delta}$. In fact, take (27) and solve for s_i^{ANC} obtaining $s_i^{ANC} = -(1+s_j^{ANC}\delta)(1+A_j+B_j s_j^{ANC}\delta)/\left[\delta(1+A_j+s_j^{ANC}\delta)\right]$, then substitute getting $\sum_h s_h + \frac{1}{\delta} = s_j^{ANC}\delta(1-B_j)(1+s_j^{ANC}\delta)/\left[\delta(1+A_j+s_j^{ANC}\delta)\right] < 0$. We now prove that when $\Lambda_i > 0$, $\Lambda_j < 0$, then (b) is impossible. By definition $s_h^a > s_h^b$ for $h = d, f$, and then if $-\frac{1}{\delta} \geq \dot{y}_i^a$, it must be $-\frac{1}{\delta} \geq s_i^{ANC,b}$. Moreover, in (i-1) It has been proved that $-\frac{1}{\delta} \geq s_i^{ANC,b}$ iff $\Lambda_i < 0$, thus the two are not compatible. Similarly can be proved for the other asymmetric equilibrium.

For the comparative statics use the same method employed in (i-1) (again $\Psi > 0$ from $\frac{\partial s_i}{\partial A_j} < 0$), taking into account that now $\delta S + 1 \leq 0$, $\delta\ s_i^{ANC} + 1 < 0$, $\delta\ s_j^{ANC} + 1 > 0$ and $\delta\ s_i^{ANC} + 1 < \delta\ s_j^{ANC}/(\delta\ s_i^{ANC} + 1) < 0$. Finally, when $b_i = b_j$ then $\Lambda_i = -b/\delta[1 + (\alpha_i - \alpha_j)] - (b/\delta)^2 < 0$ and similarly $\Lambda_j < 0$, thus it is impossible to have either $\Lambda_i > 0$ or $\Lambda_j > 0$..

(ii) $\delta < 0$. First notice that from corollary 3 outputs schedules are implementable only if they are non increasing. Second, now $B_i < 0$ because $B_i = -\left[p_i'(y_i) - C_{yy}\right]/\delta$ where the nominator must be negative for FI second order conditions. Moreover, it still is $(B_j B_i - 1) = \left[b_i b_j + \delta\left(b_i + b_j\right)\right]/\delta^2 > 0$, because the nominator is positive for FI outputs to be decreasing in β. Third, with the first pair of output schedules $s_i^{ANC} < 0$ iff $H_i + (B_i - 1)\sqrt{\Delta} < 0$ for $i = d, f$. Proceeding as above, with manipulations this becomes (see part (i)) $s_i^{ANC} < 0$ iff $\Lambda_j < 0$, or $H_i < 0$ and $\Lambda_j > 0$. On the contrary, with the second pair of output schedules $s_i^{ANC} < 0$ iff $H_i - (B_i - 1)\sqrt{\Delta} < 0$ for $i = d, f$. With manipulations this becomes $s_i^{ANC} < 0$ iff $(1 + A_i)B_i(1 - B_i B_j)\Lambda_i > 0$, that is iff $\Lambda_i > 0$. However, $\Lambda_h > 0$ for both $h = i$ and $h = j$ can never be, thus (b) is never an equilibrium.

For the signs of the derivatives,

$$\frac{\partial s_i^{ANC}}{\partial \alpha_j} = \frac{(B_i - 1)\left[-1 + (-A_i + A_j - B_i B_j(1 + 2Aj))\Delta^{-1/2}\right]}{2B_i(B_i B_j - 1)\delta} > 0,$$

for the same reasoning used in (i-1). Thus, it is $\Psi > 0$ and, being $\frac{\delta S + 1}{\delta\ s_i^{ANC} + 1} < 0$, $\left[-B_j + A_j \frac{\delta\ s_i^{ANC}}{\left(\delta\ s_j^{ANC} + 1\right)^2}\right] > 0$, the results follow as above.

Finally, to see when the asymmetric equilibrium with an increasing output may arise notice that if b_i decreases (the elasticity in market i increases) then Λ_i rises and Λ_j lowers and equilibrium can shift from one with both decreasing output schedules to another with y_j increasing. For the same profit weight, $b_i < b_j$ is necessary. Furthermore $\frac{\partial \Lambda_i}{\partial \alpha_i} < 0$, $\frac{\partial \Lambda_i}{\partial \alpha_j} > 0$. ■

Note that when $\alpha_i = 1$ the solution to the system (26) is $s_i^{ANC} = -[b_i b_j + \alpha_j b_{i\delta} + \delta(b_j - b_i)]/[(b_i + \delta)\Gamma]$ and $s_j^{ANC} = -(2 - \alpha_j)b_i/\Gamma$.

Proof of proposition 11. We have $\left.\frac{\partial^2 Y^{ANC}}{\partial \alpha_i^2}\right|_{d\alpha_i = -d\alpha_j} = 2\frac{[3(B_i + B_j) - 6B_i B_j + B_i^2 B_j + B_i B_j^2 - 2B_i B_j]}{\delta\sqrt{\Delta}}$.

With $\delta > 0$ the numerator is non positive, in fact it can be rewritten as $-2[2(b_i b_j)^2 + 3\delta(b_i^2 b_j + b_i b_j^2) + \delta^2(b_i^2 + b_j^2 + 10 b_i b_j + 4\delta^3(b_i + b_j))] < 0$ and then $\left.\frac{\partial^2 Y^{ANC}}{\partial \alpha_i^2}\right|_{d\alpha_i = -d\alpha_j} \leq 0$: the

MNE's program is concave. With $\delta < 0$ the numerator is still non positive (recall $B_h \leq 0$) and then $\left.\frac{\partial^2 Y^{ANC}}{\partial \alpha_i^2}\right|_{d\alpha_i = -d\alpha_j} \geq 0$: the MNE's program is convex. With equal demands $(b_i = b_j = b)$, $\left.\frac{\partial Y^{ANC}}{\partial \alpha_i}\right|_{d\alpha_i = -d\alpha_j} = 2b\frac{1-2\theta_i}{\delta(b+\delta)\sqrt{\Delta}}$ where Δ is defined in the proof of proposition 10. On the contrary, assuming equal owner shares $(\theta_j = \theta_i = 1/2)$ but different demands, it is $\left.\frac{\partial Y^{ANC}}{\partial \alpha_i}\right|_{d\alpha_i = -d\alpha_j} = \frac{b_j - b_i}{(b_i+\delta)(b_j+\delta)}$. Note that with the LQL model the distinction between total input and output is irrelevant and then $\Pi(\beta) = \int_{\beta}^{\bar{\beta}} Y^{ANC}(u, \alpha_i, \alpha_j) du$. The profit is strictly increasing in total output. ■

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