Precommitment and flexibility in internationalization strategies of heterogeneous firms

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Abstract

This paper considers an asymmetric cost duopoly to examine the exports versus foreign direct investment (FDI) decision in a game with demand uncertainty. One of the firms, the more efficient, is allowed to commit or delay its choice once uncertainty is resolved. It is shown that firms’ internationalization strategies are complements, i.e. the more efficient firm opts for commitment FDI and the less efficient one imitates the leader’s behaviour, when demand uncertainty is low enough and so are set-up costs; this is less likely to occur as firms become more heterogeneous. Firms’ strategies are complements in exports when demand uncertainty is very low together with large set-up costs. An equilibrium where the less efficient firm engages in FDI and the more efficient one exports cannot occur when the leader role is given to the more efficient firm. However, this may be so when it is given to the less efficient firm, a finding in contrast with the received wisdom on productivity thresholds that emphasizes the strategic setting under consideration.

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1 Introduction

This paper considers an asymmetric cost duopoly to examine the exports versus foreign direct investment (FDI) decision in a multi-stage game with demand uncertainty. The literature has extensively studied how firms internationalize in oligopolistic settings. However, whether a firm prefers to precommit rather than remain flexible regarding internationalization strategies has not been formally addressed. The strategic advantage of committing early in the game, and to a particular cost structure, may be offset by the gains associated with flexibility to then adjust its output when demand uncertainty is resolved. A model with foreign firm interaction is developed that accounts for such tradeoffs. Our analysis therefore emphasizes the relevance of picking not only the right timing of entry but also the entry mode; besides, it provides a simple framework to endogenize follow-the-leader behaviour in internationalization strategies.

The model generalizes the basic setting in Spencer and Brander (1992) by introducing cost heterogeneity and letting firms decide their internationalization strategies. Firm heterogeneity allows us to investigate the prediction that the relatively more efficient firm opts for an FDI strategy while the less efficient adopts an exports strategy. Additionally, and provided the conditions for precommitment by the potential leader, we study when follower firms imitate or not the leader’s entry decision via FDI according to Knickerbocker’s (1973) "oligopolistic reaction" hypothesis.\footnote{According to Helpman, Melitz and Yeaple (2004) the least productive firms serve only the domestic market, the relatively more productive firms export, and the most productive firms engage in FDI. The authors provide evidence confirming the model predictions. The self-selection hypothesis states that firms with export activity are more productive than those without, and is largely confirmed empirically (see e.g. Wagner 2012). Regarding the oligopolistic reaction hypothesis, some studies lend empirical support to such behaviour by exploring whether firms’ FDI decisions are strategic complements- as done by Head et al. (2002) and Altomonte and Pennings (2008). Blonigen (2001) finds evidence of substitution and complementary effects between exports and FDI by using product-level data.}

The papers by Das (1983) and Itagaki (1992), that take as given the existence of a multinational firm, examined the behaviour of a multinational enterprise under cost and demand uncertainties. Strategic entry into a new market under demand uncertainty requires a dynamic setting, as in Saggi (1998) and Rob and Vettas (2003), who consider a monopolist’s choice between FDI and exports. Moner-Colonques et al. (2007) study an oligopolistic market with asymmetric information where the host firms have superior information about local demand. In addition to the well-known trade-off between a technology with lower marginal costs (FDI) and a technology with lower fixed costs (exports), these models draw attention to elements that affect the variability in profits for either entry strategy. In an environment of certainty, Horstmann and Markusen (1992) and Motta (1994) characterize equilibrium market structures where firms decide to serve a foreign market by exports or by setting up a plant in models with homogeneous and differentiated products, respectively. The latter analyzes the decisions about FDI taken in sequence in an attempt to provide an intuition for follow-the-leader investments, although the author acknowledges that a fully dynamic setting is required to show that follower investment is in response to the FDI of the leader. Markusen (2002) develops a two period model where the multinational firm chooses between exports and FDI before the rival host firm takes its entry decision. In an extension the host firm can delay entry to a later period when market demand is larger. Basically, the incum-
bent multinational firm can often preempt competition by building a plant in the host country. Recent contributions by Head et al. (2002) and Almonte and Pennings (2008) theoretically and empirically address oligopolistic reaction. The model by Head et al. (2002) incorporates important elements of Knickerbocker’s framework - oligopoly, uncertainty, and risk aversion. It is shown that when uncertainty exists about costs in the foreign market, a sufficiently risk-averse firm is more likely to establish a manufacturing facility in a foreign country once its rivals have done so. With certainty and risk neutrality the incentive falls. The dynamics in Almonte and Pennings (2008) emphasize follow-the-leader behavior driven by Bayesian learning: the observation of FDI by rival firms reveals information which is used by potential investors to update their priors about a market variable. In contrast to the received literature, our paper considers firms that are asymmetric in costs and allows one of the firms to delay its choice about exports and FDI. The analysis identifies conditions under which sequential entry strategies arise in equilibrium and so the follower matches the leader’s move.

Fundamentally, our analysis elaborates on Spencer and Brander (1992) and their focus on the pre-commitment and flexibility dichotomy. They present a duopoly model with uncertainty in demand where one firm has exogenously been given the possibility to commit the quantity before the realization of the uncertainty, taking advantage of moving first and acting as a Stackelberg leader; or defer its decision till the uncertainty is resolved, thereby losing its leading role. Without uncertainty, the first option will be always preferred by the leader, but the introduction of a demand shock makes the second case a possible equilibrium, as long as demand uncertainty is large enough.

This paper extends this line of research by applying the dichotomy pre-commitment vs flexibility to the internationalization strategies of heterogeneous firms. It is assumed that only one of the firms has the chance to commit its output choice and so the analysis distinguishes the effects of giving this opportunity to either the more or the less productive firm. Consider the case when the potential leader firm is more efficient. A wider cost gap between firms, either because of a greater difference in the initial efficiency of firms or because of greater transport cost, increases the possibility of obtaining an equilibrium outcome where the more efficient firm commits its output in FDI while the rival exports. That is, cost heterogeneity plays against oligopolistic reaction. The most remarkable result is that neither the committed nor the flexible outcome, where the more productive firm exports while the rival less productive firm does FDI, are an equilibrium of

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2Research devoted to examine the endogenous timing of moves and hence the allocation of roles in oligopoly include Hamilton and Slutsky (1990), Mailath (1993), van Damme and Hurkens (1999, 2004). In van Damme and Hurkens (1999 and 2004) it is shown that the leader role in a Stackelberg game will be undertaken by the most efficient firm (in terms of variable costs) under quantity competition in the former and price competition with differentiated products in the latter.

3To be sure, the pre-commitment vs flexibility choice has been explored in many contexts. Regarding trade policy, it is worth mentioning the papers by Dewit and Leahy (2004) on how an export subsidy affects the firms’ strategic investment decisions for an export market where demand is uncertain; and by Li and Rajan (2009) on a foreign investor’s decision under policy uncertainty in a less developed economy.

4The recent paper by Gilpatric and Li (2015) studies how superior information by one firm about stochastic demand can result in market leadership. Getting that information advantage is costly. There it is the disadvantaged firm that faces the tradeoff between not ceding leadership and waiting to play when fully informed. A larger variance makes the disadvantaged firm prefer being an informed Stackelberg follower - whereas a larger variance plays for a simultaneous Cournot competitor in Spencer and Brander (1992).
the game. By choosing the export strategy - committing or not its production - while the rival
does FDI, the more efficient firm foregoes its advantage in the initial variable cost gap. Aware
of this result, the more efficient firm decides to avoid these strategies and it will rather opt for
investment to be a stronger competitor in the market. Oligopolistic reaction behaviour, i.e. the
more efficient firm commits in FDI and the less efficient follows the same internationalization
strategy, happens when demand uncertainty is low enough and for small set-up costs. On the
other hand, switching the leading position between firms helps the less productive firm overcome
the initial cost disadvantage. So now the equilibrium where the less productive firm invests abroad
(committing or not its production) whereas the more efficient firm exports are equilibria of the game
under some conditions, yet this is less likely to happen when firms become more heterogeneous.
Oligopolistic reaction behaviour can arise for not too large demand uncertainty together with low
enough values of set-up costs.

The paper is structured as follows. The first part of section two presents the model where the
leader is the more productive firm and the equilibrium is characterized in different subsections; the
last subsection the less productive firm is granted with the opportunity to lead and study its strategic
implications. The last section concludes.

2 The model: a productive leader

Consider two foreign firms willing to serve a market with no pre-existing firms in that market.
Demand is uncertain and given by

$$ p = a - (q_1 + q_2) + \tilde{u} $$

(1)

where \( q_i \) represents the output produced by firm \( i = 1, 2 \) and \( p \) is the price. The random variable \( \tilde{u} \)
represents a demand shock with a mean equal to 0 and variance \( \sigma^2 \); the density \( f(\tilde{u}) \) is defined on
the support \([\tilde{u}, \tilde{u}]\). Precise conditions on \( \tilde{u} \) to ensure that firms have positive outputs are taken into
account in the analysis. One of the firms, denoted by firm \( F1 \), has constant marginal cost \( c \) whereas
the rival, denoted by firm \( F2 \), has constant marginal cost \( c + \delta \), with \( \delta > 0 \) representing the cost
gap between firms. We assume that firms are risk-neutral. The introduction of cost heterogeneity
 together with the internationalization strategies constitute our main contributions relative to the
setting in Spencer and Brander (1992).

The game unfolds in four stages. In the first stage firm \( F1 \) decides its internationalization
strategy between exports (\( E \)) and foreign direct investment (\( F \)). Exports imply incurring an
additional per unit cost of \( t \), whereas \( FDI \) implies a fixed cost of \( G \) of setting up a plant. In stage
two, firm \( F1 \) is exogenously given the opportunity to commit its output before \( \tilde{u} \) is known, which
may correspond to either the output of a committed exporter or to the output of a committed
investor. In case it opted for commitment, it makes its output choice under demand uncertainty\(^5\),
and plays the leader role. Alternatively, it can retain flexibility and defer its output choice when
uncertainty is resolved, which happens at the end of stage two. In stage three, firm \( F2 \) decides its

\(^5\)In the pre-commitment model we assume a total commitment of the quantity as in Spencer and Brander (1992),
to avoid multiplicity of equilibria.
entry strategy: $E$ or $F$. In the last stage, if firm $F1$ decided to remain flexible it play a Cournot competition game with firm $F2$, knowing the realization of the random variable $\tilde{u}$, denoted by $u$.

This model is intended to capture the advantages of moving first with the alternative advantages of flexibility, in the context of the FDI versus $E$ decision; the internationalization strategy endogenizes technology choice and allows us to study heterogeneity in several respects. On the one hand, when firms decide their entry mode they are choosing between exporting, with greater variable cost without any fixed costs, and foreign investment, preserving their variable cost level while incurring a fixed cost. On the other hand, there is an initial technological gap between firms, such that heterogeneities in variable costs remain, even if they choose symmetric internationalization strategies. Additionally, it allows for (partial) endogenization of roles in the context of asymmetric cost firms possibly giving rise to follow-the-leader behaviour. Figure 1 displays the game tree.

![Game Tree Diagram](image)

Figure 1. Decision Tree when $F1$ has the option of commitment.

Although it is clear that firms choose output levels, our focus is on the internationalization strategies. So there are eight different outcomes to study depending on the decision taken by firm $F1$ in the first stage and firm $F2$ in stage three.

We will denote the outcomes of the game by the pair $CI_1I_2$, where $I_i \in (E, F)$ stands for the internationalization strategy: in exports ($E$) or in FDI ($F$) chosen by firm $i = 1, 2$, when firm $F1$ selects commitment in $I_1$, whereas firm $F2$ chooses $I_2$. Likewise, the pair $I_1I_2$ refers to the flexible Cournot outcome where firms decide the corresponding entry strategy to the new market. As an
example, let us see in detail the outcome CEE where firm $F_1$ selects commitment in exports, whereas firm $F_2$ enters as an exporter.

Firm $F_2$ maximizes its profit as follows,

$$\max_{q_2} \pi_2 = (a - (q_1 + q_2) + u - (c + t + \delta))q_2$$

from where we obtain

$$q_2(q_1, u) = \frac{a - (c + t + \delta) + u}{2} - \frac{q_1}{2}$$

Firm $F_1$ sets output before uncertainty is resolved so it maximizes expected profit, that is,

$$\max_{q_1} E\pi_1 = E[(a - (q_1 + q_2(q_1, u)) + \bar{u} - (c + t)q_1]$$

Making use of $E[q_2(q_1, u)] = \frac{(a - c - t - \delta - q_1)}{2}$ and $E[\bar{u}] = 0$, we get the equilibrium output of the committed exporter, denoted by $q_1^{CEE}$, and of the flexible follower who also exports, denoted by $q_2^{CEE}$. These are given by,

$$q_1^{CEE} = \frac{1}{2}(a - c - t + \delta)$$

$$q_2^{CEE} = \frac{1}{4}(a - c - t - 3\delta + 2u)$$

Since demand uncertainty has no effect on the output chosen by the leader firm $F_1$, expected profit $E\pi_1^{CEE}$ reduces to the familiar expression - accounting for the cost asymmetry - where demand uncertainty plays no role:

$$E\pi_1^{CEE} = \frac{1}{8}(a - c - t + \delta)^2$$

The follower’s expected profit is,

$$E\pi_2^{CEE} = E[\frac{1}{16}(a - c - t - 3\delta + 2u)^2] =$$

$$= \frac{1}{16}(a - c - t - 3\delta)^2 + \frac{1}{4}(E[u] + \sigma^2) + \frac{1}{4}E[u](a - c - t - 3\delta)$$

that is,

$$E\pi_2^{CEE} = \frac{1}{16}((a - c - t - 3\delta)^2 + 4\sigma^2)$$

Note, however, that demand uncertainty does affect the value of firm $F_1$’s alternative: the flexible Cournot duopoly in exports. It is straightforward to obtain the equilibrium outputs,

$$q_1^{EE} = \frac{1}{3}(a - c - t + \delta + u)$$

$$q_2^{EE} = \frac{1}{3}(a - c - t - 2\delta + u)$$

which lead to expected profits as follows,

$$E\pi_1^{EE} = \frac{1}{9}((a - c - t + \delta)^2 + \sigma^2)$$

$$E\pi_2^{EE} = \frac{1}{9}((a - c - t - 2\delta)^2 + \sigma^2)$$

Expression $E\pi_1^{EE}$ indicates that expected profit increases with the variance of demand. The firm can increase output in good states and reduce it in bad states; these adjustments allow the
firm, on average, to do better than it would in case of pure certainty with demand always at its expected level.

Proceeding in the same manner one can characterize equilibrium output and expected profits for the remaining six outcomes, summarized in the following Table 1.

<table>
<thead>
<tr>
<th>i</th>
<th>$q_1^i$</th>
<th>$q_2^i$</th>
<th>$\Pi_1^i$</th>
<th>$\Pi_2^i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFE</td>
<td>$\frac{1}{2}(a - c + t + \delta)$</td>
<td>$\frac{1}{2}(a - c - 3t - 3\delta + 2u)$</td>
<td>$\frac{1}{2}(q_1^{C F E})^2 - G$</td>
<td>$\frac{(q_2^{C F E} - 2u)^2 + \sigma^2}{\pi}$</td>
</tr>
<tr>
<td>FE</td>
<td>$\frac{1}{2}(a - c + t + \delta + u)$</td>
<td>$\frac{1}{3}(a - c - 2t - 2\delta + u)$</td>
<td>$((q_1^{F E} - u)^2 + \frac{\sigma^2}{\pi}) - G$</td>
<td>$\frac{(q_2^{F E} - u)^2 + \sigma^2}{\pi}$</td>
</tr>
<tr>
<td>CEF</td>
<td>$\frac{1}{2}(a - c - 2t + \delta)$</td>
<td>$\frac{1}{3}(a - c + 2t - 3\delta + 2u)$</td>
<td>$\frac{1}{2}(q_1^{C E F})^2$</td>
<td>$\frac{(q_2^{C E F} - 2u)^2 + \sigma^2}{\pi} - G$</td>
</tr>
<tr>
<td>EF</td>
<td>$\frac{1}{2}(a - c - 2t + \delta + u)$</td>
<td>$\frac{1}{3}(a - c + t - 2\delta + u)$</td>
<td>$\frac{(q_1^{E F} - u)^2 + \frac{\sigma^2}{\pi}}{\pi}$</td>
<td>$\frac{(q_2^{E F} - u)^2 + \sigma^2}{\pi} - G$</td>
</tr>
<tr>
<td>CFF</td>
<td>$\frac{1}{2}(a - c + \delta)$</td>
<td>$\frac{1}{3}(a - c - 3\delta + 2u)$</td>
<td>$\frac{1}{2}(q_1^{C F F})^2 - G$</td>
<td>$\frac{(q_2^{C F F} - 2u)^2 + \sigma^2}{\pi} - G$</td>
</tr>
<tr>
<td>FF</td>
<td>$\frac{1}{2}(a - c + \delta + u)$</td>
<td>$\frac{1}{3}(a - c - 2\delta + u)$</td>
<td>$\frac{(q_1^{F F} - u)^2 + \frac{\sigma^2}{\pi}}{\pi}$</td>
<td>$\frac{(q_2^{F F} - u)^2 + \sigma^2}{\pi} - G$</td>
</tr>
</tbody>
</table>

Table 1. Equilibrium Quantities and Expected Profits when the Leader is More Efficient.

2.1 Characterization of the equilibrium

Once we have obtained all the expressions, we start with the construction of the bounds that will delimit the strategies chosen by each firm relative to the ones chosen by the rival. Best responses (BR) by firm F2 are obtained by comparing the bottom part in each path of the tree in Figure 1, that is, all pairs of profits in exports versus FDI for firm F2. Since we have four different paths for a given choice by firm F1, we obtain four different bounds on the level of the set-up cost. For instance, in the path with committed exports we get that the best response for firm F2, given that F1 decides to commit in exports, will be to export as long as $\pi^{C F E}_2 > \pi^{C E F}_2$, that is, when:

$$G > \frac{3t(2a - 2c + t - 6\delta)}{16} \equiv g1$$

Otherwise, firm F2’s BR will be to invest if $G$ is smaller than $g1$. We proceed in the same manner to construct the other three bounds related to the BR of firm F2, which are to be compared with the level of the set-up cost. The bounds are given by:

$$\pi^{E E}_2 > \pi^{E F}_2 \Rightarrow G > \frac{4t(a - c - 2\delta)}{9} \equiv g2$$
$$\pi^{C F E}_2 > \pi^{C F F}_2 \Rightarrow G > \frac{3t(2a - 2c - 3t - 6\delta)}{16} \equiv g3$$
$$\pi^{F E}_2 > \pi^{F F}_2 \Rightarrow G > \frac{4t(a - c - t - 2\delta)}{9} \equiv g4$$

It can be checked that all the bounds $g_i$, $i = 1, 2, 3, 4$ increase with the transport cost, making export obviously less attractive as it increases. However, they decrease with the cost gap $\delta$, discouraging entry via FDI for the less productive firm provided that firm heterogeneity becomes more important. These bounds reflect the familiar trade-off between costs (proximity and concentration) and account for cost heterogeneity. As expected, the variance of demand does not play a role in the comparisons for firm F2 given that it always plays once demand uncertainty has been resolved. By using the condition for positive quantities$^6$, we can establish an ordering on $g_i$ bounds

$^6$The condition for positive quantities comes from $q_2^{C F E}$, specifically $a - c > 3t + 3\delta - 2u$. 
as follows:

$$\max \{g_i\} = g2, \ \forall i \text{ and } \min \{g_i\} = g3, \ \forall i$$ \hspace{1cm} (18)

Moving upwards we next delimit the BR of firm F1 regarding the commitment decision. To do it we proceed by comparing the pair of expected profits under commitment or flexibility when the leader firm decided to export on one hand, and when it decided to do FDI, on the other. In this case, the strategy chosen by the rival can be any of the E or F strategies. Specifically, firm F1 prefers committed exports to flexible exports, provided that the rival will choose to export too, $E\pi_1^{CEE} > E\pi_1^{EE}$, when

$$\frac{1}{8}(a-c-t+\delta)^2 > \frac{1}{9}((a-c-t+\delta)^2 + \sigma^2) \Rightarrow \sigma^2 < \frac{(a-c-t+\delta)^2}{8} \equiv b1$$ \hspace{1cm} (19)

The intuition behind this comparison is the following: in the absence of demand uncertainty, $\sigma^2 = 0$, firm F1 will always prefer to be a Stackelberg leader. It is obvious that, in this case, both expressions in (19) just differ in the denominator, which is higher in the Cournot setting. Nevertheless, when in the face of uncertainty, remaining flexible becomes more attractive and we obtain an upper bound on the demand uncertainty reducing the parameter range for which committed exports is more profitable. In other words, for a sufficiently large level of demand uncertainty, staying flexible will be preferred. Were a good state of demand realized — values close to $\bar{u}$— flexibility would allow firm F1 to adjust its output to this higher demand once revealed, and consequently increase its profits. Moreover, in case of bad state of demand realizations — values close to $\underline{u}$— the firm avoids losses by reducing output. Obviously, significant demand uncertainty makes more important the potential gains or losses the firm cannot accommodate to when committing.

In a similar manner by comparing, for firm F1; the following commitment versus flexibility expected profits when the rival switches its strategy $E\pi_1^{CEE} > E\pi_1^{EF}$, we obtain another bound on the demand uncertainty, specifically

$$\frac{1}{8}(a-c-t+\delta)^2 > \frac{1}{9}((a-c-2t+\delta)^2 + \sigma^2) \Rightarrow \sigma^2 < \frac{9(a-c-t+\delta)^2}{8} - (a-c-2t+\delta)^2 \equiv b2$$ \hspace{1cm} (20)

First of all, relative to the role played by the demand uncertainty in (20) the same intuition will remain. Thus the Cournot setting will become more attractive as the demand uncertainty increases. Moreover, comparing both bounds we can see that the bound $b1$ from (19) is smaller than the bound $b2$ from (20). This means that there are some levels of uncertainty ($b1 < \sigma^2 < b2$) under which the commitment option will be preferred if the rival is going to enter the market via FDI but not if the rival chooses to export, where flexibility will be chosen. Note that if the rival chooses FDI then the variable cost difference shrinks, so firm F1 would rather choose commitment to keep a competitive advantage for certain values of $\sigma^2$. When both firms choose to export, large enough demand uncertainty makes F1 retain flexibility.

The comparison of all the outcomes results in a total of eight bounds; however, in the resolution of the game only six of them will be operative\footnote{Combining these $b1$ bounds with the decision obtained from the BRs of $F2$, its number boils down to only six since firm F1 never chooses between $E\pi_1^{CEF}$ and $E\pi_1^{EE}$ or $E\pi_1^{CEF}$ and $E\pi_1^{EE}$.}. Specifically, in addition to $b1$ and $b2$, we obtain
the following:

\[
\begin{align*}
E\pi_{1}^{CEF} > E\pi_{1}^{EF} & \Rightarrow \sigma^2 < \frac{(a - c - 2t + \delta)^2}{8} \equiv b3 \\
E\pi_{1}^{CFE} > E\pi_{1}^{FLE} & \Rightarrow \sigma^2 < \frac{(a-c+t+\delta)^2}{8} \equiv b4 \\
E\pi_{1}^{CFE} > E\pi_{1}^{FFE} & \Rightarrow \sigma^2 < \frac{9(a-c+t+\delta)^2}{8} - (a - c + \delta)^2 \equiv b5 \\
E\pi_{1}^{CFE} > E\pi_{1}^{FFE} & \Rightarrow \sigma^2 < \frac{(a-c+\delta)^2}{8} \equiv b6
\end{align*}
\]

Finally, we define the bounds associated to the choice of the internationalization strategy made by the leader firm. As we did for firm F2, we need to establish some bounds on the set-up cost that will define the BR of firm F1 between E and FDI. For instance, under commitment and \(I_2 = E\), firm F1 will prefer to export as long as \(E\pi_{1}^{CEF} > E\pi_{1}^{CFE}\), that is if

\[G > \frac{t}{2}(a - c + \delta) \equiv \gamma 1\]  

Following the same procedure we construct the next additional \(\gamma i\) bounds\(^8\):

\[
\begin{align*}
E\pi_{1}^{CEF} > E\pi_{1}^{FE} & \Rightarrow G > \frac{1}{9} ((a - c - t + \delta)^2 + \sigma^2)^2 - \frac{1}{8}(a - c - t + \delta)^2 \equiv \gamma 2 \\
E\pi_{1}^{CEF} > E\pi_{1}^{FFE} & \Rightarrow G > \frac{3}{4}(2a - 2c - t + 2) \equiv \gamma 3 \\
E\pi_{1}^{CEF} > E\pi_{1}^{FFE} & \Rightarrow G > \frac{1}{2}(a - c - t + \delta) \equiv \gamma 4 \\
E\pi_{1}^{EE} > E\pi_{1}^{CEF} & \Rightarrow G > -\frac{1}{8} ((a - c - t + \delta)^2 + \sigma^2)^2 + \frac{1}{8}(a - c + t + \delta)^2 \equiv \gamma 5 \\
E\pi_{1}^{EF} > E\pi_{1}^{CFE} & \Rightarrow G > \frac{4}{9}(a - c + \delta) \equiv \gamma 6 \\
E\pi_{1}^{EF} > E\pi_{1}^{CEF} & \Rightarrow G > -\frac{1}{8} ((a - c - 2t + \delta)^2 + \sigma^2)^2 + \frac{1}{8}(a - c + t + \delta)^2 \equiv \gamma 7 \\
E\pi_{1}^{EF} > E\pi_{1}^{CFE} & \Rightarrow G > -\frac{1}{8} ((a - c - 2t + \delta)^2 + \sigma^2)^2 + \frac{1}{8}(a - c + \delta)^2 \equiv \gamma 8 \\
E\pi_{1}^{EE} > E\pi_{1}^{FFE} & \Rightarrow G > \frac{t}{3}(2a - 2c - t + 2\delta) \equiv \gamma 9 \\
E\pi_{1}^{EE} > E\pi_{1}^{FFE} & \Rightarrow G > \frac{4}{9}(a - c - t + \delta) \equiv \gamma 10
\end{align*}
\]

As the traditional proximity-concentration trade-off predicts a greater trade cost, other things equal, favours entry via FDI since all the bounds \(\gamma i, i = 1, ..., 10\), are increasing with \(t\). Additionally, the cost gap \(\delta\) also favours F1’s entry via FDI. There is only one exception for \(\gamma 2\) where an increase in firm cost heterogeneity can either encourage or discourage FDI depending on the relationship of \(\delta\) with the other parameters.

Summarizing, we have defined the bounds that will characterize the equilibria of the multistage game by rolling backwards\(^9\). Before presenting the full characterization in the following section, it is instructive to look at the example displayed in Figure 2 - the game tree has been simplified excluding the output decision for expositional purposes. Consider a large enough level of set-up

\(^8\)By construction we can obtain a total of 16 different bounds \(\gamma\) on \(G\). However, some of them will not be operational for the resolution of the game.

\(^9\)Moreover, if we limit the resolution of the game only to the situations when all firms’ profits are positive, then an additional condition is required. The condition for positive profits imposes an upper bound on the set-up cost, namely the \(\min\{E\pi_{1}^{F*}, E\pi_{2}^{F*}, E\pi_{2}^{F*}\}\) where * indicates that the corresponding expected profits (CPP) are gross of the set-up costs. We have checked that although in some cases the CPP limits the range of levels of set-up cost for which a particular outcome is the equilibrium it is not excluding in any case. For that reason we omit its inclusion in Proposition 1 where the SPNE are defined.
cost, so that $G > g_2$. Therefore, in stage three the BR by firm $F2$ is always to internationalize via exports. Hence, a contradiction to Helpman et al. (2004) predictions cannot be observed. And neither can follow-the-leader behaviour in FDI strategies. Moving upwards, we study the choice of firm $F1$ by its BRs on both trade-offs, commitment versus flexibility and exports versus FDI. The first decision will depend on the bounds $bi$ related with the variance of demand uncertainty. In Figure 2 this corresponds to comparisons within the same branch, under each internationalization strategy. Such comparisons results in the green paths obtained by ordering two bounds: $b1$ from the comparison between $E\pi_{1}^{CEE}$ and $E\pi_{1}^{EE}$, and $b4$ from $E\pi_{1}^{CFE}$ vs $E\pi_{1}^{FE}$. Finally, the exports versus FDI decision leads to some bounds on the set-up cost. Now the comparison occurs across branches. Specifically, the bounds are $\gamma1$ from $E\pi_{1}^{CEE}$ vs $E\pi_{1}^{CFE}$, $\gamma5$ from $E\pi_{1}^{EE}$ vs $E\pi_{1}^{CFE}$ and $\gamma6$ from $E\pi_{1}^{EE}$ vs $E\pi_{1}^{FE}$. Notice that the comparison of $E\pi_{1}^{CEE}$ and $E\pi_{1}^{FE}$ associated to bound $\gamma2$ is not operative. This is because this bound depends on the level of demand uncertainty that, as mentioned in Section 2, affects differently the decision on commitment depending on the internationalization strategy choice. It can be verified that in turn these three $\gamma i$ bounds are greater than $g_2$. Finally, following the different paths in this particular example we find four different equilibria\(^{10}\) depending on specific levels on demand uncertainty and the set-up cost: $CEE$, $EE$, $CFE$ and $FE$.

---

\(^{10}\)Specifically, the more efficient firm decides its strategies, when the rival less efficient firm exports, according to the following. For low levels of uncertainty ($\sigma^2 < b_1$) and very large set-up costs ($G > \gamma_1$), the strategy of the more efficient firm will be to commit its output in exports. For large levels of uncertainty ($b_1 < \sigma^2$), the flexible outcome will arise in exports if the set-up cost is again high enough ($G > \max[\gamma_5, \gamma_6]$). Now, commitment in FDI couple with also low levels of uncertainty ($\sigma^2 < b_4$) but with a slightly wider range than under exports and when set-up cost is low enough ($G < \min[\gamma_1, \gamma_5]$). Finally, greater levels of uncertainty ($b_4 < \sigma^2$) and lower fixed cost ($G < \gamma_6$) result in the flexible exports outcome.
2.1.1 The equilibrium in internationalization strategies

Before presenting the Nash equilibrium of the game, we would like to offer some intuition. Ponssard (1979) first noticed that in an oligopolistic Cournot market the equilibrium profits of an informed firm are increasing with the variance of the demand uncertainty. His random variable corresponds to the parameter $a$ in our equation (1). However, the profits of an uninformed firm do not change with respect to the no informed game. Therefore in the simultaneous moves game there exists a positive incentive for each firm to acquire private information. Spencer and Brander (1992) showed that the same property holds true in a sequential moves game where demand uncertainty has no effect on the leader’s output whereas the follower’s profits are increased by the variance of demand. Then, giving up commitment amounts to becoming informed and therefore competing on the variance of the demand function, thus gaining an oligopolistic rent due to the precise knowledge of the demand function.

Let us now suppose that firm $F_2$ has no options and that it enters as an exporter. Firm $F_1$ is exogenously given the opportunity to commit or postpone its decision about its internationalization strategy and the corresponding quantity. Why would firm $F_1$ prefer commitment, despite not knowing demand, in E or FDI rather than flexibility? With commitment the firm assumes the risk of uncertain demand but seeks the profits of a Stackelberg leader, either by committing to exports or to FDI. However, the gains from moving first can be overcome when the uncertainty on the realization of demand is high, that is, when the variance of the random variable is large. That is because the profits of the rival informed firm are increasing with $\sigma^2$. In other words, if the realization of demand differs a lot from the expected value then having complete information (staying flexible) is more attractive although it entails giving up the first mover advantage. However, if being uninformed is not that bad - low variance - then commitment is preferred. This is the argument put forward by Spencer and Brander (1992) which, as can be seen, applies here regarding entry strategies.

In addition, our analysis considers cost asymmetry. Suppose that firm $F_1$ has to choose between commitment and flexibility in exports. As already argued, it will opt for commitment when the variance is low enough. Thus, other things equal, the more advantaged is firm $F_1$ with respect to firm $F_2$ (higher $\delta$) favours committed exports. In contrast, a higher $t$ discourages that option. But firm $F_1$ has two alternatives to internationalize: exports and FDI. All else equal, the wider the cost gap the stronger the incentive towards commitment in FDI. However, larger transport costs now increase the range of values for committed investment by firm $F_1$. Provided commitment, the size of the set-up cost determines the choice between exports and FDI, where cost heterogeneity favours the FDI option. The foregoing argument precisely notes the trade-off between proximity and concentration, which is finally shaped by the effect of uncertainty. As noted above, large enough variance of demand coupled with large enough set-up costs will make firm $F_1$ opt for flexibility in exports; low enough values of $\sigma^2$ and $G$ result in firm $F_1$ choosing commitment in FDI.

There are additional effects at play when firm $F_2$ can also choose the internationalization strategy. If firm $F_2$ opts for FDI it will save on the trade cost $t$ and this means an outward shift on its reaction function, and its position varies depending on the realization of demand. This
introduces variability in the expected residual demand faced by a commitment option by firm \( F_1 \), and such variability owes to demand uncertainty and also to the internationalization strategy that firm \( F_2 \) may choose. This is to be anticipated by firm \( F_1 \) in taking advantage of its early move. For example, its favourable cost difference would be lessened if it chose exports and the rival engaged in FDI, a point that precisely emphasizes the relevance of foreign firm interaction.

The Proposition that follows displays the characterization of the equilibrium in entry strategies.

**Proposition 1** Consider the game where both firms choose their internationalization strategies between exports and FDI and the more efficient firm \( F_1 \) can either commit its strategy or remain flexible. The resulting equilibria will be the following outcomes:

i) Commitment in exports, while the rival exports too, when \( \sigma^2 < b_1 \) and \( G > \gamma_1 \),

ii) Commitment in FDI, while the rival exports, when \( \sigma^2 < b_4 \) and \( g_4 < G < \min\{\gamma_1, \gamma_5\} \) or when \( \sigma^2 < b_5 \) and \( g_4 > G > \gamma_3 \),

iii) Commitment in FDI, while the rival does FDI too, when \( \sigma^2 < b_6 \) and \( G < \gamma_3 \),

iv) Flexibility in exports, while the rival exports too, when \( b_1 < \sigma^2 \) and \( G > \max\{\gamma_5, \gamma_6\} \),

v) Flexibility in FDI, while the rival exports, when \( b_4 < \sigma^2 \) and \( g_4 < G < \gamma_6 \), and

vi) Flexibility in FDI, while the rival does FDI too, when \( b_5 < \sigma^2 \) and \( g_3 < G < g_4 \) or when \( b_6 < \sigma^2 \) and \( g_3 > G \).

It can be seen that we cannot find an equilibrium where the more efficient firm becomes an exporter and the less efficient one an investor, a result in accordance with the self-selection hypothesis. If firm \( F_1 \) selected exports then it would see its initial cost advantage diminished. Were firm \( F_2 \) opting for FDI the cost gap would close further. In a strategic environment this explains why \( F_1 \) chooses neither commitment nor flexibility in exports. This remarkable result is presented in the Corollary.

**Corollary** In this game, the following outcomes:

i) Commitment in exports, while the less efficient firm chooses FDI and

ii) Flexibility in exports, while the less efficient firm chooses FDI,

will never be an equilibrium of the game.

There is an equilibrium outcome where firms' internationalization strategies are complements, CEE, which occurs when demand variability is very low together with large set-up costs. In case firm \( F_1 \) decided to commit in FDI it would save on transport costs. This makes the commitment option more attractive for a wider range of demand variability; the constraint on \( \sigma^2 \) is stronger when firm \( F_1 \)'s variable costs are higher - when it is exporting - or when the cost gap between firm shrinks reducing the initial cost advantage. Next, to find that the follower firm selects FDI a very low set-up cost is required. Given that the variable profit of the leader firm exceeds that of the follower, the bound on \( G \) will also be met by firm \( F_1 \). Therefore, item iii) in the Proposition tells us that the size of demand variability determines the choice by firm \( F_1 \) and the size of the set-up cost determines the choice of firm \( F_2 \) to find Knickerbocker’s (1973) oligopolistic reaction behaviour in foreign investment.
2.2 Robustness analysis

We now wish to check how important the sequentiality assumption is, compared to cost heterogeneity. For this reason, we solve the previous game by reversing the decision order of the firms. This means that the potential leader role in entry strategies and the associated output is given to the less efficient firm $F_2$, the firm with marginal cost $c + \delta$. In this case the commitment option, apart from the already mentioned advantages and disadvantages, can be seen as a strategy that mitigates the cost disadvantage of firm $F_2$. Obviously, in the flexible outcomes the payoffs of firms and quantities produced will not vary despite the reversion of roles.

For the sake of exposition, the precise expressions and the analysis have been relegated to the Appendix.

Firstly, consider once again the simpler game where the less efficient firm chooses its internationalization strategy but the rival more efficient firm has no alternative and exports. As expected, the results obtained show that reverting the leading roles shrinks the intervals of uncertainty under which commitment arises in equilibrium. These findings are in line with the results found in van Damme and Hurkens (1999) where the more efficient firm has more to gain than the less efficient firm when taking the leader’s role. Moreover, since the restrictions on the set-up cost are also weaker now flexibility in exports is more likely to arise in equilibrium. An increase in the transport cost has the same effect as in the previous game, increasing the range for which $CFE$ can be the equilibrium outcome. Note however that this implies that the more efficient firm will export while the less efficient will invest, an outcome which cannot arise in equilibrium when the early move is given to the more efficient firm. All things equal, any bound operative in equilibrium will now decrease with $\delta$, so a wider cost heterogeneity is now increasing the range of both flexible outcomes instead of the commitment ones, which is logical given that the cost gap favours the rival firm.

Secondly, allow for $F_1$ to either export or invest abroad. In characterizing the equilibria in internationalization strategies, the amount of conditions is larger now. The bounds in constructing the BR of $F_1$ are more prevalent than those of $F_2$ since the follower is now more productive than the potential leader. The following Proposition emphasizes an interesting result.

Proposition 2 Consider the game represented in the tree in Figure 1 and assume that the less efficient firm has the option to either commit its strategy or to remain flexible. Compared to the game where the more efficient firm may play first, the outcomes $CFE$ and $FE$ can now arise in equilibrium.

Therefore, the result stated in Proposition 2 can be viewed as an example of a break in the monotonicity of productivity thresholds, which also highlights the relevance of cost heterogeneities in the current strategic setting. Table 4 in the Appendix shows the specific conditions when the outcomes $CFE$ and $FE$ are the equilibria of the game. We would like to remark that in both outcomes $CFE$ and $FE$ the interval on the set-up cost shrinks, and can even disappear, as long as the cost gap increases, independently of the level of transport cost. That means that, firms need to be quite similar in costs for the less efficient firm to profit from the advantage of moving first to find a counterexample to the monotonicity threshold result in Helpman et al (2004). As any outcome involving commitment, $CFE$ is associated with low enough levels of demand uncertainty,
although the range of values is wider as compared with the range when the rest of the commitment outcomes arise.

Follow-the-leader behaviour occurs for not too large demand uncertainty together with low enough values of set-up costs. Interestingly the less efficient firm may find it profitable to give up the advantage of moving first and even opt for larger variable costs against the rival. Thus the flexible outcome $EE$ can arise in equilibrium although it is less likely to occur relative to the game where the more efficient firm can take the leader role.

3 Conclusions

We have extended Spencer and Brander’s (1992) commitment versus flexibility model introducing cost heterogeneities among firms and the entry mode decision between exports and FDI. The model combines two types of trade-offs studied in the literature. On the one hand, the trade-off between proximity and concentration and, on the other, the trade-off between flexibility and commitment. Some interesting results arise. When the more efficient firm has the chance to lead, the outcomes $CEE$ and $CFF$ associated with oligopolistic reaction where both firms follow the same strategy can be an equilibrium. However, for the case where each firm follows a different internationalization strategy, we show that an outcome where the more efficient firm exports and the less efficient rival engages in FDI is not possible; this would make the more efficient firm a weak competitor. This conclusion sits well with the received empirical results found in the literature on productivity thresholds.

However, when we have a "lagged leader" all the outcomes, even the one that implies a reversion of the monotonicity in productivity thresholds, will be plausible. Moreover, the range for which the setting $CFE$ is the equilibrium is larger as the transport cost rises. This result points out the relevance of the sequentiality in uncertain contexts with firm heterogeneity. In connection with this, when the lagged firm confronts the flexibility vs commitment trade-off, an interesting trade policy implication is obtained. Governments can help less efficient producers to assume a credible strategic commitment on its output when demand uncertainty in new markets is sufficiently low. By doing so, firms will more likely become leaders and undercut the initial disadvantage in costs relative to more efficient international competitors.

References


4 Appendix

Table 2 shows the quantities and expected profits obtained in each outcome when the less efficient firm $F2$ is playing the leader role.

<table>
<thead>
<tr>
<th>$i$</th>
<th>$q^*_2$</th>
<th>$q^*_1$</th>
<th>$E\Pi^*_2$</th>
<th>$E\Pi^*_1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEE</td>
<td>$1/2(a - c - t - 2\delta)$</td>
<td>$1/4(a - c - t + 2\delta + 2u)$</td>
<td>$(q^1_{CFF})^2$</td>
<td>$(q^1_{CFF} - 2u)^2 + \frac{\sigma^2}{4}$</td>
</tr>
<tr>
<td>EE</td>
<td>$1/3(a - c - t - 2\delta + u)$</td>
<td>$1/3(a - c - t + \delta + u)$</td>
<td>$(q^2_{CFF} - u)^2 + \frac{\sigma^2}{4}$</td>
<td>$(q^1_{CFF} - u)^2 + \frac{\sigma^2}{4}$</td>
</tr>
<tr>
<td>CFE</td>
<td>$1/2(a - c + t - 2\delta)$</td>
<td>$1/4(a - c - 3t + 2\delta + 2u)$</td>
<td>$(q^2_{CFF})^2 - G$</td>
<td>$(q^1_{CFF} - 2u)^2 + \frac{\sigma^2}{4}$</td>
</tr>
<tr>
<td>FE</td>
<td>$1/3(a - c + t - 2\delta + u)$</td>
<td>$1/3(a - c - 2t + \delta + u)$</td>
<td>$((q^2_{CFF} - u)^2 + \frac{\sigma^2}{4}) - G$</td>
<td>$(q^1_{CFF} - u)^2 + \frac{\sigma^2}{4}$</td>
</tr>
<tr>
<td>CEF</td>
<td>$1/2(a - c - 2t - 2\delta)$</td>
<td>$1/4(a - c + 2t + 2\delta + 2u)$</td>
<td>$(q^2_{CFF})^2$</td>
<td>$(q^1_{CFF} - 2u)^2 + \frac{\sigma^2}{4} - G$</td>
</tr>
<tr>
<td>EF</td>
<td>$1/3(a - c - 2t - 2\delta + u)$</td>
<td>$1/3(a - c + t + \delta + u)$</td>
<td>$(q^2_{CFF} - u)^2 + \frac{\sigma^2}{4}$</td>
<td>$((q^1_{CFF} - u)^2 + \frac{\sigma^2}{4}) - G$</td>
</tr>
<tr>
<td>CFF</td>
<td>$1/2(a - c - 2\delta)$</td>
<td>$1/4(a - c + 2\delta + 2u)$</td>
<td>$(q^2_{CFF})^2 - G$</td>
<td>$(q^1_{CFF} - 2u)^2 + \frac{\sigma^2}{4} - G$</td>
</tr>
<tr>
<td>FF</td>
<td>$1/3(a - c - 2\delta + u)$</td>
<td>$1/3(a - c + \delta + u)$</td>
<td>$((q^2_{CFF} - u)^2 + \frac{\sigma^2}{4}) - G$</td>
<td>$((q^1_{CFF} - u)^2 + \frac{\sigma^2}{4}) - G$</td>
</tr>
</tbody>
</table>

Table 2. Equilibrium Quantities and Expected Profits when the Leader is the Less Efficient Firm.

For the construction of the BR of both firms we proceed in the same manner as in Subsection 2.1. The BR of firm $F1$ gives rise to bounds $g^i$, with $i = 1, ..., 4$ as follows:

$$E\pi^{CEF}_1 > E\pi^{CFE}_1 \Rightarrow G > \frac{3(a^2 - 2c + t + 4\delta)}{16} \equiv g1'$$

(35)

$$E\pi^{EF}_1 > E\pi^{FE}_1 \Rightarrow G > \frac{4(a^2 + c + \delta)}{9} \equiv g2'$$

(36)

$$E\pi^{CFF}_1 > E\pi^{CFE}_1 \Rightarrow G > \frac{3(a^2 - 2c - 3t + 4\delta)}{16} \equiv g3'$$

(37)

$$E\pi^{FF}_1 > E\pi^{FE}_1 \Rightarrow G > \frac{4(a^2 - c + t + \delta)}{9} \equiv g4'$$

(38)

Using the condition for positive quantities\(^{11}\) we get that $g2' > g4'$ and $g1' > g3'$. Therefore, there are five different possible orderings of the $g1'$ bounds. To classify them we can consider some

\(^{11}\)The condition for positive quantities is obtained from the following: $q^1_{CFF}$, $q^2_{CFF}$ and $q^2_{CFF}$. Specifically, $a - c > \max\{2t + 2\delta - u, 3t - 2\delta - 2u\}$.
conditions on the oligopoly margin \((a - c)\), that are presented in the following table:

<table>
<thead>
<tr>
<th>Ordering:</th>
<th>Condition:</th>
</tr>
</thead>
<tbody>
<tr>
<td>(g_2^2 &gt; g_4^4 &gt; g_1^1 &gt; g_3^3)</td>
<td>(\frac{10}{10} \left(\frac{44\delta + 91t}{27t}\right) &lt; a - c)</td>
</tr>
<tr>
<td>(g_2^2 &gt; g_1^1 &gt; g_4^4 &gt; g_3^3)</td>
<td>(\frac{10}{10} \left(\frac{44\delta - 91t}{27t}\right) &lt; a - c)</td>
</tr>
<tr>
<td>(g_1^1 &gt; g_2^2 &gt; g_4^4 &gt; g_3^3)</td>
<td>(\frac{10}{10} \left(\frac{44\delta + 17t}{17t}\right) &lt; a - c)</td>
</tr>
<tr>
<td>(g_1^1 &gt; g_2^2 &gt; g_3^3 &gt; g_4^4)</td>
<td>(\frac{10}{10} \left(\frac{44\delta - 81t}{81t}\right) &lt; a - c)</td>
</tr>
<tr>
<td>(g_1^1 &gt; g_3^3 &gt; g_2^2 &gt; g_4^4)</td>
<td>(\frac{10}{10} \left(\frac{44\delta}{81t}\right) &lt; a - c)</td>
</tr>
</tbody>
</table>

Table 3. Orderings of \(g_i^i\) Bounds.

As we know, the BR of the leader firm \(F_2\) depend on the level of demand uncertainty and also on the size of the set-up cost. For the first one, we define the bounds \(b_i^i, i = 1, \ldots, 8\) that are shown below and that discriminate between the commitment and flexibility decision.

\[
E_{\pi_2}^{CEE} > E_{\pi_2}^{EE} \Rightarrow \sigma^2 < \frac{(a - c - t - 2\delta)^2}{8} \equiv b_1^i
\]

(39)

\[
E_{\pi_2}^{CEE} > E_{\pi_2}^{EF} \Rightarrow \sigma^2 < \frac{9(a - c - t - 2\delta)^2}{8} - (a - c - 2t - 2\delta)^2 \equiv b_2^i
\]

(40)

\[
E_{\pi_2}^{CEF} > E_{\pi_2}^{EE} \Rightarrow \sigma^2 < \frac{9(a - c - t - 2\delta)^2}{8} - (a - c - t - 2\delta)^2 \equiv b_3^i
\]

(41)

\[
E_{\pi_2}^{CEF} > E_{\pi_2}^{EF} \Rightarrow \sigma^2 < \frac{(a - c - 2t - 2\delta)^2}{8} \equiv b_4^i
\]

(42)

\[
E_{\pi_2}^{CFF} > E_{\pi_2}^{EE} \Rightarrow \sigma^2 < \frac{(a - c - 2t - 2\delta)^2}{8} \equiv b_5^i
\]

(43)

\[
E_{\pi_2}^{CFF} > E_{\pi_2}^{EF} \Rightarrow \sigma^2 < \frac{(a - c - 2t - 2\delta)^2}{8} \equiv b_6^i
\]

(44)

\[
E_{\pi_2}^{CFF} > E_{\pi_2}^{FF} \Rightarrow \sigma^2 < \frac{9(a - c - 2t - 2\delta)^2}{8} - (a - c - t - 2\delta)^2 \equiv b_7^i
\]

(45)

\[
E_{\pi_2}^{CFF} > E_{\pi_2}^{FF} \Rightarrow \sigma^2 < \frac{(a - c - 2t - 2\delta)^2}{8} \equiv b_8^i
\]

(46)

For the internationalization strategy choice, we have to construct the bounds \(\gamma_i^i, i = 1, \ldots, 12\) that categorize the BRs for \(F_2\).

\[
E_{\pi_2}^{CEE} > E_{\pi_2}^{CFF} \Rightarrow G > \frac{t}{2} (a - c - 2\delta)^2 \equiv \gamma_1^i
\]

(47)

\[
E_{\pi_2}^{CEE} > E_{\pi_2}^{FFE} \Rightarrow G > \frac{1}{9} (a - c + t - 2\delta)^2 + \sigma^2) - \frac{1}{8}(a - c - t - 2\delta)^2 \equiv \gamma_2^i
\]

(48)

\[
E_{\pi_2}^{CEF} > E_{\pi_2}^{CEE} \Rightarrow G > \frac{3}{8}(2a - 2c - t - 4\delta) \equiv \gamma_3^i
\]

(49)

\[
E_{\pi_2}^{CFF} > E_{\pi_2}^{CEE} \Rightarrow G > \frac{t}{2} (a - c - t - 2\delta)^2 \equiv \gamma_4^i
\]

(50)

\[
E_{\pi_2}^{CEF} > E_{\pi_2}^{FFE} \Rightarrow G > \frac{1}{9} ((a - c + t - 2\delta)^2 + \sigma^2) - \frac{1}{8}(a - c - 2t - 2\delta)^2 \equiv \gamma_5^i
\]

(51)

\[
E_{\pi_2}^{CFF} > E_{\pi_2}^{FFE} \Rightarrow G > \frac{1}{8} ((a - c + t - 2\delta)^2 + \sigma^2) \equiv \gamma_6^i
\]

(52)

\[
E_{\pi_2}^{CEF} > E_{\pi_2}^{FF} \Rightarrow G > \frac{1}{8} ((a - c + t - 2\delta)^2 + \sigma^2) \equiv \gamma_7^i
\]

(53)

\[
E_{\pi_2}^{CFF} > E_{\pi_2}^{FF} \Rightarrow G > \frac{t}{2} (a - c - 2t - 2\delta)^2 \equiv \gamma_8^i
\]

(54)

\[
E_{\pi_2}^{CEF} > E_{\pi_2}^{FF} \Rightarrow G > \frac{1}{8} ((a - c - t - 2\delta)^2 - \frac{1}{8}(a - c - t - 2\delta)^2 + \sigma^2) \equiv \gamma_9^i
\]

(55)

\[
E_{\pi_2}^{CFF} > E_{\pi_2}^{FF} \Rightarrow G > \frac{1}{8} ((a - c - 2\delta)^2 - \frac{1}{8}(a - c - t - 2\delta)^2 + \sigma^2) \equiv \gamma_{10}^i
\]

(56)

\[
E_{\pi_2}^{CEF} > E_{\pi_2}^{EFF} \Rightarrow G > \frac{1}{8} (2a - 2c - t - 4\delta) \equiv \gamma_{11}^i
\]

(57)

\[
E_{\pi_2}^{CFF} > E_{\pi_2}^{EFF} \Rightarrow G > \frac{1}{8} (a - c - t - 2\delta) \equiv \gamma_{12}^i
\]

(58)
Finally, we combine the best responses of both firms to solve the game. Table 4 contains the particular conditions that characterize all the equilibria when the leader firm is less efficient than the follower.

<table>
<thead>
<tr>
<th>SPNE</th>
<th>Conditions:</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEE</td>
<td>[ \sigma^2 &lt; b_{1}' \land G &gt; \max {g_{1}', g_{2}', \gamma_{1}' } ]</td>
</tr>
<tr>
<td></td>
<td>[ \sigma^2 &lt; b_{2}' \land g_{2'} &gt; G &gt; \max {g_{1}', \gamma_{1}', \gamma_{2}' } ]</td>
</tr>
<tr>
<td>CEF</td>
<td>[ \sigma^2 &lt; b_{3}' \land g_{1}' &gt; G &gt; \max {g_{2}', \gamma_{3}' } ]</td>
</tr>
<tr>
<td></td>
<td>[ \sigma^2 &lt; b_{4}' \land \min {g_{3}', g_{2}' } &gt; G &gt; \gamma_{4}' ]</td>
</tr>
<tr>
<td></td>
<td>or [ \min {g_{1}', g_{2}' } &gt; G &gt; \max {g_{3}', \gamma_{3}' } ]</td>
</tr>
<tr>
<td>CFE</td>
<td>[ \sigma^2 &lt; b_{5}' \land \min {g_{1}', g_{3}', \gamma_{9}' } &gt; G &gt; \max {g_{3}', g_{4}' } ]</td>
</tr>
<tr>
<td></td>
<td>or [ \min {g_{1}', g_{3}', \gamma_{6}' } &gt; G &gt; \max {g_{2}', g_{3}' } ]</td>
</tr>
<tr>
<td></td>
<td>or [ \min {g_{2}', g_{1}' } &gt; G &gt; \max {g_{1}', g_{4}' } ]</td>
</tr>
<tr>
<td></td>
<td>[ \sigma^2 &lt; b_{6}' \land \min {g_{4}', g_{3}', \gamma_{9}' } &gt; G &gt; g_{3}' ]</td>
</tr>
<tr>
<td></td>
<td>or [ \min {g_{4}', \gamma_{1}', \gamma_{9}' } &gt; G &gt; g_{1}' ]</td>
</tr>
<tr>
<td>CFF</td>
<td>[ \sigma^2 &lt; b_{8}' \land \min {g_{3}', g_{4}', \gamma_{10}' } &gt; G ]</td>
</tr>
<tr>
<td>EE</td>
<td>[ b_{3}' &lt; \sigma^2 \land \max {g_{2}', \gamma_{6}' } &lt; G &lt; g_{1}' ]</td>
</tr>
<tr>
<td></td>
<td>[ b_{1}' &lt; \sigma^2 \land \max {g_{1}', g_{2}', \gamma_{6}' } &lt; G ]</td>
</tr>
<tr>
<td>EF</td>
<td>[ b_{4}' &lt; \sigma^2 \land \max {\gamma_{10}', \gamma_{12}' } &lt; G &lt; \min {g_{2}', g_{3}' } ]</td>
</tr>
<tr>
<td></td>
<td>or [ \max {g_{3}', \gamma_{9}', \gamma_{12}' } &lt; G &lt; \min {g_{1}', g_{2}' } ]</td>
</tr>
<tr>
<td></td>
<td>[ b_{2}' &lt; \sigma^2 \land \max {g_{1}', \gamma_{9}', \gamma_{12}' } &lt; G &lt; g_{4}' ]</td>
</tr>
<tr>
<td></td>
<td>or [ \max {g_{1}', g_{4}', \gamma_{11}' } &lt; G &lt; g_{2}' ]</td>
</tr>
<tr>
<td>FE</td>
<td>[ b_{5}' &lt; \sigma^2 \land \max {g_{3}', g_{4}' } &lt; G &lt; \min {g_{1}', g_{2}', \gamma_{11}' } ]</td>
</tr>
<tr>
<td></td>
<td>or [ \max {g_{1}', g_{4}', \gamma_{11}' } &lt; G &lt; \min {g_{2}', g_{2}', \gamma_{11}' } ]</td>
</tr>
<tr>
<td>FF</td>
<td>[ b_{6}' &lt; \sigma^2 \land g_{3}' &lt; G &lt; \min {g_{4}', \gamma_{12}' } ]</td>
</tr>
<tr>
<td></td>
<td>[ b_{8}' &lt; \sigma^2 \land G &lt; \min {g_{3}', \gamma_{12}' } ]</td>
</tr>
</tbody>
</table>

Table 4. Equilibrium Conditions when the Less Efficient Firm has the Commitment Option.