Who Contributes? A Strategic Approach to a European Immigration Policy

Russo, Giuseppe and Senatore, Luigi
Dipartimento di Scienze Economiche e Statistiche - University of Salerno

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Giuseppe Russo†
University of Salerno and CSEF

Luigi Senatore
University of Salerno and University of Leicester

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Abstract

According to the Lisbon Treaty the increasing cost of enforcing the European border against immigration shall be shared among the EU members. Nonetheless, the Treaty is rather vague with respect to the "appropriate measures" to adopt in order to distribute the financial burden. Members who do not share their borders with source countries have an incentive to free ride on the other countries. We study a contribution game where a northern government and a southern government minimize a loss function with respect to their national immigration target. We consider both sequential and simultaneous decisions and we show that the contribution of both governments is positive when their immigration targets are not too different. We show that total contribution is higher when decisions are simultaneous, but the conditions for both contributions to be positive are less restrictive in the sequential framework.

Jel Codes: D78, H72, H77

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1 Introduction

It is well-known that immigration control in the EU suffers from a serious lack of coordination (see Boeri and Bruecker, 2005). This should not be surprising because by its very nature immigration is a supranational process, but its regulation still concerns mainly the national governments. This is particularly evident in the case of the EU where internal borders are not enforced in the Schengen

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†Corresponding author. Università di Salerno, Dipartimento di Scienze Economiche, via Ponte don Melillo, 84084 Fisciano (SA), Italy. email: grusso@unisa.it

area, and spending on external border enforcement concerns especially Southern European countries, who therefore provide a public good.

Northern members of the EU seem indeed reluctant to contribute to enforce the border in the South (Wolff, 2008). Somewhat surprisingly, even the ongoing emigration wave from Northern Africa is producing pressures to reintroduce internal border checks rather than promoting a European immigration policy.[1]

The Lisbon Treaty defines external border enforcement as a "shared competence", disciplined by the ordinary legislative procedure. In particular, "the policies of the Union [...] and their implementation shall be governed by the principle of solidarity and fair sharing of responsibility, *including its financial implications,* between the Member States" (article no. 80).

In spite of its importance, article no. 80 does not provide any rule on how to share these costs in practice, though article no. 77 calls for the development of a European border surveillance system (EUROSUR). The final implementation of EUROSUR will represent a major financial effort for the EU budget (European Commission, 2008b; Jeandesboz, 2008), but it seems quite likely that the current fiscal crisis is going to delay its achievement for several years.[2]

Since there is no federal authority allowed to tax and redistribute in order to fund a European immigration policy, the current state of the integration process prevents the use of a mechanism able to redistribute resources from northern countries to southern countries. For this reason, an approach based on mechanism design (like the one proposed by Haake et al., 2010[3]) seems not practicable in the near future.[4]

On the contrary, it is necessary to restrict our attention to very simple and viable institutional frameworks, where countries interact without a federal immigration ministry.[5] Contribution games provide the proper framework to understand to what extent it is possible to obtain some sharing of the financial burden for external border control in the present situation.

However, a distinctive feature of immigration policy is that each country has its own optimal inflow: while immigrant workers are necessary to the economy, their potential supply largely exceeds the demand of any national labour mar-

[1] In April 2011 French President Nicolas Sarkozy and Italian Prime Minister Silvio Berlusconi sent a joint letter to the European Commission and the European Council, requesting EU to "review the possibility of temporarily restoring controls at international borders" in the Schengen area.

[2] So far, the main attempt to move immigration control to a supranational level has been the establishment of the FRONTEX agency in 2005. The intent of FRONTEX is coordinating national immigration policies at the European level.

[3] Haake et al. (2010) propose the adoption of the "expected externality mechanism", where a supranational authority asks each country its own marginal willingness to pay for the public good, then countries are taxed and provided with the public good *according to the revealed information.* Unfortunately, this mechanism does not always satisfy the participation constraints.

[4] In addition, mechanisms are especially used to deal with informational asymmetries (see Clarke, 1971; Arrow, 1979; d' Aspremont and Gerard-Varet, 1979) while our results are obtained under perfect information.

[5] Mayr et al. (2009) move from the same concern, but in their model immigration externalities arise only after an immigration amnesty in a border country. In addition, they consider only simultaneous decisions, and do not study a sequential budget process.

ket. As a consequence, we introduce loss functions with respect to a national immigration target in a contribution game.

Heterogeneity in national targets is crucial in our analysis, and we show that, although information is complete and symmetric, it could easily prevent cooperation. A conclusion is that imperfect information is *not* the main culprit for the lack of a European immigration policy.

Our model includes a northern or central government (henceforth C) and a southern or local government (henceforth L). L shares its border with an emigration country and must provide some border enforcement, while C does not. C and L have different targets and different resources to control immigration.

Since our purpose is to check whether there exists an institutional framework which dominates the others in terms of total contribution or incentive to contribute, we compare simultaneous and sequential decisions. In the sequential case we explore what happens when the leader is C or L.[6]

By confronting the alternative regimes we find that:

1) in order to obtain positive contributions, the immigration targets of C and L must not be "too" different;

2) the admissible difference in the immigration targets is wider in the sequential game;

3) when both contributions are positive, total contribution is unambigously higher in the simultaneous game (no matter who is the leader in the sequential game);

4) in the sequential game the leader always contributes more than the follower;

5) in the simultaneous game a simple condition determines whether C or L contributes more.

With respect to the possibility of a European immigration policy, we conclude that a simultaneous regime, in which northern countries decide jointly with southern countries, produces tighter border enforcement but makes it more likely that some countries do not contribute. On the other hand, the sequential regime provides an incentive to contribute at the cost of a smaller total contribution.

The paper is organised as follows: the next section introduces our model, Section 3 presents the results when decisions are sequential or simultaneous, Section 4 studies the effect of the cost asymmetry on the equilibrium contribution, Section 5 is devoted to compare the equilibrium contributions under the different institutional frameworks and Section 6 concludes.

2 The model

Our model must depict the basic issues related to the European immigration policy we have discussed in the introduction. First of all, external border en-

[6] A great deal of literature studies joint provision of public goods within a sequential or simultaneous game (see for example Warr, 1982 and 1983; Cornes and Sandler, 1984; Bergstrom et al., 1986; Varian, 1994).

forcement is a public good, and there exists a conflict over its funding. At the moment, no supranational authority can enforce a scheme of taxes and subsidies, thus countries interact strategically with nobody being forced to contribute.

Finally, we assume that C and L face different costs in raising the resources needed to curb immigration and that their preferences over the optimal inflows are different.

In what follows, we develop the simple contribution game able to include all of these points into our analysis.

2.1 Immigration control

Immigration control is an expensive activity which requires resources to enforce the border, screen the immigrants, contrast illegal inflows and so on. A convenient way to summarize these actions is describing immigration restriction as an output produced through the resources C and L are willing to spend in order to achieve their targets.

We define with g_L and g_C the contributions by L and C respectively. Let M be the inflow of immigrants. Then, we can depict immigration restriction as follows:

$$M = \bar{M} - d(g_L + g_C) \qquad 0 < d < 1; \tag{1}$$

Where $\bar{M}$ is the inflow into the federation in case of no restriction ($g_L = g_C = 0$). This kind of production function fits the idea that the amount of restriction is proportional to the resources used.[7]

2.2 Payoffs

As we pointed out in the introduction, the peculiarity of immigration policy is the existence of a bliss point coinciding with the national optimal inflow. Thus, we assume that each country has a quadratic loss function with respect to its own target, and bears a quadratic cost to collect the resources needed to enforce the border.[8] As a consequence, we write the utilities as follows:

$$U_C = -\frac{1}{2}(M - M_C^*)^2 - \frac{1}{2}g_C^2 \tag{2}$$

$$U_L = -\frac{1}{2}(M - M_L^*)^2 - \frac{\pi}{2}g_L^2 \tag{3}$$

where $\pi > 1$ means that for L it is relatively costlier to gather the resources needed to curb immigration. This assumption is used because C and L may bear different costs to gather the same contribution, and it mirrors a situation

[7] Notice that setting the value of $0 < d < 1$ gives a good approximation of a strictly concave technology when we are in a sufficiently flat interval of the function.

[8] Gathering real resources always generates costs: they can be the political costs of raising taxes, or even the opportunity costs of diverting funds from alternative projects.

in which a small border country provides immigration restriction for the whole federation.[9]

Finally, we assume $\bar{M} > M_C^*$ and $\bar{M} > M_L^*$.

By substituting (1) into (2) and (3) we can rewrite the payoffs:

$$U_C = -\frac{1}{2}(\bar{M} - d(g_L + g_C) - M_C^*)^2 - \frac{1}{2}g_C^2 \tag{4}$$

$$U_L = -\frac{1}{2}(\bar{M} - d(g_L + g_C) - M_L^*)^2 - \frac{\pi}{2}g_L^2 \tag{5}$$

We are now going to solve the model under sequential and simultaneous decisions.[10]

2.3 Results: sequential decisions

In the case of sequential decisions, both C and L could have the right to move first. We are now going to explore both cases.

2.3.1 C moves first

Assume for the moment that C is the leader and L is the follower. We solve the game by backwards induction. The best response of L to C is

$$\bar{g}_L = \frac{d(\bar{M} - M_L^*) - d^2 g_C}{\pi + d^2} \tag{6}$$

The leader therefore has to solve the following problem:

$$\max_{g_C} U_C = -\frac{1}{2}\left[\bar{M} - d\left(g_C + \frac{d(\bar{M} - M_L^*) - d^2 g_C}{\pi + d^2}\right) - M_C^*\right]^2 - \frac{1}{2}g_C^2$$

which yields

$$g_C^* = \frac{\Delta_C(\pi + d^2)\pi d - \pi d^3 \Delta_L}{\pi^2 d^2 + (\pi + d^2)^2} \tag{7}$$

where $\Delta_C \equiv (\bar{M} - M_C^*)$, and $\Delta_L \equiv (\bar{M} - M_L^*)$ measure the desired entry restriction.

[9] Consider for example the following figures: the aggregate GDP of Italy, Spain and Greece in 2010 -possibly the Local government in our model- is 23.4% of the EU GDP. In contrast, the aggregate GDP of France, Germany, Austria, Netherlands and the Nordic countries -possibly the Central government- accounts for 49.5%. Hence, the fiscal base of C is wider than the fiscal base of L.

[10] Since immigrants settle either in C or in L it may seem incorrect that M is the same in both payoffs. However, for a single country, a *national* immigration target implies a *federal* immigration target: suppose that C wants 100 immigrants. Suppose also that one half immigrants settle in C and one half immigrants settle in L. Then, $M_C^* = 200$. In other words, M_C^* and M_L^* can be interpreted as the optimal inflow for the federation from the point of view of C and L respectively. Also note that this depicts quite well the ongoing conflict between Italy, France and Germany over the responsibility for refugees from Northern Africa.

By substituting (7) into (6) we get

$$g_L^* = \frac{\Delta_L(\pi + d^2 + \pi d^2)d - \pi d^3 \Delta_C}{\pi^2 d^2 + (\pi + d^2)^2} \tag{8}$$

we therefore have obtained the equilibrium contributions of both players when C moves first.

These contributions are positive under the following conditions:

$$g_C^* > 0 \qquad for \quad \frac{\Delta_C}{\Delta_L} > \frac{d^2}{\pi + d^2} \tag{9}$$

$$g_L^* > 0 \qquad for \quad \frac{\Delta_C}{\Delta_L} < \frac{\pi + d^2 + \pi d^2}{\pi d^2} \tag{10}$$

Now we are going to present the results when L is the leader.

2.3.2 C moves second

When L moves first, the best response function of C is

$$\bar{g}_C = \frac{d(\bar{M} - M_C^*) - d^2 g_L}{1 + d^2} \tag{11}$$

and the equilibrium contributions are

$$g_C^{**} = \frac{\Delta_C(d^2 + \pi + \pi d^2)d - d^3 \Delta_L}{d^2 + \pi(1 + d^2)^2} \tag{12}$$

$$g_L^{**} = \frac{\Delta_L(1 + d^2)d - d^3 \Delta_C}{d^2 + \pi(1 + d^2)^2}. \tag{13}$$

The conditions for having positive contributions are summarized below:

$$g_C^{**} > 0 \qquad for \quad \frac{\Delta_C}{\Delta_L} > \frac{d^2}{d^2 + \pi + \pi d^2} \tag{14}$$

$$g_L^{**} > 0 \qquad for \quad \frac{\Delta_C}{\Delta_L} < \frac{1 + d^2}{d^2}. \tag{15}$$

Finally, we are going to solve the simultaneous game.

2.4 Results: simultaneous decisions

In a simultaneous game, the best response functions for C and L are, respectively, (11) and (6), and the solutions are

$$\tilde{g}_C = \frac{\Delta_C(\pi + d^2)d - d^3\Delta_L}{d^2 + \pi + \pi d^2} \tag{16}$$

$$\tilde{g}_L = \frac{\Delta_L(1 + d^2)d - d^3\Delta_C}{d^2 + \pi + \pi d^2}. \tag{17}$$

These contributions are positive under the following conditions:

$$\tilde{g}_C > 0 \qquad for \quad \frac{\Delta_C}{\Delta_L} > \frac{d^2}{d^2 + \pi} \tag{18}$$

$$\tilde{g}_L > 0 \qquad for \quad \frac{\Delta_C}{\Delta_L} < \frac{1 + d^2}{d^2} \tag{19}$$

By observing (7), (8), (12), (13), (16) and (17) it is evident that the equilibrium contribution of each player is decreasing with respect to the desired immigration restriction of the other player. In other words, in all cases the contribution of C is decreasing with Δ_L, and the contribution of L is decreasing with Δ_C.

Intuitively, suppose that L prefers strict border enforcement and C is relatively open. Then, the latter has an incentive to free ride, because L will provide enough immigration control for both countries. This conveys the essential insight that, in order for both countries to contribute, the national targets M_C^* and M_L^* must not be too different. This result has crucial consequences that we are going to discuss in the rest of the paper.

Before proceeding to compare the outcomes under the sequential and the simultaneous regimes, it is indispensable to understand when both countries decide to contribute.

3 Conditions for joint contribution

We know that individual equilibrium contributions are positive when conditions (9), (10), (14), (15), (18) and (19) hold. Now we look at the conditions under which *both* contributions are positive in the different games, which are summarized in Figure 1. As we just argued, constraints on the admissible range of $\frac{\Delta_C}{\Delta_L}$ mean that the desired immigration restriction should not be "too" different.

By simple inspection of these conditions we can write the following proposition:

Proposition 1 *(Conditions for positivity of both individual contributions): equilibrium contributions are both positive if and only if the individual immigration targets are not too different. The admissible difference is broader in the sequential game.*

Proof. See the appendix. ■

The proposition is crucial because it points out that in a sequential framework the range of $\frac{\Delta_C}{\Delta_L}$ under which there exists joint contribution is wider compared to the simultaneous framework (see Figure 1). In this respect, our results depart from Varian (1994), who argues that the sequential game can exacerbate free riding problems: in Varian (1994) a leader with higher marginal utility from the public good might be better off by not contributing and free riding on the follower.

In our model this does not happen because we introduce a loss function in a contribution game.

This implies that the leader does not contribute if and only if his desired immigration restriction is sufficiently low *relative to the follower*. When the leader prefers high relative restriction, should he not contribute he would only suffer a larger loss.[11] Hence, the only way to exploit the leadership is trying to set the contribution at a level that pushes the follower to add his own contribution.

4 The role of the cost asymmetry

In this section we report some comparative statics results with respect to the effect of the cost asymmetry π.

In the Appendix we show that, quite intuitively, L reduces his equilibrium contribution as π increases. On the other hand, the equilibrium contribution of C increases with π in all cases, *provided that both contributions are positive*. Results are summarized in the following table:

	sequential	
C leader		L leader
$\frac{\partial g_C^*}{\partial \pi} > 0;$		$\frac{\partial g_C^{**}}{\partial \pi} > 0 \quad \text{for} \quad \frac{\Delta_C}{\Delta_L} < \frac{1+d^2}{d^2}$
$\frac{\partial g_L^*}{\partial \pi} < 0$		$\frac{\partial g_L^{**}}{\partial \pi} < 0$
	simultaneous	
$\frac{\partial \tilde{g}_C}{\partial \pi} > 0 \quad \text{for} \quad \frac{\Delta_C}{\Delta_L} < \frac{1+d^2}{d^2}$		$\frac{\partial \tilde{g}_L}{\partial \pi} < 0 \quad \text{for} \quad \frac{\Delta_C}{\Delta_L} < \frac{1+d^2}{d^2}$

The most important outcome of this comparative statics analysis is that when both C and L contribute the timing of the game does *not* determine the effect of π on the equilibrium contributions.

[11] To understand intuitively this point, consider an example: see Figure 1 and suppose that C is the leader. Until $\frac{\Delta_C}{\Delta_L} \leq \frac{d^2}{d^2+\pi}$, he does not contribute because L is (relatively) so averse to immigration that he provides enough restriction for C as well. When $\frac{\Delta_C}{\Delta_L} > \frac{d^2}{d^2+\pi}$, C is better off by setting a positive contribution and, when $\frac{\Delta_C}{\Delta_L}$ is very high, C provides enough restriction for both players and L has no reason to contribute.

What matters is the *decision to contribute*: once C decides to put resources in immigration control, he is going to increase his equilibrium contribution as L faces higher costs in gathering his own contribution. To understand the reason of this behaviour it is important to remember that this holds when both contributions are positive, i.e. when the targets of C and L are sufficiently close. In such a case, C finds it convenient to increase his equilibrium contribution in order to compensate the disadvantage of L.

5 Sequential vs. simultaneous decisions

5.1 Total contribution

In this section we restrict our attention to the cases in which both contributions are positive. By comparing the equilibrium solution in the three cases, it is straightforward to conclude that total contribution is higher in the simultaneous regime. This is summarized in the following proposition:

Proposition 2 *(Total contribution with simultaneous decisions): when both contributions are positive, total contribution is higher in the simultaneous game.*

Proof. See the appendix. ■

The proposition simply states that the simultaneous game dominates the sequential game in terms of total contribution -no matter who is the leader-. Unlike proposition 1, this result is in line with Varian (1994), who shows that in a game with complete information total contribution is never larger in the sequential framework.[12]

Proposition 1 and proposition 2 convey our most important result, namely that the simultaneous game increases total contribution, but it requires more stringent conditions in order to get positive contributions from both players.

In other words, the simultaneous framework is successful in increasing total contribution *given that countries are willing to contribute*, while the sequential framework is successful in *inducing contribution*. It follows that the sequential game should be recommended when the immigration targets of C and L are very different and the main issue is to provide an incentive to contribute. This seems to be the case of the EU, therefore an effort to frame a federal immigration policy at the current stage of the European integration should favor a sequential budget process.

In addition, we must stress that the simplest attempt to obtain some contribution from a reluctant country is to make it act as a follower in the sequential game. In fact, from Proposition 1 we know that the leader tries to set his own contribution at a level that encourages the follower to contribute as well. This widens the range of $\frac{\Delta_C}{\Delta_L}$ allowing a positive contribution (see Figure 1).

[12] We also have $(g_C^* + g_L^*) \geq (g_C^{**} + g_L^{**})$ when $\frac{\Delta_C}{\Delta_L} \leq \frac{\pi(1+d^2)+d^2(2+d^2)}{\pi(1+2d^2)+d^2(1+d^2)}$. There are no particular reasons why this condition should hold, thus we conclude that it is not possible to know a priori whether total contribution is higher when C or L is the leader. Note however that the right-hand side is smaller than unity.

5.2 Individual contribution

We now compare the individual contributions within the different regimes. Again, we consider only the case of positive contributions.

Our first conclusion is summarized in the following proposition:

Proposition 3 *(Equilibrium contributions in the sequential game): in the sequential game the leader contributes more than the follower.*

Proof. See the appendix. ■

This result is important because it allows us to know unambigously the player who provides the higher contribution.

The comparison of the individual contributions in the simultaneous game is reported in the next proposition:

Proposition 4 *(Equilibrium contributions in the simultaneous game): in the simultaneous game C contributes more than L if* $\frac{\Delta_C}{\Delta_L} > \frac{1+2d^2}{\pi+2d^2}$ *and viceversa.*

Proof. See the Appendix. ■

To understand intuitively the meaning of this proposition, suppose that costs are symmetric, i.e. $\pi = 1$. In such a case, the condition $\frac{\Delta_C}{\Delta_L} > \frac{1+2d^2}{\pi+2d^2}$ boils down to $\Delta_C > \Delta_L$. Hence, when the cost of gathering the resources for immigration control is the same, the country who desires more restriction contributes more. When π is larger than unity this condition is relaxed: we have $\tilde{g}_C > \tilde{g}_L$ if $\Delta_C > \left(\frac{1+2d^2}{\pi+2d^2}\right)\Delta_L$, with $\left(\frac{1+2d^2}{\pi+2d^2}\right) < 1$.

In other words, C observes that L bears a higher cost, and, if π is sufficiently high, C is going to contribute more than L even though $\Delta_C < \Delta_L$.[13]

This result is in contrast with the outcome of the sequential game, where the leader always contributes more than the follower.

6 Conclusions

The simple model we have developed has several implications for framing a European immigration policy.

The main insight of this paper is that Central governments and Local governments contribute to fund immigration control only if their objectives are not too different. Therefore, the real root of the coordination problem lies in the heterogeneity of national immigration targets rather than in imperfect information. This is even more worrying because it means that improving information will *not* make cooperation easier.

On the other hand we notice that, once joint contribution is achieved, the Central government compensates to some extent the possible lack of resources

[13] This outcome is consistent with the comparative statics results presented in the previous section, where we have showed that when both contributions are positive $\frac{\partial \tilde{g}_C}{\partial \pi} > 0$ and $\frac{\partial \tilde{g}_L}{\partial \pi} < 0$.

of the Local government. This holds for both a simultaneous and a sequential framework.

Another important result is that total contribution is higher when decisions are simultaneous but, unlike Varian (1994), achieving joint contribution is easier in the sequential game.

It follows that, if the federation members are heterogeneous and the most urgent issue is to avoid free riding, sequential decisions should be preferred at the cost of a smaller total contribution. The latter case seems closer to the current situation of the EU, thus a sequential budget process seems a promising option to implement in some measure article no. 80 of the Lisbon Treaty in the wait for a full-fledged European immigration authority.

In addition, it is interesting to note that in the sequential game the leader contributes more than the follower, whereas in the simultaneous game C contributes more than L when the cost disadvantage of the latter is sufficiently high. Hence, in the sequential framework it is clearer who is going to put more resources in immigration control.

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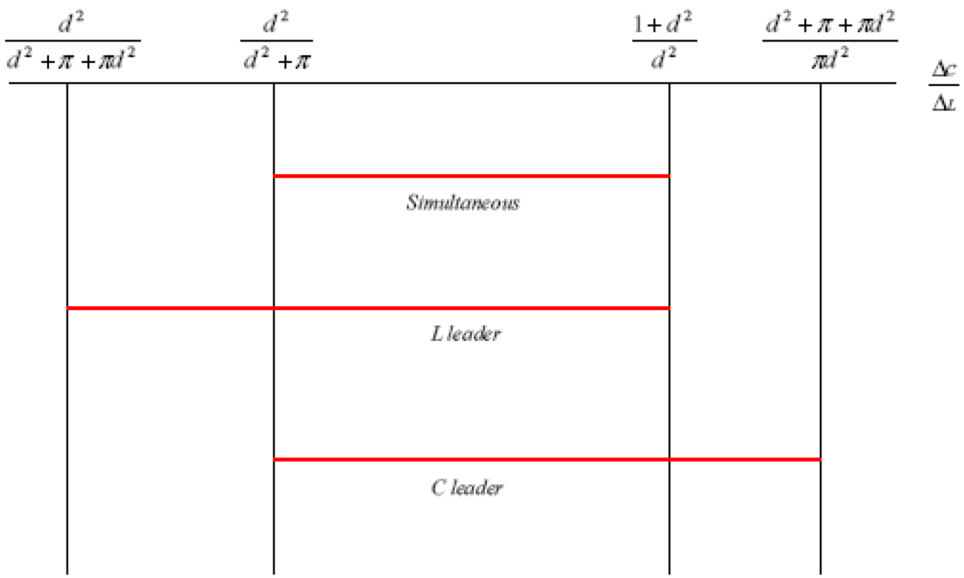

Figure 1: *positivity conditions for the equilibrium contributions*

7 Appendix

Proof of Proposition 1

In the simultaneous game both contributions are positive when

$$\frac{d^2}{\pi+d^2} < \frac{\Delta_C}{\Delta_L} < \frac{1+d^2}{d^2}. \tag{20}$$

In the sequential game when C is the leader both contributions are positive when

$$\frac{d^2}{\pi+d^2} < \frac{\Delta_C}{\Delta_L} < \frac{d^2+\pi+\pi d^2}{d^2} \tag{21}$$

since $\frac{1+d^2}{d^2} < \frac{d^2+\pi+\pi d^2}{d^2}$, it follows that the interval of $\frac{\Delta_C}{\Delta_L}$ under which both contributions are positive is wider in the sequential game.

In the sequential game when L is the leader both contributions are positive when

$$\frac{d^2}{d^2+\pi+\pi d^2} < \frac{\Delta_C}{\Delta_L} < \frac{1+d^2}{d^2} \tag{22}$$

since $\frac{d^2}{d^2+\pi+\pi d^2} < \frac{d^2}{\pi+d^2}$, it follows that the interval of $\frac{\Delta_C}{\Delta_L}$ under which both contributions are positive is wider in the sequential game.

Proof of Proposition 2

We want to prove that total contribution in the simultaneous framework ($\tilde{g}_C + \tilde{g}_L$) dominates total contribution in the sequential framework ($g_C^* + g_L^*$ and $g_C^{**} + g_L^{**}$). Thus, we have to verify that

$$\underbrace{\frac{d(\pi\Delta_C+\Delta_L)}{\pi+d^2+\pi d^2}}_{\text{simultaneous}} > \underbrace{\frac{d(\pi^2\Delta_C+\Delta_L(\pi+d^2))}{\pi^2 d^2+(\pi+d^2)^2}}_{\text{sequential, } C \text{ leader}} \tag{23}$$

Condition (23) boils down to

$$\frac{\Delta_C}{\Delta_L} > \frac{d^2}{\pi+d^2}.$$

When L is the leader we have.

$$\underbrace{\frac{d(\pi\Delta_C+\Delta_L)}{\pi+d^2+\pi d^2}}_{\text{simultaneous}} > \underbrace{\frac{d\Delta_C(\pi+\pi d^2)+d\Delta_L}{d^2+\pi(1+d^2)^2}}_{\text{sequential, } L \text{ leader}} \tag{24}$$

which boils down to

$$\frac{\Delta_C}{\Delta_L} < \frac{1+d^2}{d^2}.$$

we conclude that total contribution in the simultaneous framework dominates total contribution in the sequential framework when $\frac{\Delta_C}{\Delta_L} > \frac{d^2}{\pi + d^2}$ (C leader) and $\frac{\Delta_C}{\Delta_L} < \frac{1+d^2}{d^2}$ (L leader). However, these conditions coincide with the values of $\frac{\Delta_C}{\Delta_L}$ assuring the positivity of both contributions in the simultaneous framework. Thus we conclude that when both contributions are positive, total contribution in the simultaneous game dominates total contribution in the sequential game.

Proof of Proposition 3

We want to prove that the leader contributes more than the follower. When C is the leader, the condition is $g_C^* \geq g_L^*$, i.e.

$$\frac{\Delta_C(\pi + d^2)\pi d - \pi d^3 \Delta_L}{\pi^2 d^2 + (\pi + d^2)^2} \geq \frac{\Delta_L(\pi + d^2 + \pi d^2)d - \pi d^3 \Delta_C}{\pi^2 d^2 + (\pi + d^2)^2} \tag{25}$$

by rearranging condition (25) we obtain

$$\frac{\Delta_C}{\Delta_L} \geq \frac{\pi + d^2 + 2\pi d^2}{\pi + 2\pi d^2}$$

since

$$\frac{d^2}{\pi + d^2} < \frac{\pi + d^2 + 2\pi d^2}{\pi + 2\pi d^2} < \frac{\pi d^2 + d^2 + \pi}{\pi d^2}$$

we conclude that, when both contributions are positive, $g_C^* > g_L^*$.

When L is the leader, we have to check that $g_L^{**} \geq g_C^{**}$, i.e.

$$\frac{\Delta_L(1 + d^2)d - d^3 \Delta_C}{d^2 + \pi(1 + d^2)^2} \geq \frac{\Delta_C(d^2 + \pi + \pi d^2)d - d^3 \Delta_L}{d^2 + \pi(1 + d^2)^2}. \tag{26}$$

By rearranging condition (26) we obtain

$$\frac{\Delta_C}{\Delta_L} \leq \frac{1 + 2d^2}{\pi + \pi d^2 + 2d^2};$$

since

$$\frac{d^2}{d^2 + \pi + \pi d^2} < \frac{1 + 2d^2}{\pi + \pi d^2 + 2d^2} < \frac{1 + d^2}{d^2}$$

we conclude that, when both contributions are positive, $g_L^{**} > g_C^{**}$.

Proof of Proposition 4

To compare the individual contributions in the simultaneous game, we simply have to set $\tilde{g}_C \geq \tilde{g}_L$, i.e.

$$\frac{\Delta_C(\pi + d^2)d - d^3 \Delta_L}{d^2 + \pi + \pi d^2} \geq \frac{\Delta_L(1 + d^2)d - d^3 \Delta_C}{d^2 + \pi + \pi d^2}. \tag{27}$$

By rearranging condition (27) we obtain

$$\frac{\Delta_C}{\Delta_L} \geq \frac{\pi + 2d^2}{1 + 2d^2}.$$

The effect of π

$$\frac{\partial \tilde{g}_C}{\partial \pi} = \frac{d\Delta_C(d^2 + \pi + \pi d^2) - (1 + d^2)(\Delta_C(\pi + d^2)d - d^3\Delta_L)}{(d^2 + \pi + \pi d^2)^2}$$

$$\frac{\partial \tilde{g}_L}{\partial \pi} = \frac{d^5\Delta_C(d^2 + 2\pi) + 2d^3\pi\Delta_L(\pi d^2 + \pi + d^2)}{(d^2 + \pi + \pi d^2)^2}$$

proof that $\frac{\partial g_C^*}{\partial \pi} < 0:$

$$\frac{\partial g_L^*}{\partial \pi} < 0 \qquad \text{for} \qquad \frac{\Delta_C}{\Delta_L} \leq \frac{(\pi + d^2 + \pi d^2)^2 - d^6}{\pi^2 d^2(1 + d^2) - d^6}$$

but for both contributions to be positive we need $\frac{\Delta_C}{\Delta_L} \leq \frac{(\pi + d^2 + \pi d^2)}{\pi d^2}$. Since

$$\frac{(\pi + d^2 + \pi d^2)}{\pi d^2} < \frac{(\pi + d^2 + \pi d^2)^2 - d^6}{\pi^2 d^2(1 + d^2) - d^6}$$

we conclude that $\frac{\partial g_C^*}{\partial \pi} < 0$ when both contributions are positive.