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COLLECTIVE ENTRY DETERRENCE AND FREE RIDING: AIRBUS AND BOEING IN CHINA

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Abstract

We propose a simple two-stages duopoly game where two firms produce an homogeneous good to satisfy the demand in a foreign market. First they decide whether to serve this market with exports or with foreign direct investments and then they play a one-shot Cournot-Nash game. This game has been made even more complex by the fact that foreign direct investments induce technological spillovers which imply the possible entry of a third firm. From the complete characterization of the equilibria we show that a small disadvantage of one of the both firms can conduce this firm to invest alone in the foreign country rather than export. In this case, the investment is motivated by the fact that the dissipation risk of both firm-specific assets to a local potential entrant -triopoly payoffs- is beared by the two firms whereas the gain -increased market share in duopoly- is captured by the firm which chooses to invest abroad. We have in mind the competition between Airbus and Boeing in China.

Keywords: Entry Deterrence; FDI; Export; Cournot duopoly; Spillovers; Airbus and Boeing

1 Introduction

1.1 Airbus and Boeing in China

China is the world's second largest national air travel market. According to projections (Cliff, Ohland and Yang, 2011), Chinese airlines will purchase roughly 4,000 new aircrafts over the next twenty years. Since this demand cannot be satisfied by indigenous aircrafts manufacturers, this makes China an important battleground for Boeing and Airbus. Until quite recently, the two companies had rather different "China" strategies period Airbus decided to open two Chinese factories in Tianjin arguing that : "[l]ocalization is a foundation of Airbus's strategy to dislodge Boeing as the market leader in China. The US company came here 13 years ahead of Airbus and has a 64% market share [1] [...] the Toulouse-based firm wants to control 50% of the market by 2013 [2]". By contrast, the president of Boeing China declared: "We have no plans to set up an assembly line at this time." China makes no secret of its desire to create a domestic aerospace industry which would eventually challenge the joint dominance of Airbus and Boeing. Indeed China plans to build its first large commercial jet by 2020[3]. These plans would clearly be facilitated by the technological spillovers that local production by Airbus and Boeing might entail. Since such spillovers would eventually undermine Boeing and Airbus' joint dominance, one might wonder why one of the two companies choose to invest locally.

In this paper, we provide a simple theoretical model which is consistent with the facts above and helps explain why Airbus and Boeing made rather different choices in order to serve the China market. As we will discuss later, the predictions of our model are also in line

[1] In 1985, when Airbus moved into China, the market share was 6% from Airbus and 71% from Boeing. In 2013, Airbus' share was 49%. (http://bloga350.blogspot.fr/2013/09/airbus-allocates-5-of-a350-airframe-to.html)

[2] *China Economic Review,* Plane wars: Airbus vs. Boeing, April 2008.

[3] "It's only a matter of time before China catches up with U.S. and European plane makers because we have started the campaign," said Luo Zhenan, vice secretary general of the government-regulated China Aviation Industry Chamber of Commerce Boeing and Airbus battle for supremacy in China, *Herald Tribune*, February 28, 2007.

with Boeing' s recent announcement that it would set up a production line.[4]

To capture the Airbus/Boeing situation, we introduce technological spillovers in a standard duopoly model with entry. Boeing and Airbus are the established firms and there is a potential Chinese entrant. These spillovers run from the more to the less efficient firms and their magnitude depends on the mode of entry chosen. Our main assumption is that technological spillovers are larger if a firm serves the Chinese market through foreign direct investment (henceforth FDI) rather than through exports. This makes sense since reverse engineering is feasible under both modes of operation but FDI also opens up other spillover channels such as movement of personnel between local producers. To keep matters simple, we set the spillovers associated with exports equal to zero. Incentives for FDI comes from the lower costs of producing in China.

In this set up, both Boeing and Airbus face a trade-off between taking advantage of lower production costs by investing in China and avoiding the creation of an efficient Chinese rival by exporting and hence limiting technological leakage. If Boeing and Airbus have similarly effective technologies and face identical cost conditions in their respective home country, then we show that the only possible equilibria have either both firms export or both firms invest. Moreover, the two firms have an excessive tendency to invest compared to the decisions that would maximise their joint profits. This stems from a free riding issue between Boeing and Airbus: while both firms would benefit from keeping the Chinese rival out of the market, each firm chooses its mode of entry into China based on its own profits and therefore neglects the negative effect that investing in China and therefore leaking technological know-how to the local competitor has on the the other firm.

Three types of asymmetries can account for the observation that - initially at least - only one of the two foreign companies chose to invest. Most simply - and least interestingly - one firm might have lower home costs than the other, making investing in China less

[4] "Boeing, Comac and the government of Zhenjiang province signed a framework agreement October 28,2016 to establish the operation at Zhoushan, China." (http://aviationweek.com/zhuhai-2016/chinese-completion-center-helps-boeing-boost-737-rate)

attractive. Also predictably, the foreign firm with the best technology - and hence with the more damageable spillovers if it invests - might prefer to export even if its rival invests. However, contrary to what one might expect, this type of asymmetry can only lead to an asymmetric outcome if technological differences between the two foreign firms are sufficiently large. Finally, a firm with a large market share suffers more from the decrease in equilibrium price that the creation of a third firm involves than a firm with a smaller market share. In this sense, one would expect that there can be situations where the smaller firm invests but the larger one does not. This is the mechanism that we emphasize as it seems to fit the Boeing-Airbus situation well. Here too, we will see that asymmetric equilibria can only arise if market shares are sufficiently asymmetric.

1.2 Related literature.

Our paper is related to two main strands of the economic literature: the international trade literature on the choice of the mode of entry into foreign markets and the industrial organization literature on collective entry deterrence.

An abundant literature deals with the determinants of FDI (Faeth, 2009, for a detailed survey) and especially examines the choice between export and FDI (Horst, 1971; Hirsh, 1976). In a multisector and multicountry model in which heterogeneous firms face a proximity-concentration trade-off [5], Helpman, Melitz and Yeaple (2004) show that only the most productive firms can engage in FDI and cover the sunk cost of this investment. A lot of articles confirm that multinational companies (henceforth MNCs) are more productive than their domestic competitors (Blomström and Sjöholm, 1999; Yeaple, 2009, among others).

However strategic behaviors in oligopolistic market may change this result by introducing multiple motivations to invest abroad. In this strategic environment many countries remove their barriers to FDI and actively encourage investment by foreign MNCs. One of the

[5] The proximity-concentration hypothesis is first developed by Horstmann and Markusen (1992) for homogeneous goods and by Brainard (1993) for differentiated products. Multinational companies were more likely to invest abroad, the larger the host market was.

reasons of this policy comes from the fact that FDI generates spillovers which benefit the host economy (Blomström and Kokko, 1998; Markusen, 1995). Comparative static between exporting to the host country and market servicing from a production unit located in the host country will necessary take into account the *dissipation effect* (i.e. the leaks of the MNC's technology). The MNC seeks to reduce the cost of providing foreign market (*efficiency seeking*[6]) or it wants to improve access to this foreign market (*market seeking*) even if this entails the dissipation of its firm-specific asset to its rival. In some cases, more surprisingly it is the low-productivity firms that engage in FDI in order to source or seek foreign knowledge (Siotis, 1999; Fosfuri and Motta, 1999). In this case, the MNC try to reduce its gap by investing abroad and acquire new technology or know-how (Chung and Alcacer, 2002).

What distinguishes our contribution from previous papers on the mode of international entry is its focus on how technological spillovers linked to FDI affects both the firm that chooses the mode of entry and its international rival. In our framework, both Boeing and Airbus would rather avoid promoting the entry of a local competitor. However, such entry can still arise in equilibrium because their individual incentives to keep the local company at bay do not coincide with their joint incentives to do so. In other words, there is a potential free rider problem in deterring spill-over-based entry by the local firm.

This free riding issue has been analysed in a number of papers. Gilbert and Vives (1986) consider a situation where a symmetric oligopoly can prevent a potential entrant from entering if they jointly produce a critical level of output that exceeds the total output at the Cournot-Nash equilibrium. Each firm still chooses its own output non-cooperatively. They show that, contrary to what intuition might suggest, there is no free rider effect in entry deterrence: Every equilibrium where entry is not deterred yields higher incumbent profits than entry deterrence and there can be entry deterrence even if the resulting incumbent profits

[6] Dunning (1993) describes four motivations to invest abroad: market-seeking, resource-seeking, efficiency-seeking and strategic asset seeking

would be higher without it. The reason for this counter-intuitive results is that, in their model, entry deterrence is obtained through output expansion. This means that, conditional on entry being deterred, i.e. conditional on the critical deterring total output being reached, each incumbent wants to participate in entry deterrence since producing more simply ensures a greater share of the industry profits. This ensures that free riding does not arise in equilibrium. Bernheim (1984) reaches a similar conclusion for a situation where there are many potential entrants and entry is sequential.

Waldman (1987) shows that the absence of free riding in equilibrium can be sensitive to the introduction of uncertainty. Once the total amount of output required to deter entry is uncertain, free riding in entry deterrence re-emerges in the Bernheim model but not in the Gilbert and Vives framework. The entry-deterrence mechanism involved in our model differs markedly from the type of entry deterrence analysed in this literature. In the papers referenced above, entry deterrence is achieved by expanding output beyond the Cournot-Nash level. In our set up entry deterrence involves unilaterally choosing a less efficient entry route in order to limit the technological spillovers that would facilitate entry. Contrary to Gilbert and Vives (1985), then, a firm considering whether or not to take part in entry deterrence does face a simple trade-off between helping deter entry and incurring higher costs, i.e. the action required to deter entry remain costly to the firm even conditional on entry deterrence being achieved.

1.3 Plan of the Article.

The rest of this paper is organized as follows. Our formal model is presented in Section 2. The equilibria of the game when the foreign incumbents are identical is then discussed in Section 3. We see that there is an excessive tendency for the foreign firms to choose FDI compared to the choices of entry route that would maximize their own profits. However, a situation where one firm invests and the other exports cannot arise in equilibrium. In

Section 4 we consider a situation where one of the two foreign firms has lower production costs and/or has a technology that would yield greater benefits to the entrant if it were leaked through FDI. We show that we can then obtain asymmetric equilibria where this more efficient/larger spillovers firm serves the market through exports while its rival chooses to invest. In particular, as in the Airbus-Boeing story, the firm with the larger local market share is less likely to set up a local production activity. Section 5 discusses the robustness of our results and concludes.

2 The Model

We consider a simple three-country partial-equilibrium model in which two independent firms located in different countries compete in a third market. Both firms have a production plant in their own country and they must decide whether to serve the third country with exports or with FDI. The equilibrium outcome of our model is determined in a two-stage game. In the first stage the managers of the two foreign firms decide simultaneously to produce output either in their domestic economies or abroad, *via* FDI. In the second stage, two (a and b) or three (a, b and h) firms play a one-shot Cournot-Nash game where moves are assumed to be simultaneous. To solve this model and find subgame perfect Nash equilibria, we proceed backwards in the usual fashion. First, we compute quantity-equilibrium candidates as functions of the manager's decisions. Second we compare profits in each case in order to determine the best choice of each manager.

2.1 Demand

We assume that each firm $i = a, b, h$ resides in one country, selling an homogeneous good q_i to the consumers located in a third country (henceforth called host country and denoted h). The local price in the host market is P and the demand function $D(P)$ is linear *i.e.* the inverse market demand is $P = \alpha - Q$. α represents the size of the host market and Q is the sum of the sales of the two firms.

2.2 Technological Spillovers

We assume that without spillovers Firm h's marginal cost is too high to have positive profit. If at least one firm decides to serve the host market through FDI, then there is a risk that a local competitor h might emerge. This set up implies that spillovers do not occur through reverse engineering because this channel could also be exported through exports. This raises the question of what type of spillover channel we are thinking of. We can think of two channels: forced licensing as a condition for FDI entry or spillovers through local managers/workers. For now, let us work with the second mechanism. We further simplify matters by assuming that the probability of technology leakage does not depend on the scale of operations in the foreign country. We can then assume that if firm i chooses the FDI route, then there is a probability $s \in [0, 1]$ that its technology leaks to a potential local entrant who can then be active in the market. Let us assume that, if there is leakage, it is complete *i.e.* the local firm gets the same technology-related parameter as the foreign one. We still need to make some assumptions as to what happens to leakage if both firms decide to go through the FDI route. Clearly the spillover must be at least as large as if either of the two foreign firms was the only one using the FDI route. Assuming that the probability of leakage from either firm is independent from the probability of leakage from the others, we have:

- with probability $s(1 - s)$ the local firm gets a technology parameter equal to $max(c_i)$,
- with probability $s^2 + s(1 - s) = s$ the local firm gets $min(c_i)$.

2.3 Production

Host market can have a duopoly or a triopoly structure that depends on the marginal costs of production. Firm i has the following cost function $\forall i = a, b, h, \;\; C(q_i) = (w_i + c_i)q_i$. w_i is the wage rate in the country of production and c_i is a technology-related marginal cost.

In order to keep matters as simple as possible, we do not introduce a non-recoverable set-up cost if Firm i decide to produce in the host country. In what follows we assume that Firm b is the more technologically advanced of the two firms ($c_b \leq c_a$). We must also address the issue of technological leakage between the two firms. In particular, if the spillover mechanism we are thinking of is indeed tied to the weak intellectual property enforcement and the labour market conditions in the host country, then we should also assume that Firm a gets to copy b's better technology if they both serve the foreign country through FDI. We will solve for two cases: one where technology only leaks to the local firm and one where it leaks to all firms that actually produce in the host market. We assume that firms compete in quantities.

$$\forall \{i, j, k\} = \{a, b, h\} \text{ and } i \neq j \neq k,\ \pi_i(q_i, q_j, q_k) = [P_i(q_i, q_j, q_k) - c_i - w_i]\, q_i \qquad (1)$$

One can assume without loss of generality that $w_a = w_b = \mu w$, where w is the wage in the host country and $\mu \geqslant 1$ and $c_a = \theta c_b = \theta c$ with $\theta \geqslant 1$. We define four possible cases.

- **Case ee** occurs if Firm a and Firm b export to the third market. In this case there is no uncertainty concerning the potential entrant because there is no technological spillovers and Firm i's profit is denoted π_i^{ee}.

- **Case fe** is the case in which Firm a chooses FDI whereas Firm b exports. By choosing FDI Firm a allows the entry of a local competitor at a marginal cost of production equal to $w + \theta c$ and with the probability s. In this case Firm i's expected profit is denoted $E[\pi_i^{fe}]$.

- **Case ef** occurs if Firm a exports whereas Firm b chooses FDI. As previously there is a probability s to have a triopoly competition with new entrant's marginal cost of production equal to $w + c$. In this case Firm i's expected profit is denoted $E[\pi_i^{ef}]$.

- **Case ff** corresponds to FDI from both firms. There is a $s(1 - s)$ probability of entry at a marginal cost of production equal to $w + \theta c$ and a s probability of entry at a marginal cost of production equal to $w + c$. In this case Firm i's expected profit is denoted $E[\pi_i^{ff}]$.

3 Benchmark: No Cost Asymmetries

In this section we assume that both firms face the same costs of production when they decide to export from their home market, i.e. $\theta = 1$. Under this assumption, there can never be an equilibrium where one firm chooses to export while the other opts for the FDI route. The intuition for this result is straightforward.

Let us first assume that Firm b chooses to export, would Firm a prefer to invest? For Firm a, the decision involves a trade-off between taking advantage of lower costs of production in the third market and taking the risk of creating a local competitor with probability s.

Suppose that Firm b maximizes its expected profits by investing. Is it then possible that its rival would still prefer to select an export strategy so that we have an asymmetric equilibrium configuration? Given that Firm b decides to invest, Firm a faces a trade-off that differs from Firm b' in two respects. Firstly, choosing FDI does increase the probability that a local competitor would emerge but this increase is smaller. For Firm b, the probability went from 0 to s, for Firm a, it goes from s to $s + s(1 - s)$ -a smaller increase-.

Secondly, moving into the third country also means that Firm a's technology could leak to Firm b since Firm a also has local operations. However, under our assumption that the two foreign firms have the same costs, this second effect is irrelevant leaving only the first effect. Overall then, Firm a faces a trade-off which is more favourable to FDI than Firm b did. Hence, if Firm b did indeed choose to invest, then Firm a would invest as well. We cannot have an equilibrium where one firm invests and the other does not. The only two equilibria are then one where both firms invest and one where both firms export, as shown in Figure 1 below.

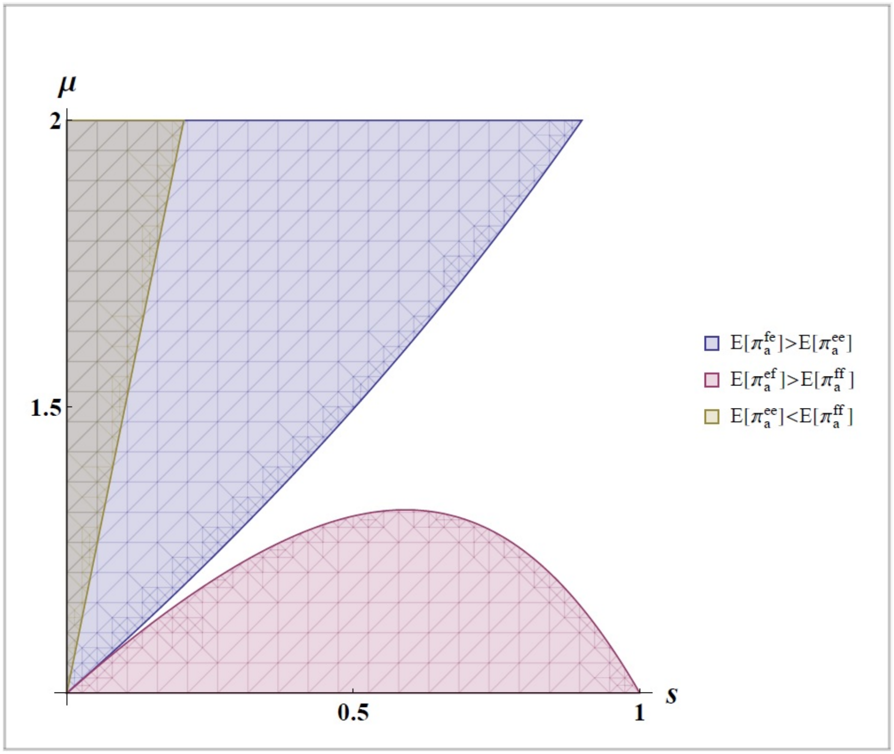

Figure 1: **Trade *versus* FDI with symmetric cost between Firm a and Firm b.** Numerical example in the space $(s;\mu)$ with $a = 5.85, w = 0.315, c = 1, \theta = 2, \rho = 1$.

There are three curves in Figure 1. The lowest of the three curves -the pink curve- represents the combination of local cost advantage and spillover risk that makes a foreign firm indifferent between export and investment, given that its rival has chosen to invest. This curve has a local maximum for intermediate values of the spillover risk. This is because, as the rival invests anyway, the additional risk of spillover entailed by the firm's own presence in the local market increases in s when the overall risk is low but then decreases in s when the overall risk is high. In other words if s is high enough that the rival's presence is already highly likely to create a third local competitor, then the additional spillover risk of also entering locally is low. The pink area below this curve shows the combinations $(s;\mu)$ of parameters for which $E[\pi_i^{ef}] \geq E[\pi_i^{ff}]$.

The other two curves are increasing over the whole range of s. The second curve -the blue one- shows the points of indifference between export and investment, given that the other firm invests. Its slope reflects the simple fact that, given that the other foreign firm sticks to exports, the risk of technological spillover linked to the firm's own decision to invest locally clearly keeps increasing with s. The highest curve -the brown curve- shows the parameter combinations for which the firms are equally well off if they both export or both invest. The positive slope comes from the fact that the risk of spillover associated with investment by both multinationals also keeps increasing as s increases, although the slope of this curve tends to zero as s tends to one. The highest curve shows the parameter combinations for which the firms are equally well off if they both export or both invest. The positive slope comes from the fact that the risk of spillover associated with investment by both multinationals also keeps increasing as s increases, although the slope of this curve tends to zero as s tends to one. The brown area implies that $E[\pi_i^{ee}] \leq E[\pi_i^{ff}]$.

Given these profits ranking we see that there is a region where the only equilibrium is for both firms to invest the blue and the brown areas- one region where both firms export -the pink area- and one region where either kind of equilibrium can arise -the white area-. For high values of home wages the equilibrium with investment maximizes the joint surplus of the multinationals. For lower values, however, we have a Prisoner's Dilemma: both firms invest even though they would both be better off if they could agree to both use the export route.

4 Asymmetric Equilibria

We now allow for differences between the technological abilities of the two foreign firms by assuming that the unit cost of Firm a is higher than the unit cost of firm b: $c_a = \theta c_b \overset{\text{def.}}{=} \theta c, \theta \geq 1$. It should not be surprising that the firm with the lowest cost would be more reluctant to invest than the firm with the higher cost. This is for two reasons. Firstly, spillovers from a low-cost firm would create a more efficient domestic rival than spillovers from a high cost firm. Secondly, the lower-cost firm has a larger market share and suffers disproportionately from the creation of a new competitor.

In order to distinguish between the two effects, we specify the spillovers from the two firms as follows.

- If Firm a invests then, with probability s, knowledge enabling production at a cost $c_a = \theta c$, leaks to the local firms.
- If Firm b invests then, again with probability s, knowledge enabling production at a cost ρc (with $\rho \in [1, \theta]$) leaks out to the local firms.

So, for $\rho = 1$, both "spillover" and "market-share" effects arise, while for $\rho = \theta$, the only source of asymmetry between the both firms is their different market shares. Finally, because Firm a and Firm b have different costs, there are now spillovers from the low cost foreign firm to the high cost foreign firm if both firms choose to invest in the target country. This makes it less attractive for the low-cost firm to invest as this gives its higher cost rival an opportunity to "catch up".

The equilibrium profits for each of the possible subgames are derived in the appendix. The results are summarized in Figure 2 and Figure 3.

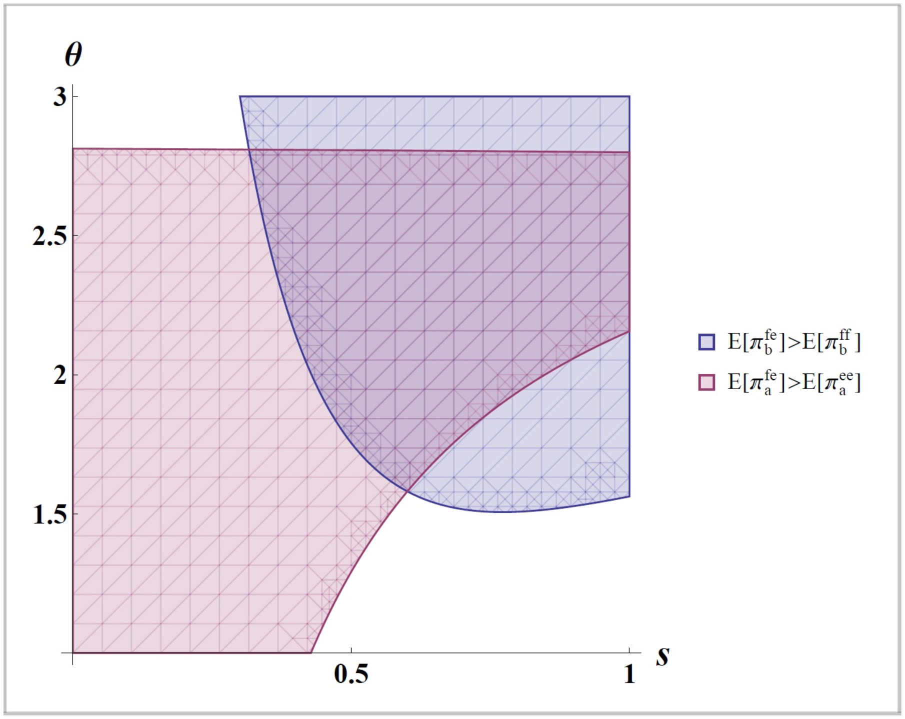

Figure 2: **Asymmetric Equilibria with both"spillover" and "market-share" effects.** Numerical example in the space $(s; \theta)$ with $\alpha = 2, w = 0.15, c = 0.4, \theta = 2, \rho = 1$.

Figure 2 is drawn for $\rho = 1$ so that all of the effects discussed above are present. We have the likelihood of technological spillover on the horizontal axis (s) and the ratio between the costs of the high and low-cost firms on the vertical axis (θ). There is of course a maximum value for the cost difference beyond which the high-cost firm would not be able to operate profitably. The pink zone shows the combinations of parameters for which the low-cost firm prefers export to investment, even though its rival chose to have a local present. The blue area is where the low cost firm prefers to invest, even though the other firm exports. Hence the intersection of the two areas show where an asymmetric equilibrium occurs. The graphs confirm our previous argument: we can only have an asymmetric equilibrium if the cost difference between the two firms is significant enough. Not surprisingly, for a given cost difference between the two firms, Firm b is less willing to invest if spillovers are high. For a given level of spillovers, Firm b is readier to export if the cost difference is high: given that it has a substantial technological advantage, benefiting from the lower local cost of production becomes less important. Turning to Firm a's decision, investment is more likely when Firm a is less efficient because, for the two reasons discussed above. Firstly, for a given probability of leakage, the effective spillover is less important if Firm a's own technology is not very efficient. Secondly, a higher cost for Firm a means a lower market share and hence less exposure to increased competition from Firm h entry.

The next figure is drawn for $\rho = \theta$. We see that, although the size of the area for which asymmetric equilibria arise is now reduced, differences in market shares can by themselves explain why the smaller of the two firms would prefer to invest, while the larger one would prefer to serve the market through exports.

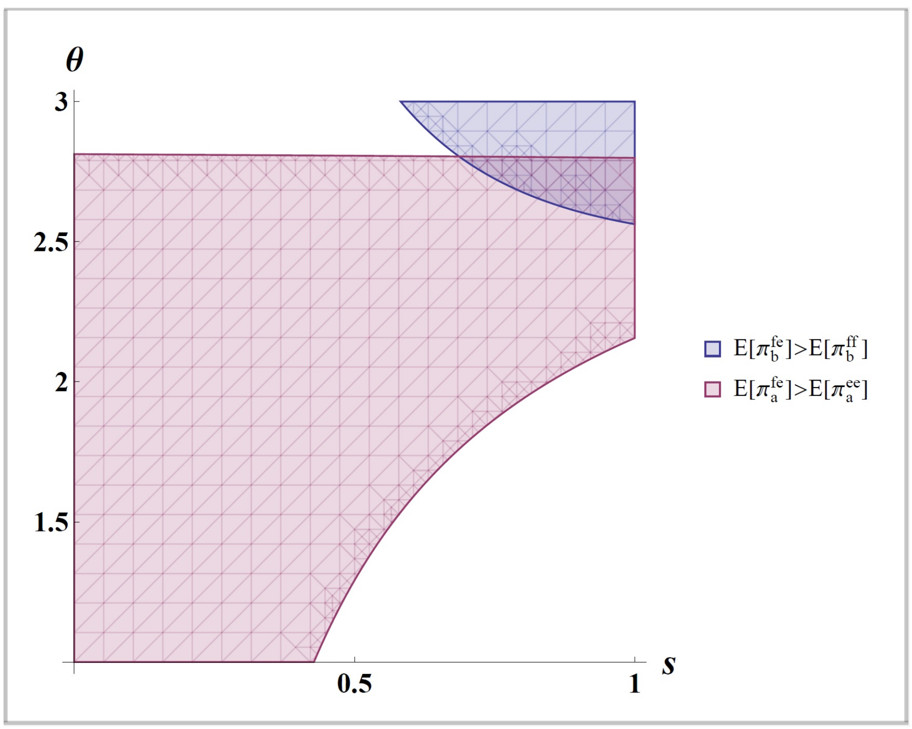

Figure 3: **Asymmetric Equilibria only with the "market-share" effect.** Numerical example in the space $(s;\theta)$ with $\alpha = 2, w = 0.15, c = 0.4, \theta = 2, \rho = 2$.

5 Conclusion

We have examined the role of local technological spillovers in explaining the choice of foreign entry mode by two firms which only differ in their relative production efficiency. Two firms must choose between serving the same market with exports or direct foreign investment. The firms face the same additional variable costs if they produce at home rather than take advantage of cheaper local conditions. However, the direct investment route entails a risk of losing technological knowledge to a potential local entrant. We have shown that, even though the two multinationals face the same cost disadvantage from home production they might choose different entry modes in equilibrium. In particular, the more efficient of the two foreign firms has lower incentives to choose direct foreign investment. This is both because it has more to lose as it is technologically more advanced and because local entry following the loss of technological exclusivity affects the firm with the larger market share more than its smaller rival. This mechanism is consistent with the observed choices of Boeing and Airbus in China. Starting with a larger market share Boeing adopted an export-only policy, in contrast to Airbus's decision to invest in two local plans. It is only recently, now that market shares are roughly equal, that Boeing has announced plan to invest in the Chinese market as well.

The main mechanism at play is free-riding. By investing, a firm increases the probability of creating a local rival but does not consider the effects of such entry on the other multinational. This "omission" is larger for the smaller firm. Since it internalizes a smaller proportion of the total cost of creating a rival for both multinationals, the smaller firm is more eager to invest, making an equilibrium where one firm invests and the other exports possible. It is worth noting that, in our framework, the firms do free-ride on the "investments" required to jointly deter entry: they tend to invest too readily. This is in contrast to much of the literature on collective entry deterrence, where free-riding does not necessarily arises. The reason for this difference is that, in our framework, entry deterrence involves a costlier mode of entry and hence is always costly. In the previous literature, entry is deterred by over-producing,but overproducing can have the strategic advantage of credibly grabbing market-share from the rivals, which can be profitable on its own. Clearly if entry-deterrence is unilaterally profitable, then it occurs in equilibrium.

In our model, the reason for investing abroad comes from the lower cost of local operations. This is only one possible example. The incentives to invest could equally well come from tariff barriers, subsidies or, more generally, that foreign firms are "encouraged" to have a local presence either on their own or by setting up joint ventures with home companies. Indeed, the concerns about technological leakages, which provide the other side of our trade-off between FDI and export, would seem to be particularly acute in this latter situation. Our main conclusions about the link between market-share asymmetries and differences in the choice of entry route would apply to any of these situations as well.

Interestingly though, our analysis also has implications for how home governments eager to attract spillover-generating firms should proceed. As we discussed in Section 3, firm's incentives to invest are larger once the other firm has already decided to choose foreign investment over exports. Accordingly, a local government could entice both firms to move in sequentially by first offering incentives (*e.g.* tax-holidays, infrastructures, subsidies) to the first mover. Once the first firm has been attracted, the second firm can then be attracted by offering a lesser incentive package.

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7 Appendix

7.1 Subgame Equilibria

The two firms compete in Cournot fashion and set non-negative quantity to maximize profits, taking the other firms' quantities as constants. If both firms choose export there is no spillovers *i.e.* no potential entrant in the host country ($q_h = 0$). Firm i' s reaction function $R_i^l(q_j, q_k)$ in Case l where $l \in \{ee, fe, ef, ff\}$ are given by

$$R_i^l(q_j^l, q_k^l) \overset{\text{def.}}{=} \arg\max_{q_i \geqslant 0} \pi_i^l(q_i^l, q_j^l, q_k^l). \tag{2}$$

From Eq.(2) it is straightforward to obtain the following Cournot-Nash equilibria (hereafter distinguished by asterisks) in each case described above. If both firms choose the exports then there is no leakage of technology and only one equilibrium emerges:

$$(q_a^{ee*}, q_b^{ee*}) = \left(\frac{c(1-2\theta)+\Omega_0}{3}, \frac{c(\theta-2)+\Omega_0}{3} \right) \tag{3}$$

where $\Omega_0 = \alpha - \mu w$. If only Firm a decides to invest abroad then with probability s (resp. $(1-s)$) there is (resp. no) leakage of technology and hence (resp. no) emergence of a domestic rival in market h. The corresponding possible production equilibria are:

$$\left(q_a^{fe*}, q_b^{fe*}\right) = \begin{cases} \left(\dfrac{c(1-2\theta)+\Omega_1}{3}, \dfrac{c(\theta-2)+\Omega_1}{3} \right) & \text{with the prob. } (1-s) \quad \text{(4a)} \\ \left(\dfrac{c(1-2\theta)+\Omega_1}{4}, \dfrac{c(2\theta-3)+\Omega_2}{4} \right) & \text{with the prob. } s \quad \text{(4b)} \end{cases}$$

where $\Omega_1 = \alpha - (2\mu - 1)w$ and $\Omega_2 = \alpha - (3\mu - 2)w$. We can see that the only difference between Eq.(3) and Eq.(4a) is the wages: Firm a obtains lower wages without a new local competitor enters.

By considering that only Firm b invest abroad the output equilibria are:

$$\left(q_a^{ef*}, q_b^{ef*}\right) = \begin{cases} \left(\dfrac{c(1-2\theta)+\Omega_1}{3}, \dfrac{c(\theta-2)+\Omega_3}{3}\right) & \text{with the prob. } 1-s \quad \text{(5a)} \\ \left(\dfrac{c(1-3\theta+\rho)+\Omega_2}{4}, \dfrac{c(\theta+\rho-3)+\Omega_3}{4}\right) & \text{with the prob. } s \quad \text{(5b)} \end{cases}$$

where $\Omega_3 = \alpha + (\mu - 2)w$.

Finally if both firms invest abroad we have

$$\left(q_a^{ff*}, q_b^{ff*}\right) = \begin{cases} \left(\dfrac{c(1-2\theta)+\Omega}{3}, \dfrac{c(\theta-2)+\Omega}{3}\right) & \text{with the prob. } (1-s)^2 \quad \text{(6a)} \\ \left(\dfrac{c(1-2\theta)+\Omega}{4}, \dfrac{c(2\theta-3)+\Omega}{4}\right) & \text{with the prob. } s(1-s) \quad \text{(6b)} \\ \left(\dfrac{c(1-3\theta+\rho)+\Omega}{4}, \dfrac{c(\theta+\rho-3)+\Omega}{4}\right) & \text{with the prob. } s \quad \text{(6c)} \end{cases}$$

where $\Omega = \alpha - w$.

7.2 Expected Profits

We can therefore compute the following expected profits $E[\pi_i^{l*}]$ of firm i at the time of choosing their mode of entry (l) into the foreign market:

$$E[\pi_a^{l*}] = \begin{cases} \left(\dfrac{c(1-2\theta)+\Omega_0}{3}\right)^2 & \text{if } l = ee \\ (1-s)\left(\dfrac{c(1-2\theta)+\Omega_2}{3}\right)^2 + s\left(\dfrac{c(1-2\theta)+\Omega_2}{4}\right)^2 & \text{if } l = fe \\ (1-s)\left(\dfrac{c(1-2\theta)+\Omega_2}{3}\right)^2 + s\left(\dfrac{c(-3\theta+\rho+1)+\Omega_2}{4}\right)^2 & \text{if } l = ef \\ s(1-s)\left(\dfrac{c(1-2\theta)+\Omega}{4}\right)^2 + (1-s)^2\left(\dfrac{c(1-2\theta)+\Omega}{3}\right)^2 + s\left(\dfrac{c(1-3\theta+\rho)+\Omega}{4}\right)^2 & \text{if } l = ff \end{cases}$$

and

$$E[\pi_b^{l*}] = \begin{cases} \left(\frac{c(\theta-2)+\Omega_0}{3}\right)^2 & \text{if } l = ee \\ (1-s)\left(\frac{c(\theta-2)+\Omega_1}{3}\right)^2 + s\left(\frac{c(2\theta-3)+\Omega_2}{4}\right)^2 & \text{if } l = fe \\ (1-s)\left(\frac{c(\theta-2)+\Omega_3}{3}\right)^2 + s\left(\frac{c(\theta+\rho-3)+\Omega_3}{4}\right)^2 & \text{if } l = ef \\ s(1-s)\left(\frac{c(2\theta-3)+\Omega}{4}\right)^2 + (1-s)^2\left(\frac{c(\theta-2)+\Omega}{3}\right)^2 + s\left(\frac{c(\theta+\rho-3)+\Omega}{4}\right)^2 & \text{if } l = ff\ . \end{cases}$$

7.3 Conditions for an Asymmetric Equilibrium

We now seek to rank the payoffs (the expected profits) in order to identify asymmetric firms' strategies. For this we define four levels of $s/\forall\{i,j\} = \{a,b\}$,

- s_i is the level of spillover for which Firm i is indifferent between exporting and investing abroad if its competitor exports and
- s_{ii} is the level of spillover for which Firm i is indifferent between exporting and investing abroad if its competitor invests.

Figure (4) below illustrates all these payoffs.

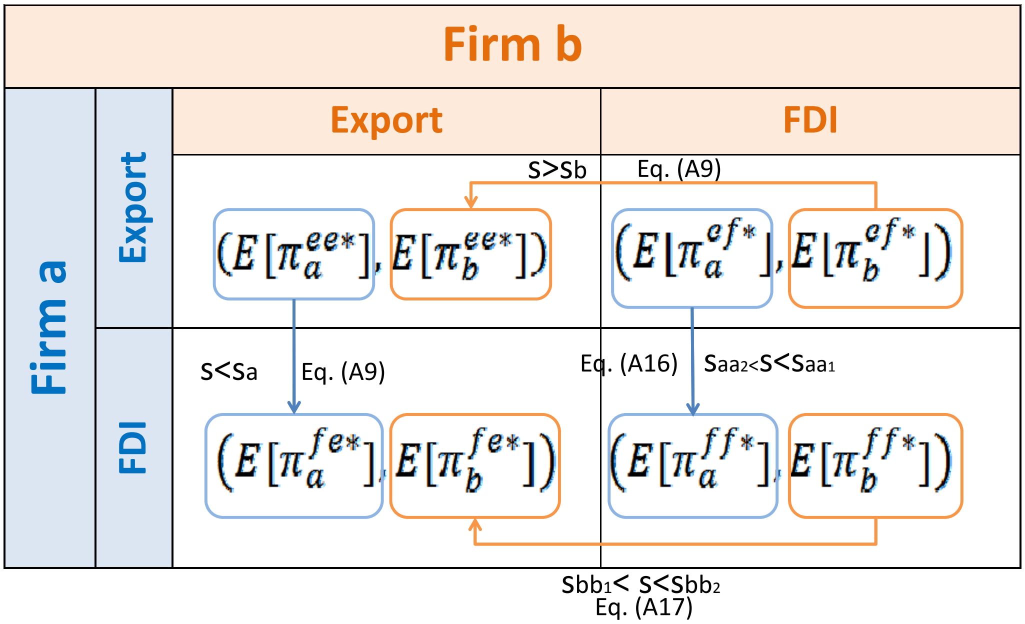

Figure 4: **Payoffs Matrix**: there are four possible configurations and the case in which Firm a invests abroad whereas Firm b exports implies that $s_a < s < s_b$, $s_{bb_1} < s < s_{bb_2}$

7.4 Exporting or Investing Abroad if the Competitor Exports (s_i)

$\forall \{i, j\} = \{a, b\}$ and $i \neq j$, if firm j exports then firm i invests abroad iff

$$s < s_i \stackrel{\text{def.}}{=} \frac{64}{7}(\mu - 1)w\frac{\Phi_i - w}{[\Phi_i + w(\mu - 2)]^2} \tag{9}$$

where $\Phi_a = \alpha + c(1 - 2\theta)$ and $\Phi_b = \alpha + c(\theta - 2)$. This condition makes sense; if $\mu = 1$ then $s_i = 0$: there is no wage advantage in entering the home country, so neither Firm a nor Firm

b invests. One also gets from Eq. (10)

$$\frac{\partial s_i}{\partial \mu} = \frac{64}{7}(\mu - 1)w\frac{(\Phi_i - w)(\Phi_i - w\mu)}{[\Phi_i + w(\mu - 2)]^3} > 0 \tag{10}$$

so that the propensity to invest does increase with the wage advantage of the home country.

$$\frac{\partial s_a}{\partial \theta} = \frac{128}{7}(\mu - 1)wc\frac{\Phi_a - w\mu}{[\Phi_a + w(\mu - 2)]^3} > 0 \tag{11}$$

$$\frac{\partial s_b}{\partial \theta} = -\frac{64}{7}(\mu - 1)wc\frac{\Phi_b - w\mu}{[\Phi_b + w(\mu - 2)]^3} < 0 \tag{12}$$

Firm a is more likely to invest if its cost disadvantage with respect to Firm b is large. Intuitively, when the difference is large, b has a large market share and it is not costly for a to take the risk of creating a new competitor especially one with its own high costs. Inversely b is less likely to invest if its cost advantage with respect to a is large. If the difference is large, b faces little competition from a (so b has a large market share). This makes it very costly for b to take the risk of creating a new competitor (especially one with its own low costs). By calculating the partial derivative of s_i from Eq. (10) with respect to Φ_i we obtain

$$\frac{\partial s_i}{\partial \Phi_i} = s_i\left(\frac{1}{\Phi_i - w} - \frac{2}{\Phi_i + w(\mu - 2)}\right) \leqslant 0 \text{ because } \mu \geqslant 1. \tag{13}$$

Then, $s_b \leqslant s_a$ because $\Phi_b \geqslant \Phi_a$. Firm a, the high cost firm, has a greater propensity to invest than the low cost firm (Firm b).

7.4.1 Exporting or Investing Abroad if the Competitor Invests

Given that Firm a invests, Firm b invests iff

$$E[\pi_b^{ff*}] - E[\pi_b^{fe*}] = s^2\psi_1 + s\psi_2 + \psi_3 < 0 \tag{14}$$

with

$\psi_1 \stackrel{\text{def.}}{=} \left(\frac{1}{9}(w-\phi_b)^2 - \frac{1}{16}(w-\phi_{bh})^2\right),$

$\psi_2 \stackrel{\text{def.}}{=} \left(\frac{1}{9}(-2\mu w+w+\phi_b)^2 - \frac{1}{16}((2-3\mu)w+\phi_{bh})^2 - \frac{23}{144}(w-\phi_b)^2 + \frac{1}{16}(w-\phi_{bh})^2\right)$

$\psi_3 \stackrel{\text{def.}}{=} \frac{1}{9}(-2\mu w+w+\phi_b)^2 + \frac{1}{9}(w-\phi_b)^2,$

where $\Phi_{bh} = \alpha + c\,(2\theta - 3)$. Since the coefficient of the square s term is positive, then the inequality can only be satisfied if s lies between the two roots of the equation.

Similarly, given that Firm b invests, Firm a invests iff

$$E[\pi_a^{ef*}] - E[\pi_a^{ff*}] = -s^2\gamma_1 + s\gamma_2 + \gamma_3 < 0 \tag{15}$$

with

$\gamma_1 \stackrel{\text{def.}}{=} \frac{7}{144}(w-\phi_a)^2,$

$\gamma_2 \stackrel{\text{def.}}{=} \left(-\frac{1}{9}(-2\mu w+w+\phi_a)^2 + \frac{1}{16}((2-3\mu)w+\phi_{ah})^2 + \frac{23}{144}(w-\phi_a)^2 - \frac{1}{16}(w-\phi_{ah})^2\right)$

$\gamma_3 \stackrel{\text{def.}}{=} \frac{1}{9}(-2\mu w+w+\phi_a)^2 - \frac{1}{9}(w-\phi_a)^2,$

where $\Phi_{ah} = \alpha + c\,(2 - 3\theta)$. This time the condition can only be satisfied for values of s that lie outside of the two roots of the equation. The roots of Eq.(15) and Eq.(14) are respectively

$$s_{\text{aa}} = \frac{\eta_a \pm \sqrt{\kappa_a + 1792(\mu-1)w(w-\phi_a)^2(\mu w-\phi_a)}}{14(w-\phi_a)^2} \tag{16}$$

$$s_{\text{bb}} = \frac{\eta_b \pm \sqrt{\kappa_b + 256(\mu-1)w(\mu w-\phi_b)(w-4\phi_b+3\phi_{bh})(7w-4\phi_b-3\phi_{bh})}}{2(7w-4\phi_b-3\phi_{bh})(w-4\phi_b+3\phi_{bh})} \tag{17}$$

with

$\eta_i = (\mu(17\mu-44)+34)w^2 + w((64\mu-78)\phi_i - 54(\mu-1)\phi_{ih}) + 7\phi_i^2$ and

$\kappa_i = ((\mu(17\mu-44)+34)w^2 + w((64\mu-78)\phi_i - 54(\mu-1)\phi_{ih}) + 7\phi_i^2)^2.$

7.4.2 Ranking the Payoffs

In order to rank the payoffs, we need to rank s_a, s_b, s_{aa} and s_{bb}. In the symmetric case, there is no cost advantage for Firm b ($i.e.$ $\theta = 1$) then $\phi_a = \phi_b = \phi_{ah} = \phi_{bh}$, $s_a = s_b$ and $s_{aa} = s_{bb}$. We already know that $s_b \leq s_a$. It seems also clear that we must have $s_{bb} \leq s_{aa}$ since, for b, investing given that a invests creates the risk of further lowering the costs of the home firm, while there is no such risk when a considers whether or not to invest when b is already in. Finally, it should also be true that $s_{aa} \geq s_a$: for a investment must be more attractive when it is not associated with the risk of creating a new competitor, especially since, with b already in there is not even the risk of lowering the competitor's costs. In principle, one would also believe that $s_b \leq s_{bb}$ since FDI comports a lesser risk in terms of creating or strengthening a competitor when firm a is also investing than when b goes in alone. With these conjectures only a few cases are possible:

- $s_b \leq s_{bb} \leq s_a \leq s_{aa}$
- $s_b \leq s_a \leq s_{bb} \leq s_{aa}$.

7.4.3 Nash Equilibria and Conditions for Asymmetric Behaviors

Figure 5 below represents the four functions s_i, s_{aa} and s_{bb} from Eqs(10, 16 and 17). These functions divide the $(s; \mu)$ space into six areas $(A1 - A6)$. $A1$ and $A2$ are areas in which both firms establish a plant in the foreign country. In these areas, they prefer FDI because wage gap (μ) between the foreign country and the domestic ones is large enough to consider the risk of dissipation of their technologies. Conversely, in Area $A4$ and Area $A5$ the firms prefer the exports. For high wage gap and spillovers there is a case (Area $A3$) in which two symmetric equilibria may occur (the cases ee and ff).

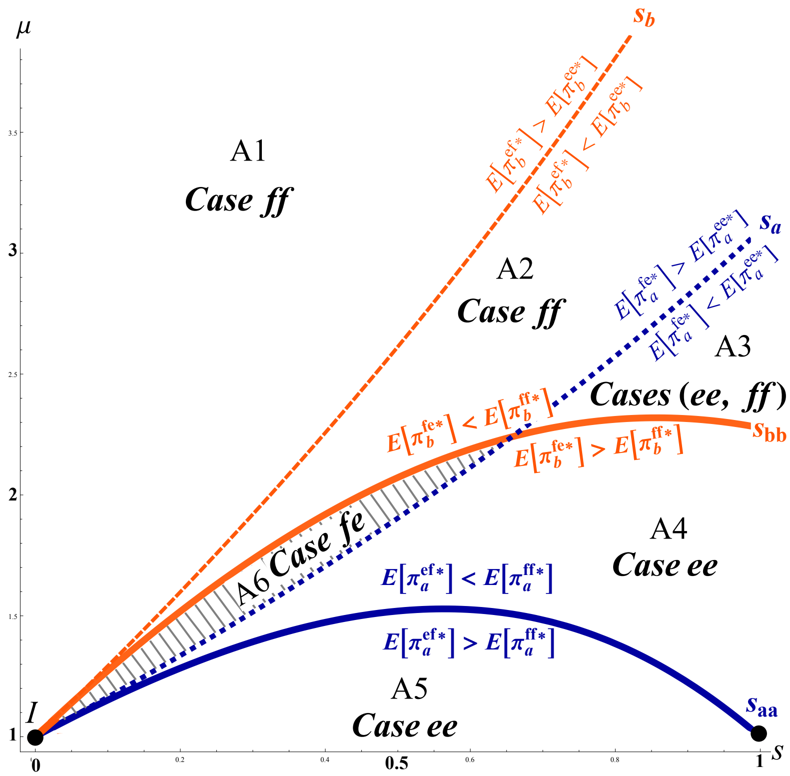

Figure 5: **Nash Equilibrium configurations in the space $(s;\mu)$ computed with $a = 8, w = 0.3, c = 1$ and $\theta = 2.15$.** Blue functions (s_a and s_{aa}) represent Firm a's indifference between exporting and investing abroad given that Firm b exports (dotted blue curve) or invests abroad (solid blue curve). Similarly orange functions (s_b and s_{bb}) represent Firm b's indifference between exporting and investing abroad given that Firm a exports (dotted orange curve) or invests abroad (solid orange curve). These four curves divide the $(s;\mu)$ space into six areas which represent each pair of possible behaviors (e or f) respectively for Firm a and Firm b described page 9. The crosshatched area represents the only asymmetric case in which Firm a invests and Firm b exports.

From Area $A1$ to Area $A5$ both firms adopt the same strategy. If we want to understand the opposite strategies of the Airbus-Boeing duopoly described above, we have to focus in particular on Area $A6$. This area is determined by an intermediate level of spillovers such that $s_{bb} \leq s \leq s_a$. $\forall i = \{a, b\}$, $s_i \leq s_{ii}$ and at Point $I(0;1)$ these functions have a common tangent. We have seen that without asymmetric costs between Firm a and Firm b ($\theta = 1$) $s_a = s_b$ and $s_{aa} = s_{bb}$ and from Eq. (11) and Eq.(12) we know that an increase in θ decreases s_b and then s_{bb} (since they have the same tangent at Point I) and it increases s_a and then s_{aa}. Consequently an increase in θ also enlarges Area $A6$ because s_a increases and s_{bb} decreases. It means that the presence of spillovers decreases the profitability of the investment strategy for both firms but this decrease is lower for the firm which is technologically behind. Then higher technologically gap increases the probability to have opposite strategies.