Learning by doing in internationalization strategies under firm heterogeneity

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Abstract

This paper develops a two period model. Two foreign firms, heterogeneous in costs, are considering entry in a host market. In period one, the more efficient firm chooses between exports and FDI and produces. In period two, both firms simultaneously decide their entry modes between exports and FDI and compete in quantities. A fundamental feature of the analysis is the property of the cost function across periods exhibiting either cost complementarity or cost substitutability. This allows us to study learning-by-doing by the leader firm. This simple setting proves useful to study the issues of learning behaviour, switching strategies for one of the firms, and oligopolistic reaction by the firm that only plays later in the game.

Under cost complementarities the following results are found: i) when the set up costs of FDI are either very large or very small it is shown that firms' internationalization strategies are complementary (follow-the-leader behaviour), and ii) for intermediate values, firms' internationalization strategies are found to be substitutes: the leader firm invests in both periods and the rival firm enters as an exporter in period two. Relative to cost complementarity, it is worth noting that iii) there is a switching strategy for the leader firm that can be an equilibrium for a sufficiently large level of cost substitutability. Such switching strategy entails the leader firm to initially enter as an exporter and then deciding to invest while the rival exports (oligopolistic reaction by the follower). Finally, iv) a switching strategy where the follower internationalizes via FDI will never be an equilibrium.

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1 Introduction

Recent work on the analysis of multinationals argues that these firms expand abroad in order to source, rather than exploit, the host markets' available knowledge. This is an alternative view which places the multinational enterprise at a disadvantage relative to host firms. Additionally, if we look at firms' strategies over time, the received literature (theoretical and empirical) suggests that firms learn from international expansion. The purpose of this paper is to study the learning-by-doing hypothesis in firms' internationalization strategies between exports and *FDI*.[1]

Heterogeneities in costs between foreign firms are maintained so we can examine whether how efficient the firm is determines, not only its internationalization path over time, but also the rival's reaction. Thus, a fundamental feature of the analysis is the property of the cost function across periods exhibiting either cost complementarity or cost substitutability. The simple setting adopted allows us to obtain a taxonomy in internationalization strategies and identify conditions under which i) a given firm expands in steps (hence switching from exports to investment or vice versa), and ii) how the rival reacts by choosing either the same entry mode (complementary strategies) or a different one (substitute strategies).

In the literature of firms' internationalization process through investments[2], Knickerbocker (1973) suggested a further motivation for firms engaging in *FDI*: the follower firms invest abroad, as a reaction to the set-up of a foreign affiliate by a first-mover competitor, the leader. Hence such follow-the-leader behaviour has become known as oligopolistic reaction and it is supported by broad empirical evidence (see e.g. Hennart and Park (1994) and Chang (1995)). Theoretically, the analysis of oligopolistic reaction demands a dynamic setting.

Saggi (1998) examines a monopolist's choice between *FDI* and exports in a two-period setting with demand uncertainty. This demand uncertainty is solved in the second period, independently of the strategy chosen by the firm in period one. So the firm can start with one of the two strategies and continue with the same in the second period, but there is also the possibility to switch and serve the foreign market in the alternative strategy.

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[2] Interesting surveys on international trade with particular attention to FDI are Saggi (2002), more focused on empirical findings, and Helpman (2006), more interested in theoretical models.

Switching from *FDI* to export, because demand happens to be not high enough, implies a loss of a part of the initial investment since it is a sunk cost. Alternatively, the firm can enter the market via exports to test the level of demand and then switch to *FDI*, if profitable, by paying the fixed cost of the investment. This implies that in Saggi's model the level of the fixed costs of *FDI* relative to the market size determine which strategy will be more profitable. Furthermore, sunk costs play an important role on the decision of internationalization: if they are low the firm can take a risk starting with *FDI* and switching if necessary, but as sunk costs rise the opposite strategy becomes optimal.

Oligopolistic interaction is considered by Head, Mayer and Ries (2002) and by Altomonte and Pennings (2008). Following Knickerbocker's (1973) analysis of oligopolistic reaction, Head, Mayer and Ries (2002) extend the idea to study whether the incentives of a firm to invest abroad will increase when its rival also does the investment. They show that when uncertainty about costs in the foreign market exists, 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. Thus, these authors identify conditions under which *FDI* decisions can be either strategic complements or substitutes. The paper by Altomonte and Pennings (2008) does take a dynamic view. The observation of *FDI* by rival firms reveals information used by potential investors to update their priors about a market variable. The model, based on Bayesian learning, provides testable implications on the follow-the-leader behaviour which are then empirically studied. Using a panel count data sample of multinationals in Central and Eastern Europe, their analysis finds empirical support to oligopolistic reaction based on learning from rivals' behaviour. This paper is a contribution to the theoretical literature on oligopolistic reaction in a two-period model by considering two types of internationalization strategies: *FDI* and exports. Learning behaviour is assumed on the part of one of the firms which internationalizes and produces in the first period. There is cost interaction that transmit competition across periods and influences not only the firm's choices in period two, but also the rival's reaction.

The concepts of strategic complementarity and substitutability were introduced by Bulow, Geanakoplos and Klemperer (1985). This paper includes an example of a multi-product firm facing competition in one market and being a price-taker in the other. Interestingly enough, a lower price results in lower profits for the multi-product firm, this is because its cost function exhibits diseconomies of scope. Dixon (1994) notes the relevance of joint economies in divestiture decisions. We shall use the cost function employed by Cantos, Moner and Sempere (2003) and adapt it to account for either complementarity or substitutability in production over time. Our analysis thus provides testable predictions on the follow-the-leader behaviour based on properties of the cost function, in addition to the well-know variables.

The empirical literature about the learning-by-exporting hypothesis is quite extensive. For instance in Salomon and Shaver (2005) and Salomon and Jin (2010) the learning by exporting of Spanish firms is analyzed. In the former paper, learning is captured through innovation and patent applications. They find positive evidence of an increase in product innovation after two years of exporting activity. In the latter, the analysis is extended by looking for implications of heterogeneities between technological leaders and lagged firms. Both firm types can learn, but heterogeneities are translated to learning as more efficient firms obtain more patents than lagged ones. Learning has also been studied through export spillovers by Aitken, Hanson and Harrison (1997). They find that exporting firms reduce the entry costs for potential entrants via learning or establishing commercial linkages. By analyzing a sample of Mexican manufacturing firms, they obtain evidence of positive spillovers from multinationals, but not explicitly from exporting. Crespi, Criscuolo and Haskel (2008) show empirical evidence of learning by exporting for UK firms, where these exhibit significant learning from clients, more than from any other sources.

The model proposed features two periods. There are two foreign firms, heterogeneous in costs, considering its entry in a host market. In period one, the leader firm chooses between exports and *FDI* and then produces. In period two, both firms simultaneously decide their entry modes between exports and *FDI* and compete in quantities afterwards. As already noted, both periods are strategically linked via variable costs which can make the leader firm's outputs either complements or substitutes across periods. Such a setting allows us to study the issues of learning behaviour, switching strategies for one of the firms and oligopolistic reaction by the follower firm.

The analysis thus distinguishes the case of cost complementarities and cost substitutabilities. The former one leads to very clean results. When the set-up costs of *FDI* are either very large or very small it is shown that firms' internationalization strategies are complements. The prediction of the follow-the-leader behaviour in exports is obtained for large enough set-up costs, whereas this behaviour in *FDI* is observed for low enough set-up costs. For intermediate values, firms' internationalization strategies are found to be substitutes: the leader firm invests in both periods and the rival firm enters as an exporter in period two. Switching strategies by the leader firm never arise in equilibrium. The follow-the-leader behaviour still arises under cost substitutabilities with the same qualitative conditions than under cost complementarities. For very large set-up costs all the internationalization strategies chosen by firms are to export. For low enough set-up costs firms will always invest. Relative to cost complementarity, it is worth noting that there is a switching strategy for the leader firm which can be an equilibrium for a sufficiently large level of cost substitutability. Such switching strategy entails the leader firm to initially enter as an exporter, then deciding to invest while the rival exports (oligopolistic reaction by the follower). However, it does not happen for sufficiently low levels of cost substitutability. Finally, a switching strategy where the follower internationalizes via *FDI* is never an equilibrium. These findings throw a number of testable implications. Under learning behaviour it is possible to discriminate between strategic complementarities and substitutabilities by mainly looking at the size of set-up costs. Internationalization processes which occur in steps are only compatible with cost substitutabilities.

This paper is structured in the following manner. The next section describes the model, characterizes the different outcomes and establishes the formal conditions on the model parameters. Section 3 is devoted to the analysis of the equilibrium. We begin by constructing the best responses of firms in period two and characterize the equilibria of the full game by distinguishing the case of cost complementarities and cost substitutabilities. Section 4 briefly concludes.

2 The model

2.1 Description and assumptions

The dynamic game unfolds in two periods and it is organized as follows. Two foreign firms are considering their internationalization strategies into a host market. One of the firms, firm $F1$, is exogenously given the opportunity to enter the host market in the first period. The expression of the inverse demand is the following:

$$p = a - q_{11} \tag{1}$$

where p is the price and q_{11} is the output produced by firm $F1$ in period one. In this first period firm $F1$ chooses its internationalization strategy: via exports (E) or via foreign direct investment (F) and its level of output. As we introduce dynamics in the model there is a second period in which we assume that firm $F1$ is again given the chance to make its mind up about its internationalization strategy. The firm can switch its mode of entry or continue with the same one it entered in the first period. Rather obviously, this decision will be influenced by competition from a foreign rival. Firm $F2$, which is less efficient, has a constant marginal cost $c + \delta$, where $\delta > 0$. In this period both firms, $F1$ and $F2$, decide simultaneously their entry mode between the two possible strategies and then compete in quantities. Inverse demand in period two is given by:

$$p_2 = a - (q_{12} + q_{22}) \tag{2}$$

where p_2 is price in period two, q_{12} is the output produced by firm $F1$ in period two and q_{22} the output produced by firm $F2$ in that period. From now on, we will represent the strategic internationalization decisions by the triplet (s_{11}, s_{12}, s_{22}), where s_{ij} denotes the strategy chosen by firm Fi in period j, $\forall i, j = 1, 2$. In other words, the triplet represents the path of a possible equilibria firms may follow in the game and which are shown in the tree below. For the sake of presentation, Figure 1 does not display firms' output choices to focus on the entry mode choice. Summing up, the model relies on the following structure: linear demand and cost heterogeneities between rival firms.

Each type of internationalization is associated to different cost structures. Entry via exports has an added variable cost t (transport or tariff) and entry via *FDI* leaves the variable cost unchanged but entails a fixed set-up cost G. If firm $F1$ chooses to export in both periods it has to pay t in each period. However, if the firm chooses to do *FDI* in both periods, then it only incurs the fixed cost G once, and saves on the trade cost. This implies that there is some cost advantage to continue doing *FDI* in the second period when this type of internationalization was selected in the first period. How does competition/learning transmit across periods? Through the cost structure of firm $F1$. In particular, variable costs of firm $F1$ are given by $C = cq_{11} + cq_{12} + \lambda q_{11} q_{12}$, where parameter

λ (the inter-period marginal cost) links both periods by interacting the outputs produced in either period. The joint cost function has an interesting property which is given by the sign of the crossed partial derivative, that is,

$$\frac{\partial^2 C}{\partial q_{11} \partial q_{12}} = \lambda \tag{3}$$

The inter-period marginal cost parameter tells that costs are reduced (or increased) in proportion to the product of the outputs in each period. A positive λ implies the cost function exhibiting cost substitutabilities. This is a bad property: as the production of any period increases so does cost, and hence, profits are reduced by this parameter. On the other hand, if λ is negative then the cost function will be said to exhibit cost complementarities, which is a good property because an increase in period one output implies a reduction in total costs. This property of costs can be understood as a positive learning effect: new abilities and some "know-how" are achieved as production grows, allowing the firm to reduce its total variable costs. We will leave the sign of λ undefined and analyze the results in both scenarios: under cost complementarity and under cost substitution.

In this context, we can study, firstly, whether firm $F1$ "switches" its internationalization strategy from exports to *FDI* or vice versa, and secondly, how does firm $F2$ react. As noted in the introduction, Knickerbocker (1973) introduced the notion of oligopolistic reaction (OR) to explain why firms follow rivals into foreign markets. In the tree from Figure 1 we represent all the possible paths of equilibria in the game described. The paths of OR, represented in the tree by the dotted lines, arise when firm $F1$ chooses either strategy E or *FDI* in the first period and there is a follow-the-leader behaviour by firm $F2$ if also choosing E or *FDI*, that is, (E, s_{12}, E) and (F, s_{12}, F). If any of these outcomes happen to be an equilibrium of the game we will say that firms' strategies are complementary. A pure OR path is one where firms choose the same internationalization all the way, that is, (E, E, E) and (F, F, F). On the other hand, we can find also a switching strategy by firm $F1$, thus pointing out an expansion process in steps. This happens when firm $F1$ chooses one internationalization strategy in period two different from the one chosen in the first period, i.e. for (E, F, s_{22}) and (F, E, s_{22}). Notice that the broken lines (E, s_{12}, F)

and (F, s_{12}, E) would imply firms' strategies being substitutes.

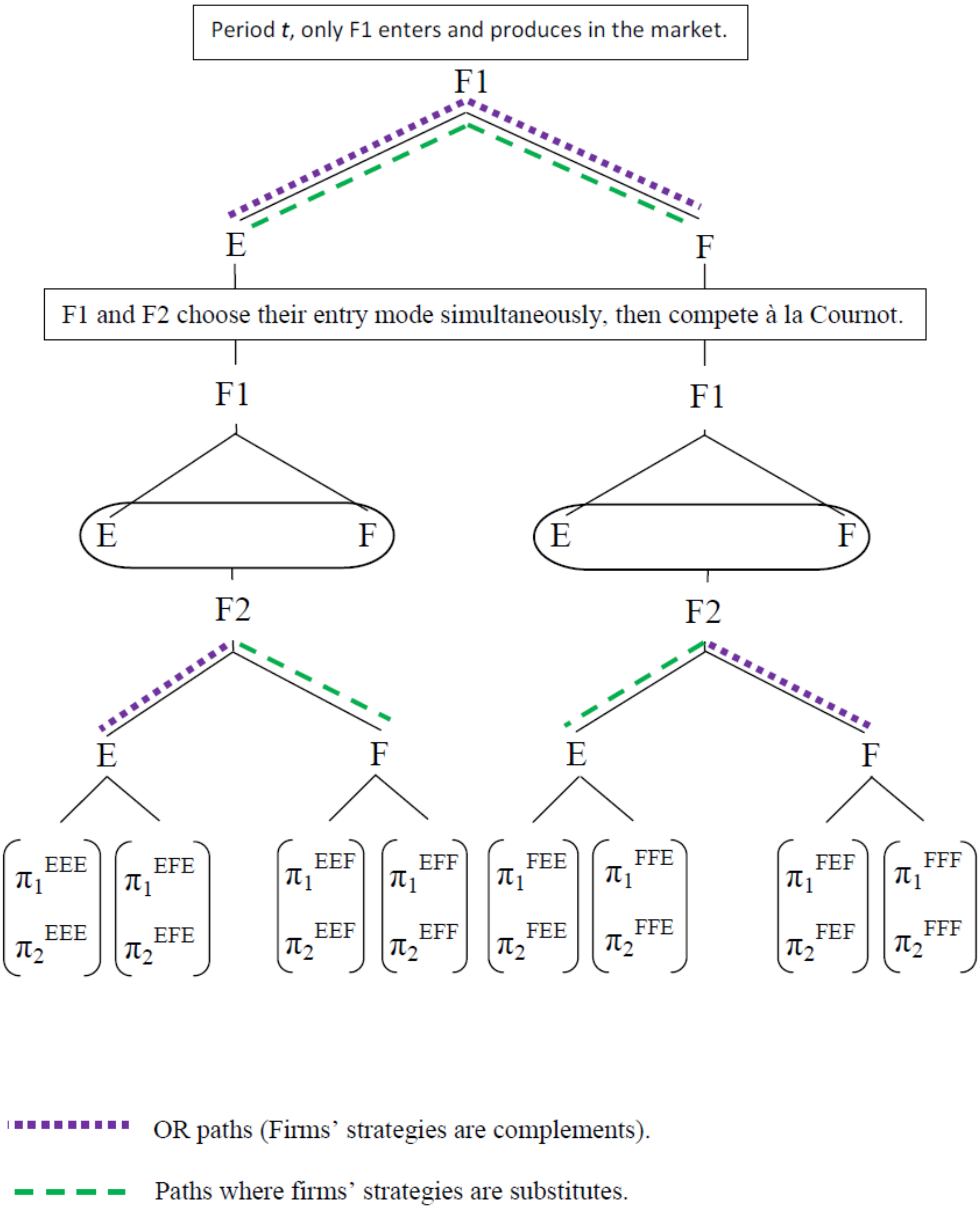

Figure 1. The Equilibrium Paths of Internationalization Strategies.

2.2 Profit maximization

We proceed with the resolution of the game. The profits maximization problem is solved in the standard backward way and it is presented in the following expressions for the case where firm $F1$ chooses the exports strategy in both periods and firm $F2$ also chooses the same strategy (a case of pure oligopolistic reaction), or in short, the triplet $(s_{11}, s_{12}, s_{22}) = (E, E, E)$. Thus we have,

$$\max_{q_{12},q_{11}} \pi_1 = \underbrace{(a - q_{11} - (c+t))q_{11}}_{\substack{\text{Period 1 profits} \\ \text{(absent cost interactions)}}} + \underbrace{(a - (q_{12} + q_{22}) - (c+t))q_{12}}_{\substack{\text{Period 2 profits} \\ \text{(absent cost interactions)}}} - \underbrace{\lambda q_{11} q_{12}}_{\substack{\text{Inter-period} \\ \text{cost term}}} \tag{4}$$

$$\max_{q_{22}} \pi_2 = (a - (q_{12} + q_{22}) - (c + \delta + t))q_{22} \tag{5}$$

Here π_i represents profits of firm i, with $i = 1, 2$. The profits expression for firm $F1$ can be grouped in three terms; the former two are the well-known output times margin terms. The latter highlights the learning and strategic implications of the first period output due to the inter-period marginal cost term. Both firms simultaneously choose the quantity they are going to produce in the second period, so we compute the first order conditions for each firm as:

$$\frac{\partial \pi_1}{\partial q_{12}} = a - c - t - 2q_{12} - q_{22} - \lambda q_{11} = 0 \tag{6}$$

$$\frac{\partial \pi_2}{\partial q_{22}} = a - c - \delta - t - q_{12} - 2q_{22} = 0 \tag{7}$$

from which we can construct the following reaction functions for each firm:

$$q_{12}(q_{11}, q_{22}) = \tfrac{1}{2} (a - c - t - q_{22} - \lambda q_{11}) \tag{8}$$

$$q_{22}(q_{12}) = \tfrac{1}{2} (a - c - \delta - t - q_{12}) \tag{9}$$

Solving $(8) - (9)$ we obtain the subgame perfect equilibrium quantities dependent on the quantity produced by firm $F1$ in the first period:

$$q_{12}(q_{11}) = \tfrac{1}{3} (a - c + \delta - t - 2\lambda q_{11}) \tag{10}$$

$$q_{22}(q_{11}) = \tfrac{1}{3} (a - c - 2\delta - t + \lambda q_{11}) \tag{11}$$

In expressions (10) and (11) we can observe the effect of the inter-period marginal cost on the quantities produced by both firms in period two. Specifically, the quantity produced by firm $F1$ in the second period is increasing in λ, and the opposite occurs with the quantity produced by the rival. This is what happens when λ is negative, so under cost complementarity or learning-by-doing. The quantity produced by firm $F1$ in the second period will rise with quantity produced in the first period. Consequently, total profits of firm $F1$ will increase. However, the quantity produced by firm $F2$ will be reduced by this term because variables are strategic substitutes. So the leader firm has the option to limit the rival's production by raising its q_{11} output. However, the presence of cost substitutability will reverse this argument. Equations (10) and (11) are substituted back in (4) to obtain the profits equation as a function of q_{11}, as follows:

$$\pi_1 = (a - q_{11} - (c+t))q_{11} + \tfrac{1}{9}(a - c - t + \delta - 2q_{11}\lambda)(a - c - t + \delta + q_{11}\lambda) -$$

$$- \tfrac{1}{3}q_{11}\lambda(a - c - t + \delta - 2q_{11}\lambda) =$$

$$= (a - q_{11} - (c+t))q_{11} + \tfrac{1}{9}(a - c - t + \delta - 2q_{11}\lambda)^2 \tag{12}$$

The corresponding FOC is given by:

$$\frac{\partial \pi_1}{\partial q_{11}} = a - c - t - 2q_{11} - \frac{4}{9}\lambda\left(a - c + \delta - t - 2\lambda q_{11}\right) = 0 \tag{13}$$

Using (13) we solve for the equilibrium value of q_{11} and, substituting this value in (10) and (11), we get the equilibrium quantities produced in the second period:

$$q_{11}(E,E,E) = \frac{(a-c-t)(9-4\lambda) - 4\delta\lambda}{2\left(9-4\lambda^2\right)} \tag{14}$$

$$q_{12}(E,E,E) = \frac{3(a-c-t)(1-\lambda) + 3\delta}{(9-4\lambda^2)} \tag{15}$$

$$q_{22}(E,E,E) = \frac{(a-c-t)(6+3\lambda-4\lambda^2) - 4\delta(3-\lambda^2)}{2\left(9-4\lambda^2\right)} \tag{16}$$

Utilizing (14), (15) and (16) in the profit functions (4) and (5), we obtain the equilibrium profits[3] for each firm in the (E,E,E) subgame, given by:

$$\pi_1(E,E,E) = \frac{(a-c)^2(13-8\lambda) + 2(a-c)(4\delta(1-\lambda) - t(13-8\lambda)) + t(t(13-8\lambda) - 8\delta(1-\lambda)) + 4\delta^2}{4\left(9-4\lambda^2\right)} \tag{17}$$

$$\pi_2(E,E,E) = \frac{\left((a-c-t)(6+3\lambda-4\lambda^2) - 4\delta(3-\lambda^2)\right)^2}{4(9-4\lambda^2)^2} \tag{18}$$

[3]We guarantee that these equilibrium profits are a maximum by the SOC, which are detailed later on in the text.

As can it be seen in the game tree from Figure 1, there are seven subgames more to be solved. The structure of the profit functions and calculations are similar, changes are in the variable and/or the fixed costs each type of internationalization implies. For instance, in subgame (F, F, F), where both firms choose *FDI* in every period, the concrete maximization problem will be the following[4]:

$$\max_{q_{12},q_{11}} \pi_1 = \underbrace{(a - q_{11} - c)q_{11}}_{\text{Period 1 profits}} + \underbrace{(a - (q_{12} + q_{22}) - c)q_{12}}_{\text{Period 2 profits}} - \underbrace{\lambda q_{11} q_{12}}_{\substack{\text{Inter-period} \\ \text{cost term}}} - \underbrace{G}_{\substack{\text{Setup} \\ \text{cost}}} \tag{19}$$

$$\max_{q_{22}} \pi_2 = (a - (q_{12} + q_{22}) - (c + \delta))q_{22} - G \tag{20}$$

Compared to the previous subgame, firm $F2$ saves the export cost by choosing *FDI*, but it has to pay the set-up cost G. Besides, as firm $F1$ does the same activity twice, it avoids an increase in its variable cost in both periods and pays only once the set-up cost.

Regarding exclusively variable costs, the (F, F, s_{22}) situation will be the most advantageous one for firm $F1$. In terms of both fixed and variable costs, it will be always better than the switching strategies (E, F, s_{22}) and (F, E, s_{22}) with $s_{22} = E, F$. A priori, given the cost structure of internationalization strategies, we can expect that subgame (F, F, s_{22}) dominates the switching paths, albeit the influence of the strategy selected by firm $F2$ and the sign and magnitude of the parameter λ, make the problem not straightforward.

Following the same order of resolution we report below the equilibrium quantities

[4]Note that expressions, denoted by *Period 1 profits* and *Period 2 profits,* from (19) are presented excluding the cost interaction term.

produced and the profits associated to each of the eight mentioned subgames:

$$\underline{\underline{\text{Subgame } (s_{11}, s_{12}, s_{22}) = (E, E, E)}} \tag{21}$$

$$q_{11} = \frac{(a-c)(9-4\lambda) - t(9-4\lambda) - 4\delta\lambda}{2\left(9-4\lambda^2\right)}$$

$$q_{12} = \frac{3((a-c)(1-\lambda) - t(1-\lambda) + \delta)}{(9-4\lambda^2)}$$

$$q_{22} = \frac{(a-c)(6+3\lambda-4\lambda^2) - t(6+3\lambda-4\lambda^2) - 4\delta(3-\lambda^2)}{2(9-4\lambda^2)}$$

$$\pi_1 = \frac{(a-c)^2(13-8\lambda)+2(a-c)(4\delta(1-\lambda)-t(13-8\lambda))-t(8\delta(1-\lambda)-t(13-8\lambda))+4\delta^2}{4(9-4\lambda^2)}$$

$$\pi_2 = \frac{\left((a-c)(6+3\lambda-4\lambda^2)-t(6+3\lambda-4\lambda^2)-4\delta(3-\lambda^2)\right)^2}{4(9-4\lambda^2)^2}$$

$$\underline{\underline{\text{Subgame } (s_{11}, s_{12}, s_{22}) = (E, F, E)}} \tag{22}$$

$$q_{11} = \frac{(a-c)(9-4\lambda) - t(9+4\lambda) - 4\delta\lambda}{2(9-4\lambda^2)}$$

$$q_{12} = \frac{3((a-c)(1-\lambda) + t(1+\lambda) + \delta)}{(9-4\lambda^2)}$$

$$q_{22} = \frac{(a-c)(6+3\lambda-4\lambda^2) - t(12+3\lambda-4\lambda^2) - 4\delta(3-\lambda^2)}{2(9-4\lambda^2)}$$

$$\pi_1 = \frac{(a-c)^2(13-8\lambda)+2(a-c)(4\delta(1-\lambda)-5t)+t(8\delta(1+\lambda)+t(13+8\lambda))+4\delta^2}{4(9-4\lambda^2)} - G$$

$$\pi_2 = \frac{\left((a-c)(6+3\lambda-4\lambda^2)-t(12+3\lambda-4\lambda^2)-4\delta(3-\lambda^2)\right)^2}{4(9-4\lambda^2)^2} \tag{23}$$

$$\text{Subgame } (s_{11}, s_{12}, s_{22}) = (F, E, E) \tag{24}$$

$$q_{11} = \frac{(a-c)(9-4\lambda) + 4t\lambda - 4\delta\lambda}{2\left(9-4\lambda^2\right)}$$

$$q_{12} = \frac{3((a-c)(1-\lambda) - t + \delta)}{(9-4\lambda^2)}$$

$$q_{22} = \frac{(a-c)(6+3\lambda-4\lambda^2) - 2t(3-2\lambda^2) - 4\delta(3-\lambda^2)}{2(9-4\lambda^2)}$$

$$\pi_1 = \frac{(a-c)^2(13-8\lambda) + 8(a-c)(\delta-t)(1-\lambda) - 4t(2\delta-t) + 4\delta^2}{4(9-4\lambda^2)} - G$$

$$\pi_2 = \frac{\left((a-c)(6+3\lambda-4\lambda^2) - 2t(3-2\lambda^2) - 4\delta(3-\lambda^2)\right)^2}{4(9-4\lambda^2)^2}$$

$$\text{Subgame } (s_{11}, s_{12}, s_{22}) = (F, F, E) \tag{25}$$

$$q_{11} = \frac{(a-c)(9-4\lambda) - 4t\lambda - 4\delta\lambda}{2\left(9-4\lambda^2\right)}$$

$$q_{12} = \frac{3((a-c)(1-\lambda) + t + \delta)}{(9-4\lambda^2)}$$

$$q_{22} = \frac{(a-c)(6+3\lambda-4\lambda^2) - 4t(3-\lambda^2) - 4\delta(3-\lambda^2)}{2(9-4\lambda^2)}$$

$$\pi_1 = \frac{(a-c)^2(13-8\lambda) + 8(a-c)(\delta+t)(1-\lambda) + 4t^2 + 4\delta^2}{4(9-4\lambda^2)} - G$$

$$\pi_2 = \frac{\left((a-c)(6+3\lambda-4\lambda^2) - 4t(3-\lambda^2) - 4\delta(3-\lambda^2)\right)^2}{4(9-4\lambda^2)^2}$$

$$\text{Subgame}(s_{11}, s_{12}, s_{22}) = (E, E, F) \tag{26}$$

$$q_{11} = \frac{(a-c)(9-4\lambda) - t(9-8\lambda) - 4\delta\lambda}{2\left(9-4\lambda^2\right)}$$

$$q_{12} = \frac{3((a-c)(1-\lambda) - t(2-\lambda) + \delta)}{(9-4\lambda^2)}$$

$$q_{22} = \frac{(a-c)(6+3\lambda-4\lambda^2) + 3t(2-\lambda) - 4\delta(3-\lambda^2)}{2(9-4\lambda^2)}$$

$$\pi_1 = \frac{(a-c)^2(13-8\lambda)+2(a-c)(4\delta(1-\lambda)-t(17-12\lambda))-t(8\delta(2-\lambda)-t(25-16\lambda))+4\delta^2}{4(9-4\lambda^2)}$$

$$\pi_2 = \frac{\left((a-c)(6+3\lambda-4\lambda^2)+3t(2-\lambda)-4\delta(3-\lambda^2)\right)^2}{4(9-4\lambda^2)^2} - G$$

$$\text{Subgame } (s_{11}, s_{12}, s_{22}) = (E, F, F) \tag{27}$$

$$q_{11} = \frac{(a-c)(9-4\lambda) - 9t - 4\delta\lambda}{2\left(9-4\lambda^2\right)}$$

$$q_{12} = \frac{3((a-c)(1-\lambda) + t\lambda + \delta)}{(9-4\lambda^2)}$$

$$q_{22} = \frac{(a-c)(6+3\lambda-4\lambda^2) - 3t\lambda - 4\delta(3-\lambda^2)}{2(9-4\lambda^2)}$$

$$\pi_1 = \frac{(a-c)^2(13-8\lambda)+2(a-c)(4\delta(1-\lambda)-t(9-4\lambda))+t(8\delta\lambda+9t)+4\delta^2}{4(9-4\lambda^2)} - G$$

$$\pi_2 = \frac{\left((a-c)(6+3\lambda-4\lambda^2)-3t\lambda-4\delta(3-\lambda^2)\right)^2}{4(9-4\lambda^2)^2} - G$$

$$\underline{\underline{\text{Subgame } (s_{11}, s_{12}, s_{22}) = (F, E, F)}} \tag{28}$$

$$q_{11} = \frac{(a-c)(9-4\lambda) + 8t\lambda - 4\delta\lambda}{2\left(9-4\lambda^2\right)}$$

$$q_{12} = \frac{3((a-c)(1-\lambda) - 2t + \delta)}{(9-4\lambda^2)}$$

$$q_{22} = \frac{(a-c)(6+3\lambda-4\lambda^2) + 6t - 4\delta(3-\lambda^2)}{2(9-4\lambda^2)}$$

$$\pi_1 = \frac{(a-c)^2(13-8\lambda) + 8(a-c)(\delta-2t)(1-\lambda) - 16t(\delta-t) + 4\delta^2}{4(9-4\lambda^2)} - G$$

$$\pi_2 = \frac{\left((a-c)(6+3\lambda-4\lambda^2) + 6t - 4\delta(3-\lambda^2)\right)^2}{4(9-4\lambda^2)^2} - G$$

$$\underline{\underline{\text{Subgame } (s_{11}, s_{12}, s_{22}) = (F, F, F)}} \tag{29}$$

$$q_{11} = \frac{(a-c)(9-4\lambda) - 4\delta\lambda}{2\left(9-4\lambda^2\right)}$$

$$q_{12} = \frac{3((a-c)(1-\lambda) + \delta)}{(9-4\lambda^2)}$$

$$q_{22} = \frac{(a-c)(6+3\lambda-4\lambda^2) - 4\delta(3-\lambda^2)}{2(9-4\lambda^2)}$$

$$\pi_1 = \frac{(a-c)^2(13-8\lambda) + 8(a-c)\delta(1-\lambda) + 4\delta^2}{4(9-4\lambda^2)} - G$$

$$\pi_2 = \frac{\left((a-c)(6+3\lambda-4\lambda^2) - 4\delta(3-\lambda^2)\right)^2}{4(9-4\lambda^2)^2} - G$$

2.2.1 Conditions required in the resolution of the game

To ensure that all the outcomes presented in this paper and detailed above are possible equilibrium paths of the game we need to have positive equilibrium outputs and profits, therefore, we have to establish some conditions described next. We also wish to remark that all of them are taken into account in the specification of the Nash equilibria.

A) The Second Order Condition (SOC)

This condition is necessary to guarantee that we are maximizing profits. The optimum obtained from the First Order Condition *(FOC)* will be a maximum, as long as, the second partial derivative of the profits' expression of each firm, with respect to the output produced by this firm, is negative. In the case of firm $F2$, we can immediately see from (7) that this will be always true. However, in the case of firm $F1$ the sign of the SOC depends on the sign of the inter-period marginal cost term λ. As an example, consider subgame (E, E, E). If we differentiate (12) twice with respect to q_{11}, we obtain the following expression:

$$\frac{\partial^2 \pi_1}{\partial q_{11}^2} = -2 + \frac{8}{9}\lambda^2 < 0 \Rightarrow \lambda^2 < \frac{9}{4} \tag{30}$$

and this condition will be negative for:

$$-(3/2) < \lambda < 3/2 \tag{31}$$

The same SOC is obtained for each of the remaining subgames of the game. So this condition imposes a lower and an upper bound on the magnitude of the inter-period marginal cost λ. Given the mentioned range of values for λ, it is clear that the SOC is also satisfied for the quantity produced by firm $F1$ in period two (q_{12}).

B) Conditions for positive quantities (CPQ).

We use the expressions of quantities calculated in the profit maximization problem and look for the conditions on the oligopoly margin $a - c$ that make outputs positive. For example, in subgame $(s_{11}, s_{12}, s_{22}) = (E, E, E)$ the quantity produced by the more productive firm $F1$ will be positive if:

$$q_{11} = \frac{(a-c)(9-4\lambda) - t(9-4\lambda) - 4\delta\lambda}{2\left(9-4\lambda^2\right)} > 0 \tag{32}$$

which simplifies to[5]:

$$(a-c) > \frac{t(9-4\lambda) + 4\delta\lambda}{(9-4\lambda)} \tag{33}$$

[5] The denominator of (32) is positive by the *SOC*.

We repeat the same pattern of calculation for each quantity - three for each subgame - and, once we have all the conditions, we check which one is the most demanding. To be accurate we calculate these conditions taking into account, on the one hand, the sign of λ values [6] and, on the other, the *SOC.*

For the range $-(3/2) < \lambda \leq 1/8(3-\sqrt{105})$ we cannot ensure positive quantities for both firms and periods, so we establish a new, more restrictive, lower bound on the inter-period marginal cost. For the rest of values, we relate below the most restrictive *CPQ*:

$B.1)$ If $\frac{1}{8}(3-\sqrt{105}) \simeq -0.906 < \lambda \leq 0 \rightarrow$ cost complementarities.

$$a-c > \frac{4(t+\delta)(3-\lambda^2)}{(6+3\lambda-4\lambda^2)}$$

B.2) If $0 < \lambda < 1 \rightarrow$ cost substitutabilities.

$$a-c > \frac{2t-\delta}{(1-\lambda)} \qquad \text{when} \quad 0 < \delta \leq \frac{t\lambda\left(15-\lambda-4\lambda^2\right)}{(2-\lambda)\left(9-4\lambda^2\right)}$$

$$a-c > \frac{3t\lambda+4(t+\delta)(3-\lambda^2)}{(6+3\lambda-4\lambda^2)} \quad \text{when} \quad \delta > \frac{t\lambda\left(15-\lambda-4\lambda^2\right)}{(2-\lambda)\left(9-4\lambda^2\right)}$$

B.3) If $1 < \lambda < \frac{3}{2} \rightarrow$ cost substitutabilities.

$$\frac{2t-\delta}{(1-\lambda)} > a-c > \frac{3t\lambda+4(t+\delta)(3-\lambda^2)}{(6+3\lambda-4\lambda^2)} \text{ when } \delta > \frac{t\lambda\left(15-\lambda-4\lambda^2\right)}{(2-\lambda)\left(9-4\lambda^2\right)}$$

C) Positive marginal costs for F1

Since the marginal cost of firm $F1$ depends on λ, whose sign is open we also need to guarantee that these costs are positive. We compute the partial derivative of the total cost function, with respect to the quantity produced in each period, to obtain the following expressions:

$$\frac{\partial C}{\partial q_{11}} = c+\lambda q_{12} > 0 \text{ and } \frac{\partial C}{\partial q_{12}} = c+\lambda q_{11} > 0$$

[6] The inter-period marginal cost λ appears in the denominator of some CPQ, so we create different intervals for λ depending on the value that makes these denominators equal to zero.

Since the equilibrium quantities also depend on λ we rearrange the conditions and look for the most demanding one for each interval of the inter-period marginal cost. In this case we obtain two different restrictions on c:

C.1) If cost complementarities, $\frac{1}{8}(3-\sqrt{105}) < \lambda \leq 0$, then it is required that:

$$c > \frac{\lambda(9a - 4\lambda(a+t+\delta))}{(-18+9\lambda+4\lambda^2)}$$

C.2) If cost substitutabilities, $0 < \lambda < \frac{3}{2}$, then it is required that: $c > 0$

D) Conditions for positive profits (CPP).

In all the expressions of profits under *FDI* choices, an upper bound on the level of the set-up cost must be established. There are ten different conditions on G. We have been unable to reduce these conditions to a unique most demanding one because of the complexity of the expressions and the high number of parameters and conditions needed to be fulfilled at the same time. The way in which we have proceeded to guarantee non negative profits has been by checking all *CPP*, once we have obtained the equilibrium paths. For the calculation of the equilibrium paths we construct the bounds (denoted by b_i) related to the best responses of firms and detailed below in equations $(34)-(37)$ and $(40)-(41)$. The position of the set-up cost G relative to these bounds determines the subgame perfect Nash equilibrium (*SPNE*) of the game. Then, we can verify that indeed the *CPP* can be above the most demanding bi bounds. If so, this means that there exists an interval where the upper bound on the set-up cost established by *CPP* will not constrain any of the *SPNE* we obtain and all the equilibrium profits will be positive. Therefore, we will confirm the existence of the corresponding interval for the ten conditions on G.

3 The equilibrium

3.1 Construction of the Best Responses of firms

Once we have all profits expressions, in order to solve the game, we need to study which equilibrium paths firms will decide to follow. Solving backwards, we analyze first the second period where the entry decisions are simultaneously taken by both firms. We start by defining the best responses (BRs) of firm $F1$ in the second period to the strategy chosen in each case by its rival, and similarly for firm $F2$. Those best responses are constructed comparing the profits of one firm when it exports to the profits it will obtain under the alternative strategy, *FDI*, for a given choice by the rival. This implies that firm $F1$ has one BR if firm $F2$ exports and another BR, which can coincide or not, when the rival decides to invest abroad. So these BRs will represent the path the firms could follow in the second period and obviously not all paths will end up being part of the Nash equilibrium. To illustrate, we show an example of how the first bound, $b1$, on G is constructed as linked to one best response by firm $F1$. Suppose firm $F1$ was an exporter in period one. Then, given that the rival firm $F2$ exports in period two, the E vs *FDI* decision for firm $F1$ amounts to comparing $\Pi_1(E, E, E)$ and $\Pi_1(E, F, E)$. So firm $F1$ decides to enter via exports - given that firm $F2$ follows the rival's strategy - when $G > b1$. This would mean that firm $F1$ will use the same strategy in both periods. However, if $G < b1$ then the BR by firm $F1$ would be to switch its strategy in the second period and now enter via *FDI*. The following bounds are calculated proceeding in the same manner to characterize the BR of firms $F1$ and $F2$ for the second period:

$$\Pi_1(E, E, E) > \Pi_1(E, F, E) \Rightarrow G > \frac{4t((a-c)(1-\lambda)+t\lambda+\delta)}{(9-4\lambda^2)} \equiv b1 \tag{34}$$

$$\Pi_1(E, E, F) > \Pi_1(E, F, F) \Rightarrow G > \frac{4t((a-c)(1-\lambda)-t(1-\lambda)+\delta)}{(9-4\lambda^2)} \equiv b2 \tag{35}$$

$$\Pi_2(E, E, E) > \Pi_2(E, E, F) \Rightarrow G > \frac{2t(3-\lambda^2)((a-c)(6+3\lambda-4\lambda^2)-t\lambda(3-2\lambda)-4\delta(3-\lambda^2))}{(9-4\lambda^2)^2} \equiv b3 \tag{36}$$

$$\Pi_2(E, F, E) > \Pi_2(E, F, F) \Rightarrow G > \frac{2t(3-\lambda^2)((a-c)(6+3\lambda-4\lambda^2)-t(6+3\lambda-2\lambda^2)-4\delta(3-\lambda^2))}{(9-4\lambda^2)^2} \equiv b4 \tag{37}$$

$$\Pi_1(F, E, E) > \Pi_1(F, F, E) \Rightarrow \ FALSE \Rightarrow F1 \text{ has a Dominant Strategy: } \textit{FDI} \tag{38}$$

$$\Pi_1(F, E, F) > \Pi_1(F, F, F) \Rightarrow \ FALSE \Rightarrow F1 \text{ has a Dominant Strategy: } \textit{FDI} \tag{39}$$

$$\Pi_2(F, E, E) > \Pi_2(F, E, F) \Rightarrow G > \frac{2t(3-\lambda^2)((a-c)(6+3\lambda-4\lambda^2)+2t\lambda^2-4\delta(3-\lambda^2))}{(9-4\lambda^2)^2} \equiv b5 \tag{40}$$

$$\Pi_2(F, F, E) > \Pi_2(F, F, F) \Rightarrow G > \frac{2t(3-\lambda^2)((a-c)(6+3\lambda-4\lambda^2)-2t(3-\lambda^2)-4\delta(3-\lambda^2))}{(9-4\lambda^2)^2} \equiv b6 \tag{41}$$

Notice that we have only six, and not eight bounds[7], because when the leader firm enters the market in the first period via investment, it has a dominant strategy which is to continue doing the same activity, regardless of the strategy chosen by the rival. This is an intuitive result because, once firm $F1$ has made the investment in the new market, switching to internationalize via exports would just increase its marginal cost; since all other costs remain the same, switching is not worthy.

The next step is to match these best responses to obtain the path of the Nash equilibrium in the second period. To simplify calculations we first analyze the ordering among the six bounds and we get that $\forall\lambda$:

$$b1 > b2, \quad b3 > Max\{b4, b6\} \quad \text{and} \quad b5 > Max\{b4, b6\} \tag{42}$$

With the conditions in (42), the initial 720 possible orderings[8] reduce to only sixteen. Taking one possible ordering at a time, we will also use the relative position of the set-up cost, G, to define an associated equilibrium path. We will represent the equilibrium path as a pair of triplets:

$$(E, s_{12}, s_{22}) - (F, s_{12}, s_{22})$$

where s_{12} and s_{22} stand for the given choices in the second period under the BR strategies, obtained from the position of the six bounds and set-up cost G. Initially, we can have sixteen equilibrium paths in our outline, when unicity is assumed[9], but taking into account the dominant strategies obtained for firm $F1$ in $(38) - (39)$ the number will be reduced to a half: only eight equilibrium paths.

Before getting inside the resolution of the full game, we need to take consider the sign of the inter-period marginal cost λ. For this reason, we are going to express the equilibrium paths distinguishing between cost substitutabilities and cost complementarities trying to draw any remarkable differences in the Nash equilibria.

[7] All bounds are positive under the conditions we have established.

[8] The number of possible rankings of bounds is obtained from $6! = 720$, as we have six different bounds to be ordered.

[9] The number of possible equilibrium paths is obtained multiplying the four different equilibria that we can have in the second period: (E, E), (E, F) , (F, E) and (F, F) times the other four when $s_{11} = F$. However, if we include a multiple equilibrium: (E, F) and (F, E), then the total number of possible equilibrium paths rises to 25 (5 x 5).

3.2 Possible paths and the equilibrium under cost complementarities

First we start with the case when λ is negative, so when there are cost complementarities. This scenario is preferable for firm $F1$, since it implies that profits rise with the increase of production in each period. The production cost of one period is complementary to the one in the other period so that total costs can be reduced by producing more in any period. This case would definitely match with the so-called learning behaviour. Computing again the comparison of bounds when $1/8(3-\sqrt{105}) < \lambda < 0$ we get all these additional orderings among them:

$$b1 > Max\{bi\}, \forall i \neq 1, \quad b2 > b4 > b6 \quad \text{and} \quad b3 > b5 \tag{43}$$

When we consider simultaneously (42) and (43) there last only three possible ways to rank the six bounds:

$$b1 > b2 > b3 > b5 > b4 > b6 \tag{44}$$

$$b1 > b3 > b2 > b5 > b4 > b6 \tag{45}$$

$$b1 > b3 > b5 > b2 > b4 > b6 \tag{46}$$

Despite having only three possible classifications, remind the level of the set-up cost is not bounded. This implies that there is a possibility to have a set-up cost G above the maximum bound $b1$, below the minimum $b6$, or in the middle. Given the position of G we find seven subcases for each ordering and each of them represents one equilibrium path. What we do in Table 1, is to summarize the conditions on the set-up cost associated to each possible equilibrium path:

If $s_{11} = E$	If $s_{11} = F$	When the set-up cost is:
(E,E)	(F,E)	$G > b1$
(F,E)	(F,E)	$b1 > G > b3$ and $b2 > G > b4$
(F,E) or (E,F)	(F,E)	$b3 > G > b2$
(F,F)	(F,E)	$b4 > G > b6$
(F,F)	(F,F)	$b6 > G$

Table 1. The Equilibrium Path of Period 2 under Cost Complementarities.

Now, moving upwards, we turn to the first period where only firm $F1$ has the possibility to enter the market. Which strategy will be chosen by firm $F1$ in the first period when anticipating the possible equilibrium in the second period? To answer this question we compare, for each level of set-up cost - row by row from Table 1 - the profits that it will obtain following the equilibrium path when it chooses to export in the first period (E, s_{12}, s_{22}) with the equilibrium path when the decision in the first period is to invest (F, s_{12}, s_{22}). For example, for the specific case when the set-up cost is large enough, when $G > b1$ - first row from Table 1 - we compare $\Pi_1(E, E, E)$ against $\Pi_1(F, F, E)$. The following inequality: $\Pi_1(E, E, E) > \Pi_1(F, F, E)$ holds true for a sufficiently large set-up cost. This comparison results in a new bound on G:

$$G > \frac{t\,(2(a-c)(17-12\lambda) - t(9-8\lambda) + 8\delta(2-\lambda))}{4(9-4\lambda^2)} \equiv \beta 1 \tag{47}$$

We can prove that the new bound is operative[10], which means it can be greater than $b1$. The complete analysis leads to the next proposition.

Proposition 1 *Subject to the fulfillment of the CPP, the equilibrium of the game under cost complementarities is either*

I) The pure oligopolistic reaction outcome where firm F1 chooses the same strategy in both periods and it is followed by the rival firm F2

i) in exports, (E, E, E) *when* $G > \beta 1$,

ii) in foreign direct investment, (F, F, F) *when* $b6 > G$, *or*

II) The outcome where firm F1 chooses the investment strategy in both periods and the rival firm F2 follows the opposite strategy (F, F, E), *when* $\beta 1 > G > b6$.

Summarizing, the most efficient firm will always decide to invest in both periods unless the level of set-up cost is prohibitive. When we assume cost complementarities, as the most efficient firm has the advantage to move first and the learning-by-doing effect increases the cost gap between the firms in period two, we can observe monotonicity in productivity thresholds (part II of Proposition 1). This interpretation follows from the fact that firm $F1$ does *FDI* while the rival less efficient firm exports. Note that this result was kind of expected considering, by the previous argument, the outcome (E, E, F) which would imply a break in the monotonicity, cannot be an equilibrium.

[10]We check also the plausibility of these interval on G by the CPP.

A switching behaviour where firm $F1$ first exports and then invests is dominated by investment in both periods. This is so because the latter implies avoiding the variable export cost, while only incurring the setup cost once. This saving argument is reinforced by the learning-by-doing effect. As already noted, firm $F1$'s reaction function in period two shifts outwards when λ is negative. Such an outward shift is lessened would the leader firm choose to export as t is subtracting. Thus, choosing to invest it can further profit from cost complementarity since, for a given λ, the reaction shifts outwards more as period one output increases.

3.3 Possible paths and the equilibrium under cost substitutabilities

We repeat the same pattern of analysis for positive values of the inter-period parameter cost, where $\lambda \in \left[0, \frac{3}{2}\right]$. This is the less preferred scenario for firm $F1$ because the cost function has cost substitutabilities, so we expect to obtain different results from the previous case. Under these values of λ there are two additional sequences between bounds to those from (42). These are:

$$b3 < b5 \quad \text{and} \quad b4 < b6 \tag{48}$$

Combining all the relationships from (42) and (48) we find out that $b1 > b2$ and $b5 > b3 > b6 > b4$.

This means the position of the pair $b1$ and $b2$ is not fixed between the remaining bounds; changing their position we can obtain fifteen different cases. However, taking into account the conditions of our model specified above, we reduce this number by excluding some cases. When $0 < \lambda < 1$, the remaining cases are only nine: I$-$V, VII$-$VIII and X and XII, as it is indicated in Table 2 below. However, when $1 < \lambda < \frac{3}{2}$ all twelve orderings from Table 2 are possible.

I.	$b5 > b3 > \mathbf{b1} > b6 > b4 > \mathbf{b2}$
II.	$b5 > b3 > b6 > \mathbf{b1} > b4 > \mathbf{b2}$
III.	$b5 > b3 > b6 > b4 > \mathbf{b1} > \mathbf{b2}$
IV.	$b5 > \mathbf{b1} > b3 > b6 > \mathbf{b2} > b4$
V.	$b5 > b3 > \mathbf{b1} > b6 > \mathbf{b2} > b4$
VI.	$b5 > b3 > b6 > \mathbf{b1} > \mathbf{b2} > b4$
VII.	$\mathbf{b1} > b5 > b3 > \mathbf{b2} > b6 > b4$
VIII.	$b5 > \mathbf{b1} > b3 > \mathbf{b2} > b6 > b4$
IX.	$b5 > b3 > \mathbf{b1} > \mathbf{b2} > b6 > b4$
X.	$\mathbf{b1} > b5 > \mathbf{b2} > b3 > b6 > b4$
XI.	$b5 > \mathbf{b1} > \mathbf{b2} > b3 > b6 > b4$
XII.	$\mathbf{b1} > \mathbf{b2} > b5 > b3 > b6 > b4$

Table 2. Possible Orderings of Bounds under Cost Substitutabilities.

As it is done for negative values of the inter-period marginal cost, we compute the seven subcases for each bound ordering in Table 2 by placing the set-up cost in between the bounds.

If $s_{11} = E$	If $s_{11} = F$	When the set-up cost is:
(E,E)	(F,E)	$G > \max\{b1, b3\}$
(E,F)	(F,E)	$b5 > b3 > G > \max\{b1, b6\}$
(F,E)	(F,E)	$b1 > G > b3$ or $b2 > G > b6$
(F,E) or (E,F)	(F,E)	$\min\{b1, b3\} > G > \max\{b2, b6\}$
(E,F)	(F,F)	$b4 > G > b2$ or $b6 > G > \max\{b1, b4\}$
(F,E)	(F,F)	$\min\{b2, b6\} > G > b4$
(F,E) or (E,F)	(F,F)	$\min\{b1, b6\} > G > \max\{b2, b4\}$
(F,F)	(F,F)	$\min\{b2, b4\} > G$

Table 3. The Equilibrium Path of Period 2 under Cost Substitutabilities.

Despite there are three cases less for λ below one, this does not affect the equilibrium paths obtained for the different values of G we describe in Table 3. From the equilibrium paths we can derive some initial clear differences with the case under cost complementarities: the number of paths has doubled and two of them involve multiplicity of equilibria under $s_{11} = E$. Moving up to period one we can characterize the equilibrium in internationalization strategies of the full game. The next result arises.

Proposition 2 *Subject to the fulfillment of the CPP, the equilibrium of the game under cost substitutabilities is either*

I) The pure oligopolistic reaction outcome where firm F1 chooses the same strategy in both periods and it is followed by the rival firm F2

i) in exports, (E, E, E)*, when* $G > \max\{\beta 1, b3\}$*,*

ii) in foreign direct investment, (F, F, F)*, when* $b6 > G$ *.*

For case ii) when $b6 > G > b1$ *and* $b4 > G > b2$ *there is an additional upper bound on the set-up cost, concretely* $\beta 3 > G$*; and when* $\min\{b1, b6\} > G > b4$*, there is an additional lower bound on the oligopoly margin:* $a - c > \frac{1}{10}(t(13 + 8\lambda) + 8\delta(1 + \lambda))$*, or*

II) The outcome where firm F1 chooses the same strategy in both periods and the rival firm F2 follows the opposite strategy

iii) in exports, (E, E, F)*, when* $b3 > G > \max\{b6, \beta 2\}$*,* $b6 > G > \max\{b1, b4, \beta 3\}$ *and* $b4 > G > \max\{b2, \beta 3\}$*,*

iv) in foreign direct investment, (F, F, E)*, when* $\beta 1 > G > b6$*,*

For case iv) when $b5 > b3 > G > \max\{b6, b1\}$*, there is an additional upper bound on the set-up cost:* $\beta 2 > G$*, or*

III) The switching outcome (E, F, E)*, when* $\min\{b1, b6\} > G > b4$ *with an additional upper bound on the oligopoly margin:* $a - c < \frac{1}{10}(t(13 + 8\lambda) + 8\delta(1 + \lambda))$*.*

Where $\beta 1 = \frac{t(2(a-c)(17-12\lambda)-t(9-8\lambda)+8\delta(2-\lambda))}{4(9-4\lambda^2)}$*,* $\beta 2 = \frac{t((2(a-c)-t)(21-16\lambda)+8\delta(3-\lambda))}{4\left(9-4\lambda^2\right)}$ *and* $\beta 3 = \frac{t(2(a-c)(17-12\lambda)-t(25-16\lambda)+8\delta(2-\lambda))}{4\left(9-4\lambda^2\right)}$*.*

Corollary *Under cost substitutabilities:*

I) The outcome (E, F, F) *is never an equilibrium of the game.*

II) The outcome (E, F, E) *does not arise in equilibrium for* $\lambda \in (0, 1)$*.*

As expected, we can see how the presence of cost substitutabilities complicates the analysis and increases the number of different equilibria. However, there are some interesting conclusions worth mentioning. True to form, when firm $F1$ starts investing in the first period, it will never switch to export independently of the type of linkage between periods through costs. However, the outcome (E, F, E) can be an equilibrium of the game, thus suggesting a particular process of internationalization first via exports and then switching to investment. This occurs for strong cost substitutability. There is a lot to lose if it invested in period one. So it prefers to export, which entails higher variable cost, to decrease period one output. In this manner, the effect of cost substitutability is attenuated and the leader firm can be in a better position to compete in period two.

The pure oligopolistic reaction equilibria are still observed, and conditions leading to these outcomes are qualitatively similar to those under cost complementarity: exports all the way is observed, when the set-up costs are large enough, whereas investment all the way is observed, when they are low enough. Finally, note the outcome (E, E, F) arises as an equilibrium under some conditions. Thus, Proposition 2 discloses that cost substitutability can also be a cause to achieve the break in the monotonicity of productivity thresholds.

4 Conclusions

This paper has developed a simple model to study the oligopolistic reaction in the presence of cost linkages across periods. The analysis has distinguished between cost complementarities − the case of learning-by-doing − and cost substitutabilities. We have illustrated the well-known follow-the-leader behaviour under a number of testable conditions. If production in period one diminishes marginal cost in period two then, the size of the set-up cost associated to *FDI,* determines whether firms' internationalization strategies are complements or substitutes. Interestingly, the leader never finds it profitable to switch strategies between periods. If, on the other hand, production in period one increases marginal cost in period two, one can still observe the follow-the-leader behaviour. Relative to cost complementarity, it is worth noting that now the leader firm can switch its strategy for sufficiently high values of cost substitutability. Such switching strategy entails the leader firm to initially enter as an exporter and then deciding to invest while the rival exports (oligopolistic reaction by the follower). An internationalization process in steps starting with *FDI* and followed by exports cannot be an equilibrium, which calls for further empirical analysis.

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5 Appendix

5.1 Appendix 1. Proof of Proposition 1

In this Appendix we prove the equilibria obtained under cost complementarities expressed in Proposition 1. This approach is associated to the BRs of firm $F1$ in period one, given the equilibrium path which will arise in period two. Firm $F1$ decides to enter the market for the first time via exports or via *FDI* by checking whether $\Pi_1(E, s_{12}, s_{22}) > \Pi_1(F, s_{12}, s_{22})$. The strategies arising in the second period s_{12} and s_{22} in each case, will depend on the concrete level of set-up costs defined on its relationship to the bounds bi, $\forall i = 1, ..., 6$, from Subsection 3.3.2, for $\lambda \in (1/8(3 - \sqrt{105}), 0)$.

CASE 1) When $G > b1$, firm $F1$ decides its internationalization strategy by comparing the following equilibrium outcomes. This comparison results in a new bound on G:

$$\Pi_1(E, E, E) > \Pi_1(F, F, E) \quad \text{iff} \quad G > \tfrac{t(2(a-c)(17-12\lambda)-t(9-8\lambda)+8\delta(2-\lambda))}{4(9-4\lambda^2)} \equiv \beta 1 \tag{49}$$

We now need to know if the new bound $\beta 1$ is operative, that is if $\beta 1 > b1$, or not. Specifically, in this case the new bound is always greater than $b1$, so it imposes a new restriction on the set-up cost. Summarizing:

- Firm $F1$ will choose to export in the first period and the outcome (E, E, E) will be the equilibrium of the game iff $G > \beta 1$, however,

- Firm $F1$ will choose to invest in the first period and the outcome (F, F, E) will be the equilibrium of the game iff $\beta 1 > G > b1$.

CASE 2) When $b1 > G > b3$ and $b2 > G > b4$, firm $F1$ decides its internationalization strategy by comparing the following equilibrium outcomes, resulting in a new bound on the oligopoly margin $a - c$:

$$\Pi_1(E, F, E) > \Pi_1(F, F, E) \quad \text{iff} \quad a - c < \tfrac{9t+8\lambda(t+\delta)}{2(9-4\lambda)} \tag{50}$$

This condition will not hold since $CPQ > \frac{9t+8\lambda(t+\delta)}{2(9-4\lambda)}$, thus $a - c > \frac{9t+8\lambda(t+\delta)}{2(9-4\lambda)}$. Therefore,

- Firm $F1$ will choose to invest in the first period and the outcome (F, F, E) will be the equilibrium of the game, when $b1 > G > b3$ and $b2 > G > b4$.

CASE 3) When $b3 > G > b2$, firm $F1$ decides its internationalization strategy by comparing the following equilibrium outcomes, with the particularity that under the (E, s_{12}, s_{22}) path we can have multiplicity of equilibria:

$$\Pi_1(E,F,E) > \Pi_1(F,F,E) \quad \text{iff} \quad a-c < \tfrac{9t+8\lambda(t+\delta)}{2(9-4\lambda)} \tag{51}$$

$$\Pi_1(E,E,F) > \Pi_1(F,F,E) \quad \text{iff} \quad G > \tfrac{t((2(a-c)-t)(21-16\lambda)+8\delta(3-\lambda))}{4(9-4\lambda^2)} \equiv \beta 2 \tag{52}$$

From CASE 2) above, we know the first inequality will be false. For the second inequality, we check the relationship between the new bound $\beta 2$ on the set-up cost with the initial ones we have in this path. The relationship is: $\beta 2 > b3 > G$, which means that the second inequality is also false. Therefore,

- Firm $F1$ will choose to invest in the first period and the outcome (F, F, E) will be the equilibrium of the game when $b3 > G > b2$.

CASE 4) When $b4 > G > b6$, firm $F1$ decides its internationalization strategy by comparing the following equilibrium outcomes, this resulting in a new bound on the oligopoly margin $a - c$:

$$\Pi_1(E,F,F) > \Pi_1(F,F,E) \quad \text{iff} \quad a-c < \tfrac{5t-8\delta(1-\lambda)}{2(13-8\lambda)} \tag{53}$$

This condition will not hold since $CPQ > \frac{5t-8\delta(1-\lambda)}{2(13-8\lambda)}$, thus $a-c > \frac{5t-8\delta(1-\lambda)}{2(13-8\lambda)}$. Therefore,

- Firm $F1$ will choose to invest in the first period and the outcome (F, F, E) will be the equilibrium of the game, when $b4 > G > b6$.

CASE 5) When $b6 > G$, firm $F1$ decides its internationalization strategy by comparing the following equilibrium outcomes:

$$\Pi_1(E,F,F) > \Pi_1(F,F,F) \quad \text{iff} \quad a-c < \tfrac{9t+8\delta\lambda}{2(9-4\lambda)} \tag{54}$$

This condition will not hold since $CPQ > \frac{9t+8\delta\lambda}{2(9-4\lambda)}$, thus $a - c > \frac{9t+8\delta\lambda}{2(9-4\lambda)}$. Therefore,

- Firm $F1$ will choose to invest in the first period and the outcome (F, F, F) will be the equilibrium of the game, when $b6 > G$.

5.2 Appendix 2. Proof of Proposition 2

In this Appendix we prove the equilibrium conditions obtained under cost substitutabilities and summarized in Proposition 2 and the Corollary. The resolution of the game is similar to the one conducted under cost complementarities. Nevertheless, now there are more equilibrium paths in the analysis of the best responses of firm $F1$ to the equilibrium that will arise in period two under each internationalization strategy. In short, firm $F1$ here is also comparing its profits: $\Pi_1(E, s_{12}, s_{22}) > \Pi_1(F, s_{12}, s_{22})$, for any given strategies s_{12} and s_{22} depending on the level of set-up costs considered in each case from Table 3 in Subsection 3.3.3, when $\lambda \in (0, 3/2)$.

CASE 1) When $G > \max\{b1, b3\}$, firm $F1$ decides its internationalization strategy by comparing the following equilibrium outcomes, which results in a new bound on G:

$$\Pi_1(E, E, E) > \Pi_1(F, F, E) \quad \text{iff} \quad G > \tfrac{t(2(a-c)(17-12\lambda)-t(9-8\lambda)+8\delta(2-\lambda))}{4(9-4\lambda^2)} \equiv \beta 1 \tag{55}$$

We now check whether $\beta 1$ is operative, that is, if $\beta 1 > \max\{b1, b3\}$ or not. Specifically, in this case the new bound will be always greater when $\max\{b1, b3\} = b1$, and can also be greater when $\max\{b1, b3\} = b3$. This means that as the bound can be operative it must be taken into account in the resolution of the equilibrium in this case. Summarizing:

- Firm $F1$ will choose to export in the first period and the outcome (E, E, E) will be the equilibrium of the game iff $G > \max\{b3, \beta 1\}$, however,
- Firm $F1$ will choose to invest in the first period and the outcome (F, F, E) will be the equilibrium of the game iff $\beta 1 > G > \max\{b1, b3\}$.

CASE 2) When $b5 > b3 > G > \max\{b1, b6\}$, firm $F1$ decides its internationalization strategy by comparing the following equilibrium outcomes, which results in a new bound on the oligopoly margin $a - c$:

$$\Pi_1(E, E, F) > \Pi_1(F, F, E) \quad \text{iff} \quad G > \tfrac{t((2(a-c)-t)(21-16\lambda)+8\delta(3-\lambda))}{4\left(9-4\lambda^2\right)} \equiv \beta 2 \tag{56}$$

Putting together the new bound $\beta 2$ with the initial conditions on the set-up cost we obtain $\beta 2 > G$ when $\max\{b1, b6\} = b1$, but this relationship is not unique when $\max\{b1, b6\} = b6$. This means that the bound can be operative. Summarizing:

- Firm $F1$ will choose to export in the first period and the outcome (E, E, F) will be the equilibrium of the game iff $b5 > b3 > G > \max\{b6, \beta 2\}$, however,

- Firm $F1$ will choose to invest in the first period and the outcome (F, F, E) will be the equilibrium of the game iff $b5 > b3 > G > \max\{b1, b6\}$ and $\beta 2 > G$.

CASE 3) When $b1 > G > b3$ and $b2 > G > b6$, firm $F1$ decides its internationalization strategy by comparing the following equilibrium outcomes, that results in a new bound on the oligopoly margin $a - c$:

$$\Pi_1(E, F, E) > \Pi_1(F, F, E) \quad \text{iff} \quad a - c < \tfrac{9t+8\lambda(t+\delta)}{2(9-4\lambda)} \tag{57}$$

This condition will not hold since all the different CPQ are greater than the bound on the oligopoly margin from (57), thus $a - c > \frac{9t+8\lambda(t+\delta)}{2(9-4\lambda)}$. Therefore,

- Firm $F1$ will choose to invest in the first period and the outcome (F, F, E) will be the equilibrium of the game, when $b1 > G > b3$ or $b2 > G > b6$.

CASE 4) When $\min\{b1, b3\} > G > \max\{b2, b6\}$, firm $F1$ decides its internationalization strategy by comparing the following equilibrium outcomes, with the particularity of having multiplicity of equilibria under the (E, s_{12}, s_{22}) path:

$$\Pi_1(E, E, F) > \Pi_1(F, F, E) \quad \text{iff} \quad G > \tfrac{t((2(a-c)-t)(21-16\lambda)+8\delta(3-\lambda))}{4\left(9-4\lambda^2\right)} \equiv \beta 2 \tag{58}$$

$$\Pi_1(E, F, E) > \Pi_1(F, F, E) \quad \text{iff} \quad a - c < \tfrac{9t+8\lambda(t+\delta)}{2(9-4\lambda)} \tag{59}$$

For the first inequality we check the relationship of the bound $\beta 2$ and the set-up cost. We verify that in any case $\beta 2 > \min\{b1, b3\}$ and this means that the inequalities from (58) will be false. From CASE 3) in cost substitutabilities, we know that $a-c > \frac{9t+8\lambda(t+\delta)}{2(9-4\lambda)}$, so the second inequality will be false too. Therefore,

- Firm $F1$ will choose to invest in the first period and the outcome (F, F, E) will be the equilibrium of the game when $\min\{b1, b3\} > G > \max\{b2, b6\}$.

CASE 5) When $b4 > G > b2$ and $b6 > G > \max\{b1, b4\}$, firm $F1$ decides its internationalization strategy by comparing the following equilibrium outcomes:

$$\Pi_1(E, E, F) > \Pi_1(F, F, F) \quad \text{iff} \quad G > \tfrac{t(2(a-c)(17-12\lambda)-t(25-16\lambda)+8\delta(2-\lambda))}{4\left(9-4\lambda^2\right)} = \beta 3 \tag{60}$$

As usual, we compare the new bound $\beta 3$ with the level of set-up cost from the specific CASE 5) when λ is positive. For $b4 > G > b2$, the relationship of the set-up cost and the bound $\beta 3$ depends on the specific values of the parameters. However, in the other situation, where $b6 > G > \max\{b1, b4\}$, when $\max\{b1, b4\} = b1$ then $\beta 3 > G$ iff $0 < \lambda < 1$; otherwise the ordering is unclear. Summarizing:

- Firm $F1$ will choose to export in the first period and the outcome (E, E, F) will be the equilibrium of the game iff $b4 > G > \max\{b2, \beta 3\}$ or $b6 > G > \max\{b1, b4, \beta 3\}$, however,

- Firm $F1$ will choose to invest in the first period and the outcome (F, F, F) will be the equilibrium of the game, when $\min\{b4, \beta 3\} > G > b2$ or $\min\{b6, \beta 3\} > G > \max\{b1, b4\}$.

CASE 6) When $\min\{b2, b6\} > G > b4$, firm $F1$ decides its internationalization strategy by comparing the following equilibrium outcomes:

$$\Pi_1(E, F, E) > \Pi_1(F, F, F) \quad \text{iff} \quad a - c < \tfrac{t(13+8\lambda)+8\delta(1+\lambda)}{10} \tag{61}$$

Inequality (61) will not hold when $\lambda \in (0, 1)$ because the CPQ in this case is greater than $\frac{t(13+8\lambda)+8\delta(1+\lambda)}{10}$. Nevertheless, when $\lambda \in (1, 3/2)$ the aforementioned condition can or cannot hold. Summarizing:

- Firm $F1$ will choose to export in the first period and the outcome (E, F, E) will be the equilibrium of the game iff $\min\{b2, b6\} > G > b4$, this condition does not hold true for $\lambda \in (0, 1)$, however,

- Firm $F1$ will choose to invest in the first period and the outcome (F, F, F) will be the equilibrium of the game, when $\min\{b2, b6\} > G > b4$ and $a-c > \frac{t(13+8\lambda)+8\delta(1+\lambda)}{10}$.

CASE 7) When $\min\{b1, b6\} > G > \max\{b2, b4\}$, firm $F1$ decides its internationalization strategy by comparing the following equilibrium outcomes:

$$\Pi_1(E, E, F) > \Pi_1(F, F, F) \quad \text{iff} \quad G > \tfrac{t(2(a-c)(17-12\lambda)-t(25-16\lambda)+8\delta(2-\lambda))}{4\left(9-4\lambda^2\right)} \equiv \beta 3 \tag{62}$$

$$\Pi_1(E, F, E) > \Pi_1(F, F, F) \quad \text{iff} \quad a - c < \tfrac{t(13+8\lambda)+8\delta(1+\lambda)}{10} \tag{63}$$

The first inequality will be always false under the levels of set-up cost of this case. However, from CASE 6) above, we know the relationship of the oligopoly margin with the bound $\frac{t(13+8\lambda)+8\delta(1+\lambda)}{10}$ will depend on the level of λ and the values of the parameters too. Summarizing:

- Firm $F1$ will choose to export in the first period and the outcome (E, F, E) will be the equilibrium of the game iff $\min\{b1, b6\} > G > \max\{b2, b4\}$ and $a - c < \frac{t(13+8\lambda)+8\delta(1+\lambda)}{10}$, this condition does not hold for true for $\lambda \in (0, 1)$, however,

- Firm $F1$ will choose to invest in the first period and the outcome (F, F, F) will be the equilibrium of the game, when $\min\{b2, b6\} > G > b4$ and $a - c > \frac{t(13+8\lambda)+8\delta(1+\lambda)}{10}$.

CASE 8) When $\min\{b2, b4\} > G$, firm $F1$ decides its internationalization strategy by comparing the following equilibrium outcomes:

$$\Pi_1(E, F, F) > \Pi_1(F, F, F) \quad \text{iff} \quad a - c < \frac{9t+8\delta\lambda}{2(9-4\lambda)} \tag{64}$$

This condition will not hold since any $CPQ > \frac{9t+8\delta\lambda}{2(9-4\lambda)}$, thus $a - c > \frac{9t+8\delta\lambda}{2(9-4\lambda)}$. Therefore,

- Firm $F1$ will choose to invest in the first period and the outcome (F, F, F) will be the equilibrium of the game, when $\min\{b2, b4\} > G$.