The Strategic Role of Information Asymmetry on Demand for the Multinational Enterprise*

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Abstract

We study how asymmetric information impinge on oligopolistic firms' decision between direct investment and exports in a game-theoretic model with Bayesian learning. Host firms have superior information about market demand and foreign firms can improve their knowledge if foreign direct investment (FDI) is undertaken. In addition to the well-known tension between the fixed set-up costs of investment, the additional variable costs of exports and oligopoly sizes, the incentive to invest abroad is explained by the strategic learning effect. FDI may be observed even if foreign firms are pessimistic or trade costs are zero. Interestingly, compared with the certainty equivalent, the equilibrium number of investors is larger when foreign firms hold optimistic beliefs or, if these are pessimistic, when the strategic learning effect outweighs the conjecture effect.

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1 Introduction

Multinationals are firms that engage in foreign direct investment (FDI). There is a dominant framework about FDI pointing out that foreign multinational firms exist because they possess some specific advantages over domestic (host) firms. This point was noted by Hymer (1976) and later structured by Dunning (1981) in the by now popular ownership, location and internalization (OLI) framework; see Markusen (1995) for a survey. There is however an alternative view which suggests that firms become multinationals in an effort to acquire knowledge about foreign markets rather than to exploit advantages of any type.[1] This paper considers firms' decision to invest abroad when domestic (host) firms have superior information about market demand. A simple oligopoly model is developed to examine foreign firms' choice between direct investment and exports in the presence of uncertainty and informational asymmetries.

The internationalization process of the firms involves entry in new markets, which will typically lead firms to compete in an uncertain environment. International activities require both general knowledge and market-specific knowledge. Concerning the former, it seems natural that a firm wishes to exploit this knowledge in a second, foreign market. But market-specific knowledge will be gained mainly through experience in the market, and it is arguable whether this type of uncertainty may encourage or delay the FDI decision. The idea that domestic

[1]Knowledge about foreign markets is one of the key elements at the heart of the Uppsala Internationalization Model. Empirical research has confirmed that resources committed to foreign markets and experiential knowledge are important factors explaining international business behaviour in some industries (see Johanson and Vahlne, 1977, 1990). Also the internationalization process can be explained from an innovation-related perspective. According to it, foreign investment not only benefits host country firms but can also be a channel for acquiring technological knowledge. For evidence, see the survey paper by Blomström and Kokko (1998).

firms know the market better is not new in the literature on the multinational enterprise (Hirsch, 1976). Theoretical work includes Barros and Modesto (1995) and Horstmann and Markusen (1996). These authors compare entry by a foreign firm via FDI with entry via a contractual arrangement with a local agent, who has private information about market characteristics. This creates agency problems and the multinational must weigh the gains from information gathering - and thus avoid costly mistakes if direct investment occurs - against the surplus the agent can extract because of her having superior (private) information about the market.

In contrast with them, we will not be dealing with a game of mechanism design but still propose a game with incomplete information where only established firms are informed about market demand and also, a foreign uninformed oligopoly is considered, which emphasizes strategic interactions among the potential multinationals themselves. Since this paper investigates the rationale for FDI building on consumer based arguments it complements previous game-theoretical work focusing on technology based arguments, such as the papers by Ethier and Markusen (1996) and Fosfuri and Motta (1999). These authors identify conditions under which source-country firms prefer producing abroad (through a subsidiary or a licensee) rather than costly exporting, despite the fact that investment entails the dissemination of knowledge capital because of technological spillovers. Furthermore, FDI might be a means for non-leader firms to gain access to technological knowledge. Our contribution is to examine whether foreign oligopolistic firms have incentives to engage in FDI activities in order to gather private information on demand in a host market.

The choice of exports versus FDI has been the focus matter of quite a number of studies. There are some recent contributions which formally address the strategic role of FDI by making use of a game theoretic approach. These include

Smith (1987), Horstmann and Markusen (1987, 1992) and Motta (1992, 1994). The present paper is related to this strand of the literature. More specifically, we set up a model in which a host oligopoly faces competition from a foreign oligopoly in the form of either foreign investment or exports. Demand in the host market is uncertain. There is uncertainty about the permanent term of the demand intercept which captures the idiosyncratic features of the host demand, and there is also an additive time-dependent demand shock. Host market competition produces a signal and this provides information that uninformed foreign firms use to update their initial knowledge about market demand. The updating process is modeled as Bayesian learning. Host firms are uncertain about the additive shock but they are the only firms aware of the true permanent term of the demand intercept. However, foreign firms may learn it if FDI is undertaken. On the other hand, if the host market is served by exports then foreign firms' output choice will be based on their Bayesian updated beliefs. The basic setting, a game with incomplete information, is an extension of Ponssard (1979). We will employ Ponssard's model to study how the presence of uncertainty and asymmetric information on demand impinge on firms' decision to become multinational in a game-theoretic model with Bayesian learning. Only recently, Saggi (1998) models a monopolist's choice between FDI and exports in a two-period setting with demand uncertainty and learning in a particular way. The mere fact of serving the host market in the first period resolves uncertainty. Then, he identifies conditions under which the monopolist initially exports and engages in FDI in the second period. Furthermore, a comparison is made with a benchmark where the FDI decision involves learning while nothing is learnt under the exporting decision.[2]

[2]Apart from Saggi (1998), Rob and Vettas (2001) are concerned with the question of the timing of FDI. Further, Rob and Vettas (2001) show that, under certain conditions, the multinational firm will both export to and invest in a foreign market. Though interesting, the sequentiality and the question about the complementarity or substitutability of these deci-

Particularly, the decision to invest is influenced by the incentives for firms to acquire private information, a decision which depends on the number of firms who do so and, therefore, information acquisition is of strategic value. In fact, it will be shown that the expected profits of foreign direct investment are increasing with the expected mean of demand, decreasing with the number of informed firms and increasing with how diffuse are the updated beliefs. Potential investors must then evaluate how these effects combine to determine whether, in expected terms, it is preferable to incur the fixed costs of installing a plant abroad rather than the variable costs of exporting. To the best of our knowledge, Hoff (1997) is the only paper that treats informational asymmetries in an infant industry model where entrants update their beliefs on technology in a Bayesian fashion. She proves that the standard welfare-increasing industrial policies may not be valid when incomplete information works as a barrier to entry.

Two questions deserve particular attention. Firstly, do foreign oligopolists undertake FDI to learn about demand in the host market? Typically, the firm must choose between a technology with lower marginal costs (FDI) and one with lower fixed costs (exports). Such a trade-off is to be reshapen under oligopoly since, other things equal, more foreign firms will invest the smaller the size of the host and the foreign oligopolies. In our setting, the trade-off is related not only with how many foreign firms decide to invest and hence become informed firms, but also with how disperse beliefs are. The positive effect of market size, trade costs and the updated variance (of the demand intercept) on the expected profits of investment weakens as the number of informed firms increases. This makes it more difficult to cover the fixed set-up costs associated with FDI. It will be shown that, under certain conditions, FDI takes place even if foreign firms are

sions are beyond the scope of the present paper. We will rather focus on the strategic role of informational asymmetry in the FDI decisions of a foreign oligopoly.

pessimistic about demand in the host market. Furthermore, FDI may also be observed when trade costs are zero because of the strategic learning effect. Secondly, does uncertainty and informational asymmetry promote or depress FDI? To answer this question, we compare the equilibrium number of investors with that obtained under the certainty equivalent. While it might be expected that more firms will invest under an environment of certainty, we show that uncertainty and informational asymmetry may promote FDI. The difference of incentives to FDI under each environment can be cast in terms of two effects: a conjecture effect and a strategic learning effect. The former effect captures how the divergence between the updated mean of demand and its true value. The sign of this effect is positive (negative) when foreign firms are optimistic (pessimistic) about the demand, i.e. when they believe that the market is better (worse) than it actually is. The latter effect is always positive and is related with the oligopolistic informational rent enjoyed by informed firms. However it is decreasing with the number of informed firms. The incentives to undertake FDI under uncertainty and informational asymmetry outweigh those under certainty when either the conjecture effect is positive or when it is negative but small enough, in absolute terms, than the strategic learning effect.

The paper is organized as follows. Section 2 introduces the oligopolistic model with uncertainty and informational asymmetry. In Section 3, we characterize the equilibrium number of foreign firms that undertake FDI by comparing expected profits under the investment and the export strategies. Section 4 presents the certainty equivalent and analyzes whether uncertainty and informational asymmetry increases or reduces the equilibrium number of investors in the host market. Finally, Section 5 provides some summarizing comments.

2 A Simple Oligopoly Model with Uncertainty and Informational Asymmetry

We consider a host country h whose inverse demand for a homogenous good in period t is linear and stochastic in the following way,

$$p_t = A - \frac{1}{\gamma} Q_t + \tilde{\varepsilon}_t \tag{1}$$

with the parameter γ representing market size and Q_t the output at price p_t. There appear two sources of uncertainty: i) an unknown recurrent parameter A that reflects the permanent characteristics of the local economy, and ii) a time dependent demand shock $\tilde{\varepsilon}_t$. The second source of uncertainty makes total output a noisy signal of the demand in the host market. It is assumed that each of these two random variables has full support on $\mathbb{R}$ and that they are independently and normally distributed. In particular, $A \sim N(m,\ v)$ and $\tilde{\varepsilon}_t \sim N(0,\ \mu)$ where m is the mean of A, $v = \frac{1}{\sigma_A^2}$ is $A's$ precision and $\mu = \frac{1}{\sigma_\varepsilon^2}$ is $\tilde{\varepsilon}'s$ precision. It is convenient to define the expectation of $A + \tilde{\varepsilon}_t$ as the mean of the demand intercept, which in this case coincides with the mean of A. These distributions are known by the firms and are common knowledge. Demand is served by two types of firms, those located in country h and those located abroad.

The sequence of events is as follows. There is an initial period where Nature selects the true value a of A according to the distribution $N(m,\ v)$. This true value is not necessarily equal to m, but note that a is closer to m when v is large. Then, this value a is exclusively revealed to the established firms whereas for the rest of the firms it remains uncertain. In period $t = 1$, host firms compete à la Cournot and this produces a noisy market signal, $a + \varepsilon_1$ $(= p_1 + \frac{1}{\gamma}Q_1)$ which is observed by foreign firms; where ε_1 stands for the realization of $\tilde{\varepsilon}_t$ in period $t = 1$. Then, the following two-stage game is played in period $t = 2$. In the first stage, foreign firms decide simultaneously and independently whether to invest or export, and in the second stage all firms compete in quantities. The first-stage decision has an informational implication: a) in the event of investing, a foreign firm will learn the true value a, that is, it will be an informed firm in the second stage and b) if the foreign firm becomes an exporter, then the output choice in the second stage is based on its updated beliefs.[3] There is then an informational asymmetry between these two ways of serving the host market. Just note that, in any of the two cases, there remains some residual uncertainty linked to the random variable $\tilde{\varepsilon}_t$. Otherwise the observation of the quantity produced in period $t = 1$ plus the market price would reveal the true value a to uninformed firms. See the time line in Figure 1.

In other words, $A \sim N(m,\ v)$ and $\tilde{\varepsilon}_t \sim N(0,\ \mu)$ are the *priors* to any firm outside the host market. The posterior distribution of A for a foreign firm according to Bayesian updating is $A \sim N(\hat{m},\ \hat{v})$, where $\hat{m} = (mv + \mu(a + \varepsilon_1))/(v + \mu)$ and $\hat{v} = v + \mu$, where $\frac{1}{\hat{v}} = \hat{\sigma}^2$.[4] The posterior mean $\hat{m}$ is a function of the priors and the signal observed. Note that the sign of $(\hat{m} - m)$ is ambiguous since it is given by the sign of $(a + \varepsilon_1 - m)$ and therefore, it can be either positive or negative regardless that a be above or below m. This is because of the influence of the time dependent demand shock. Also, the posterior precision increases with the mere fact of observing the signal.

The homogenous goods industry consists of n_h host firms and n_f foreign firms. The total number of firms is denoted by N and it is assumed that all firms are risk neutral. We assume that the marginal cost of output is constant and equal to c for all firms. If a foreign firm exports its output to h, then the firm incurs

[3] This assumption relating the information about a and the way of serving the host market is made for the sake of exposition. There are no qualitative changes in the results as long as the investment strategy implies learning about a in a faster way than the exporting strategy.

[4] These formulae can be found in Degroot (1970).

an additional per unit export cost τ. It can be interpreted as due to natural (e.g. transportation costs) or artificial (e.g. tariffs) barriers to trade. If, alternatively, it establishes a plant in the host country, it incurs a set-up cost of $G \geq 0$ which includes any possible cost associated with the gathering of information.

We are interested in the choice made by *foreign firms at the beginning of period two in an environment of uncertain demand and informational asymmetries.*

3 Characterization of the equilibrium

We begin by solving the output choice made by host and foreign firms in stage two of period two, given that firms' decisions in stage one of period two are common knowledge. In order to write down the optimization program, note that if n_I foreign firms became investors in stage one of period two, then there will be $n_h + n_I \equiv n_i$ informed firms and $n_f - n_I \equiv n_u$ uninformed firms. We are solving a game with incomplete information with an infinite number of types. These calculations are a slight modification of the I_1 informed game in Ponssard (1979). Let N_i denote the subset of informed firms whereas N_u denotes the subset of uninformed firms. Thus, firms maximize expected profits which can be written as,

$$\max_{q_i} E\Pi_i = E\left[(a - \frac{1}{\gamma}Q + \tilde{\varepsilon}_2 - c)q_i \mid a\right] \qquad for \;\; i = 1, ..., \; n_h \tag{2}$$

$$\max_{q_i} E\Pi_i = E\left[(a - \frac{1}{\gamma}Q + \tilde{\varepsilon}_2 - c)q_i \mid a\right] - G \qquad for \;\; i = 1, ..., \; n_I \tag{3}$$

$$\max_{q_u} E\Pi_u = E\left[(A - \frac{1}{\gamma}Q + \tilde{\varepsilon}_2 - c - \tau)q_u \mid (a + \varepsilon_1)\right] \quad for \;\; u = 1, ..., \; n_u \tag{4}$$

where q_i denotes the output of an informed firm given that it knows a, and q_u denotes the output of an uninformed firm given that it observes the signal, $a + \varepsilon_1$.

Informed investing firms maximize expected profits conditional on a whereas uninformed exporters maximize expected profit conditional on the signal, the "new" information. The first order conditions are,

$$a - c - \frac{q_i(a)}{\gamma} - \frac{1}{\gamma}\sum_{j\in N_i} q_j(a) - \frac{1}{\gamma}\sum_{k\in N_u} q_k = 0 \quad for \;\; i \in N_i \tag{5}$$

$$\hat{m} - c - \tau - \frac{q_u}{\gamma} - \frac{1}{\gamma}\sum_{j\in N_i} Eq_j - \frac{1}{\gamma}\sum_{k\in N_u} q_k = 0 \quad for \;\; u \in N_u \tag{6}$$

Following the notation in Ponssard, $q_j(a)$ denotes that the output of an informed firm is a function of the true value of a and Eq_j stands for the expectation the uninformed firms have over the output of informed firms. Adding up the f.o.c. in (6) over n_u,

$$n_u(\hat{m} - c - \tau) - \frac{n_u + 1}{\gamma}\sum_{k\in N_u} q_k - \frac{n_u}{\gamma}\sum_{j\in N_i} Eq_j = 0 \tag{7}$$

Now, add up the f.o.c. of informed firms to obtain,

$$n_i(a - c) - \frac{n_i}{\gamma}\sum_{k\in N_u} q_k - \frac{n_i + 1}{\gamma}\sum_{j\in N_i} q_j(a) = 0 \tag{8}$$

Take expectations in (8) to get,

$$E\sum_{j\in N_i} q_j = \frac{\gamma n_i(\hat{m} - c) - n_i \sum_{k\in N_u} q_k}{n_i + 1} \tag{9}$$

Substitute (9) in (7) to solve for $\sum_{k\in N_u} q_k$, which turns out to be,

$$\sum_{k\in N_u} q_k = \frac{\gamma n_u(\hat{m} - c - (n_i + 1)\tau)}{n_i + n_u + 1} \tag{10}$$

This is the total output produced by the uninformed firms, which is logically only a function of these firms' beliefs about the demand intercept, that is, $\hat{m}$. By substituting (10) in (8) and dividing by n_i we obtain the output of an informed firm,

$$q_i^* = \frac{\gamma(a - c + n_u\tau)}{n_i + n_u + 1} + \frac{\gamma n_u(a - \hat{m})}{(n_i + 1)(n_i + n_u + 1)} \tag{11}$$

On the other hand, the output of an uninformed firm is,

$$q_u^* = \frac{\gamma(\hat{m} - c - (n_i + 1)\tau)}{n_i + n_u + 1}$$

which can be rewritten as

$$q_u^* = \frac{\gamma(a - c - (n_i + 1)\tau)}{n_i + n_u + 1} - \frac{\gamma(a - \hat{m})}{n_i + n_u + 1} \tag{12}$$

The above output expressions[5] contain two terms: the first one gathers the absence of uncertainty while the second one captures the effect of demand uncertainty and informational asymmetry. Note that $\frac{\partial q_i^*}{\partial \hat{m}} < 0$ whereas $\frac{\partial q_u^*}{\partial \hat{m}} > 0$. In fact, how optimistic uninformed firms are influences the difference $(q_i^* - q_u^*)$. If firms have pessimistic beliefs, that is, if $a > \hat{m}$, then the established informed firms will always produce more than the uninformed exporters at equilibrium. In contrast, if firms have optimistic beliefs, $a < \hat{m}$, the difference $(q_i^* - q_u^*)$ shrinks and it might well become negative; this occurs when $\hat{m} > a + (n_i + 1)\tau$. The larger the number of informed firms the more optimistic should firms be for $q_u^* > q_i^*$. Thus, if uninformed firms think that the market is better than what it actually is, they will produce more as compared with a setting where all firms knew the true value a of demand. Since the choice variables are strategic substitutes under Cournot competition, rival informed firms respond with an output decrease. The opposite happens when uninformed firms are pessimistic. This strategic behaviour leads to less price adjustments. Graphically, informed firms face a downward sloping demand with an expected vertical intercept a whereas uninformed firms with an expected intercept $\hat{m}$. The distance between these vertical intercepts depends on

[5] A sufficient condition for positive equilibrium outputs is that the updated priors $\hat{m}$ belong to the following interval: $c + \tau N < \hat{m} < a + \frac{[a - c + \tau n_f](n_h + 1)}{n_f}$.

The upper bound is obtained from the numerator in q_i^* in the most unfavourable case ($n_u = n_f$) whereas the lower bound follows from the numerator in q_u^* for $n_u = 1$.

how precise the observed signal is. Information acquisition is more valuable when beliefs are more disperse. To sum up, anything making demand more variable will benefit the FDI option. The certainty equivalent output expressions can be easily obtained by taking $a = \hat{m}$ in (11)-(12). Then, the individual output of an established firm exceeds that of an exporting firm when the following familiar condition holds, $n_f > n_h + 1$; the opposite otherwise. Furthermore, the equilibrium outputs display the following comparative statics with respect to the oligopoly structure. Thus, we have that $sign[\frac{\partial q_i^*}{\partial n_u}] = sign[\frac{\partial q_u^*}{\partial n_u}] < 0$, $\frac{\partial q_i^*}{\partial n_i} \lesseqgtr 0$ and $\frac{\partial q_u^*}{\partial n_i} < 0$; these signs follow from the conditions for positive equilibrium outputs. The only surprising sign which deserves a comment is that $\frac{\partial q_i}{\partial n_i}$ can be positive. The derivative with respect to the absence of uncertainty term in (11) is always negative reflecting the standard output reduction due to more competition. On the other hand, the derivative with respect to the uncertainty and informational asymmetry term has a positive sign when uninformed firms are optimistic. The latter effect offsets the former when $\hat{m} > a + \frac{(n_i+1)^2(a-c+n_u\tau)}{n_u(2+2n_i+n_u)}$. In such an eventuality, informed firms increase their output with the number of informed firms. The negative externality imposed on the informed firms when the uninformed firms are sufficiently optimistic is shared among more firms.

What we need now is to write down the expression of *expected* profits since the investment versus export decision is taken in stage one of period two, on an ex-ante basis. Total output is,

$$Q = \frac{\gamma}{n_i + n_u + 1} \left(\frac{n_i(n_i + n_u + 1)a + n_u\hat{m}}{n_i + 1} - (n_i + n_u)c - n_u\tau \right)$$

The realized margin for informed firms is,

$$p - c = \frac{a - c + n_u\tau}{n_i + n_u + 1} + \frac{n_u(a - \hat{m})}{(n_i + 1)(n_i + n_u + 1)} + \varepsilon_2$$

and for uninformed firms is,

$$p - c - \tau = \frac{a - c - (n_i + 1)\tau}{n_i + n_u + 1} + \frac{n_u(a - \hat{m})}{(n_i + 1)(n_i + n_u + 1)} + \varepsilon_2$$

Thus, the expected profits of deciding to invest are,

$$E\Pi_I = E[\gamma(q_i)^2 + \tilde{\varepsilon}_2 q_i] - G$$

Further note that we must consider the updated beliefs since the foreign firm was an uninformed firm at the end of period one. Hence,

$$E\Pi_I = \frac{\gamma(\hat{m} - c + n_u\tau)^2}{(n_i + n_u + 1)^2} + \frac{\gamma\hat{\sigma}^2}{(n_i + 1)^2} - G \tag{13}$$

The expected profits of becoming an investor, of learning the permanent part of the demand intercept, are increasing with the updated variance of A and decreasing with the number of informed firms. On the other hand, the expected profits of an exporter are given by,

$$E\Pi_E = \frac{\gamma(\hat{m} - c - (n_i + 1)\tau)^2}{(n_i + n_u + 1)^2} \tag{14}$$

Since we are interested in obtaining the equilibrium number of investors it is convenient to rewrite the above expected profits as functions of n_I; that is,

$$E\Pi_I(n_I) = \frac{\gamma(\hat{m} - c + (n_f - n_I)\tau)^2}{(N + 1)^2} + \frac{\gamma\hat{\sigma}^2}{(n_h + n_I + 1)^2} - G \tag{15}$$

$$E\Pi_E(n_I) = \frac{\gamma(\hat{m} - c - (n_h + n_I + 1)\tau)^2}{(N + 1)^2} \tag{16}$$

where $N = n_u + n_i = n_h + n_f$ is the total oligopoly size, $n_i = n_h + n_I$ and $n_u = n_f - n_I$. We may now compare the expected profits under each strategy taking n_I as an integer. In order to characterize that n_I^* firms is an interior equilibrium ($0 < n_I^* < n_f$), two conditions are required:

i) $E\Pi_I(n_I^*) \geq E\Pi_E(n_I^* - 1)$, that is, the $n_I - th$ firm is better off investing than exporting and,

ii) $E\Pi_I(n_I^*+1) < E\Pi_E(n_I^*)$, the $(n_I+1)-th$ firm finds it unprofitable to change from exporting to investing.

From these two conditions, which must hold simultaneously, we obtain the following interval for G/γ. It is a normalized measure of the costs associated with establishing a subsidiary in the host market. In the sequel, they will be referred to as adjusted set-up costs.

$$\begin{aligned} & \frac{[2(\hat{m}-c)-\tau(n_h-n_f+2n_I^*)]N\tau}{(N+1)^2}+\frac{\hat{\sigma}^2}{(n_h+n_I^*+1)^2} \\ \geq\ & \frac{G}{\gamma} > \frac{[2(\hat{m}-c)-\tau(n_h-n_f+2(n_I^*+1))]N\tau}{(N+1)^2}+\frac{\hat{\sigma}^2}{(n_h+n_I^*+2)^2} \end{aligned} \tag{17}$$

Corner solutions cannot be disregarded. In particular,

$$\begin{array}{ll} n_I^*=n_f & \text{for } \frac{[2(\hat{m}-c)-\tau(n_h+n_f)]N\tau}{(N+1)^2}+\frac{\hat{\sigma}^2}{(N+1)^2} \geq \frac{G}{\gamma} \\ n_I^*=0 & \text{for } \frac{[2(\hat{m}-c)-\tau(n_h-n_f+2)]N\tau}{(N+1)^2}+\frac{\hat{\sigma}^2}{(n_h+2)^2} < \frac{G}{\gamma} \end{array}$$

These mean that, other things equal, either all foreign firms will invest if adjusted set-up costs are rather low or none of them will if these costs are too large.

The equilibrium number of investors follows by solving $E\Pi_I(n_I^*)-E\Pi_E(n_I^*)=0$, which defines a cubic function in n_I^* and where the integer constraint assumption on n_I^* has been dropped. Hence, taking the l.h.s. of (17) with an equality, we obtain

$$\underbrace{\frac{[2(\hat{m}-c)-\tau(n_h-n_f+2n_I^*)]N\tau}{(N+1)^2}}_{\text{"traditional" effect}}+\underbrace{\frac{\hat{\sigma}^2}{(n_h+n_I^*+1)^2}}_{\text{strategic learning effect}}=\frac{G}{\gamma} \tag{18}$$

an expression that captures foreign firms' incentives to engage in FDI. By using the implicit function theorem we get the following comparative statics,

$$\begin{array}{llll} sign[\frac{\partial n_I^*}{\partial \hat{m}}]>0 & sign[\frac{\partial n_I^*}{\partial \gamma}]>0 & sign[\frac{\partial n_I^*}{\partial n_f}]<0 & sign[\frac{\partial n_I^*}{\partial \tau}]>0 \\ sign[\frac{\partial n_I^*}{\partial \hat{\sigma}^2}]>0 & sign[\frac{\partial n_I^*}{\partial G}]<0 & sign[\frac{\partial n_I^*}{\partial n_h}]<0 & sign[\frac{\partial n_I^*}{\partial c}]<0 \end{array}$$

An interpretation of these results can be cast in the following terms. It is useful to think of a no information game, namely a game with uncertainty and *without* informational asymmetry. If the demand intercept is unknown to all firms, standard calculations will lead us to (18) with only the "traditional" effect, where the expected or updated demand intercept $\hat{m}$ appears. The "traditional" effect embodies variables whose role is fairly well-known in the literature on the exports versus the FDI decision. In particular, a larger market size or lower adjusted set-up costs make the parameter space for FDI larger. Also, under oligopoly and Cournot competition, it is hardly surprising to find that higher oligopoly sizes, host and foreign, do not encourage direct investment. More firms suppose competition is more intense and the reduction in the expected profits of exporting is lower than that of investing; therefore, a fewer amount of foreign firms decide to invest. Furthermore, an increase in the additional per unit cost of exports is equivalent to an increase in the relative efficiency, and hence profitability, of direct investment vis a vis exports. Remark that, if we consider τ as a tariff and is set equal to zero, no foreign firm decides to invest, in concordance with the standard tariff-jumping argument for FDI. In fact, this will happen no matter we depart from optimistic or pessimistic beliefs. However, in a setting with uncertainty and informational asymmetry there is a second effect: the strategic learning effect, which is independent of τ. Only the informed firms "compete" on the updated variance of the demand function. Thus, more foreign firms will invest the more disperse beliefs are. The rent obtained on the variance is lower when it is shared among a higher number of informed firms. This point is reminiscent of the concept of oligopolistic rent on the variance stated by Ponssard (1979). Therefore, we conclude that there may exist FDI regardless that beliefs over the host market are optimistic or pessimistic. Besides, the possibility of FDI is present even if τ is zero because of the strategic learning effect. This will arise, other things equal, for sufficiently disperse beliefs in order to cover the adjusted set-up costs.

4 A Comparison with the Certainty Equivalent

To fully understand the role played by *uncertain demand and informational asymmetries* in the export versus FDI decision we proceed to compare the equilibrium condition under uncertainty and informational asymmetry with that under the certainty equivalent. It is easy to compute the equilibrium profits under a certainty environment. The analysis of the certainty case can be found in our companion paper, Moner-Colonques et al. (2002). The corresponding expressions for the investment and exporting decisions are given by,

$$\Pi_I^c = \frac{\gamma(a - c + (n_f - n_I)\tau)^2}{(N+1)^2} - G \tag{19}$$

$$\Pi_E^c = \frac{\gamma(a - c - (n_h + n_I + 1)\tau)^2}{(N+1)^2} \tag{20}$$

The certainty equivalent interval which determines the equilibrium number of investors is the following:

$$\frac{[2(a-c) - (n_h - n_f + 2n_I^c)\tau]N\tau}{(N+1)^2} \geq \frac{G}{\gamma} > \frac{[2(a-c) - (n_h - n_f + 2(n_I^c + 1))\tau]N\tau}{(N+1)^2} \tag{21}$$

Denote by n_I^c the equilibrium number of investors under the certainty equivalent. Proceeding in the same above manner and taking n_I^c as a continuous variable results in the following expression:

$$n_I^c = \frac{a-c}{\tau} + \frac{n_f - n_h}{2} - \frac{G(N+1)^2}{2\gamma N\tau^2} \quad \text{for } n_I^c \in (0, n_f)$$

and where corner solutions are

$$\begin{array}{ll} n_I^c = 0 & \text{for } \frac{[2(a-c) - \tau(n_h - n_f)]N\tau}{(N+1)^2} \leq \frac{G}{\gamma} \\ n_I^c = n_f & \text{for } \frac{[2(a-c) - \tau(n_h + n_f)]N\tau}{(N+1)^2} \geq \frac{G}{\gamma} \end{array} \tag{22}$$

In order to draw the comparison we will resort to graphical reasoning. Firstly, note that the equilibrium condition under uncertainty and informational asymmetry $E\Pi_I(n_I^*) - E\Pi_E(n_I^*) = 0$, which determines n_I^*, is equivalent to finding n_I^* such that $\Omega(n_I)$ equals $\frac{G}{\gamma}$, where:

$$\Omega(n_I) = \frac{[2(\hat{m} - c) - (n_h - n_f + 2n_I)\tau]N\tau}{(N+1)^2} + \frac{\hat{\sigma}^2}{(n_h + n_I + 1)^2} \tag{23}$$

Similarly, for the certainty environment, the equilibrium condition $\Pi_I(n_I^c) - \Pi_E(n_I^c) = 0$ is equivalent to finding n_I^c such that $\Psi(n_I)$ equals $\frac{G}{\gamma}$, where:

$$\Psi(n_I) = \frac{[2(a - c) - (n_h - n_f + 2n_I)\tau]N\tau}{(N+1)^2} \tag{24}$$

These two functions are in fact defining a foreign firm's incentive to invest gross of adjusted set-up costs corresponding to each of the environments. They are both decreasing with the number of investors since an additional investor imposes a negative externality on the rest of competitors, as the number of more efficient competitors increases. However, under certainty, such an incentive decreases at a constant rate as more foreign firms decide to invest, while under uncertainty and informational asymmetry, the incentive decreases at a decreasing rate.

Functions $\Omega(n_I)$ and $\Psi(n_I)$ can be plotted in the same diagram and their intersection points with $\frac{G}{\gamma}$ determine the equilibrium number of investors corresponding to each of the environments. In order to find whether n_I^* is greater or smaller than n_I^c, we need to study the relative position of $\Omega(n_I)$ and $\Psi(n_I)$ and also whether they intersect each other for some n_I between zero and n_f. Concerning their relative position, the difference $\Omega(n_I) - \Psi(n_I) = \frac{2N\tau}{(N+1)^2}(\hat{m} - a) + \frac{\hat{\sigma}^2}{(n_h+n_I+1)^2}$ has to be analyzed. For example, if it is the case that the difference is always positive, that is $\Omega(n_I)$ lies above $\Psi(n_I)$ $\forall$ $n_I \in [0, n_f]$, then we will conclude that $n_I^c \leq n_I^*$. Whenever $\Omega(n_I) - \Psi(n_I) > 0$, we will then say that, for given adjusted set-up costs, uncertainty and informational asymmetry provide foreign firms with stronger incentives to invest relative to the certainty equivalent; the opposite holds for $\Omega(n_I) - \Psi(n_I) < 0$.

On the one hand, if foreign firms are optimistic about the host market, i.e. $\hat{m} > a$, then the difference will always be positive and therefore no intersection point exists. This situation will be labelled as *Case I.*

On the other hand, if firms have pessimistic beliefs, i. e. $a > \hat{m}$, then the difference $\Omega(n_I) - \Psi(n_I)$ has an ambiguous sign. It will more likely be positive the higher the updated variance of A and the lower both the number of investors and the host oligopoly size, whereas total oligopoly size and additional unit export costs narrow it down. Two cases can be distinguished, either both functions cross each other or they do not, in which case the difference is negative for all $n_I \in [0, n_f]$.

The intersection point, denoted by $\bar{n}$, is the greatest root obtained by equating $\Omega(n_I)$ to $\Psi(n_I)$, where $\bar{n} = -(n_h + 1) + \frac{(N+1)\sqrt{2N\tau(a-\hat{m})\hat{\sigma}^2}}{2N\tau(a-\hat{m})}$. We now need to identify conditions under which $\bar{n}$ is nonnegative and smaller than or equal to n_f. Firstly, since $a > \hat{m}$, it follows that $\bar{n}$ is positive as long as $0 < (a - \hat{m}) < \frac{(N+1)^2\hat{\sigma}^2}{2N\tau(n_h+1)^2}$. Note that $\bar{n}$ is smaller than n_f for $(a - \hat{m}) > \frac{\hat{\sigma}^2}{2N\tau}$. Therefore, either the intersection point occurs at $\bar{n} > n_f$ for $(a - \hat{m}) \in (0, \frac{\hat{\sigma}^2}{2N\tau})$, or it lies between zero and n_f, which happens for $(a - \hat{m}) \in (\frac{\hat{\sigma}^2}{2N\tau}, \frac{(N+1)^2\hat{\sigma}^2}{2N\tau(n_h+1)^2})$. These two cases will be referred to as *Case II.1* and *Case II.2*, respectively. Finally, for $(a - \hat{m}) > \frac{(N+1)^2\hat{\sigma}^2}{2N\tau(n_h+1)^2}$ the difference $\Omega(n_I) - \Psi(n_I)$ is negative for all $n_I \in [0, n_f]$ and this will be labelled as *Case III.*

A final piece of notation. Let us define $\tilde{n}$ as the number of investors that satisfy $\Omega(\tilde{n}) = 0$; similarly $\hat{n}$ is such that $\Psi(\hat{n}) = 0$. In order to better read the figures below, it is important to note that $n_f < \hat{n}$, as proven in the Appendix.

We may now proceed to characterize the comparison between n_I^c and n_I^* as a function of adjusted set-up costs and foreign oligopoly size, for each of the above mentioned cases. For expositional purposes, the complete characterization is relegated to an Appendix. The next results will strictly focus on the ranking of n_I^c with respect to n_I^* corresponding to each case. Figures 2 to 4 show some examples. We will carefully describe the interpretation of Figure 2 only. Thus under the optimistic beliefs case the following result can be established.

Result 1 *Under Case I,* $(a - \hat{m}) < 0$, *it occurs that* $n_I^c < n_I^*$, *unless both are zero or both are equal to* n_f.

[Figure 2 about here]

Optimistic beliefs about the host market is a sufficient condition for $\Omega(n_I)$ to always lie above $\Psi(n_I)$ -see Figure 2. Then, for given adjusted set-up costs, the incentives to invest are stronger under uncertainty and informational asymmetry and, therefore, the equilibrium number of investors is never smaller than that under the certainty equivalent. Since both $\Omega(n_I)$ and $\Psi(n_I)$ are decreasing with n_I it also follows that the equilibrium number of investors is greater the lower the adjusted set-up costs. The situations where the equilibrium number of investors coincide in both environments arise because of one of the following two reasons. Either the adjusted set-up costs are so large, i. e. $\frac{G}{\gamma} > \Omega(0)$, that it does not pay any foreign firm to become an investor irrespective of the environment analyzed. Or these costs are so small, i. e. $\frac{G}{\gamma} < \Psi(n_f)$, that all foreign firms prefer to invest no matter the environment under consideration. Further note that it may happen that $n_I^* > 0$ while $n_I^c = 0$ for $\frac{G}{\gamma} \in (\Psi(0), \Omega(0))$, as happens for $\left(\frac{G}{\gamma}\right)_1$ in Figure 2. It may also happen that $0 < n_I^c < n_I^* = n_f$ for values of $\frac{G}{\gamma}$ belonging to $(\Psi(n_f), \Omega(n_f))$, as for $\left(\frac{G}{\gamma}\right)_3$ in Figure 2.

A further interesting situation can be observed when the foreign oligopoly size is sufficiently small, i.e. $n_f < n^o$ where n^o is defined by $\Psi(0) = \Omega(n^o)$. In such a case it is possible to find values of $\frac{G}{\gamma}$ such that $n_I^c = 0$ and $n_I^* = n_f$ (see Lemma 1 in the Appendix for the details). This situation can be considered as the one where the comparison between the certainty environment and that under uncertainty and informational asymmetry has the most drastic consequences since under the former environment there will be no FDI at all, while for the latter we will observe the greatest possible FDI level. This is an example of a non marginal change in FDI due to the presence of uncertainty and informational asymmetry.

As a general summarizing comment for the optimistic beliefs case we may say that the presence of uncertainty with informational asymmetry will never work against FDI compared to the certainty environment. We will develop an intuition of the results that rests on the role played by each of the two terms in the $\Omega(n_I) - \Psi(n_I)$ difference, that is,

$$\underbrace{\frac{2N\tau}{(N+1)^2}(\hat{m}-a)}_{\text{conjecture effect}} + \underbrace{\frac{\hat{\sigma}^2}{(n_h+n_I+1)^2}}_{\text{strategic learning effect}} \tag{25}$$

Note that each of the terms is gathering a different effect on (the difference of) the incentives under each environment. The former is related to whether foreign firms have optimistic or pessimistic beliefs, which will be called a *conjecture effect*. It measures the difference in the conjectures between the uninformed and the informed firms about the demand. If foreign firms are optimistic (pessimistic) then the conjecture effect is positive (negative) this meaning that firms think that the host market is "better" ("worse") than it actually is. Graphically, this amounts to an upward (downward) shift of the expected demand function relative to its true position. The latter effect is decreasing with the posterior precision of the information about the market and it is always positive. Only the latter term is a function of the endogenous number of investors and therefore captures the interaction among all of the foreign firms. It is the *strategic learning effect* of becoming an informed firm. In Case I both effects reinforce each other.

We turn now to Case II, $0 \leq (a-\hat{m}) < \frac{(N+1)^2\hat{\sigma}^2}{2N\tau(n_h+1)^2}$, which will be referred to as the mild pessimistic beliefs case. Then it follows that $\Omega(0) > \Psi(0)$, $\bar{n}$ is positive and satisfies $\bar{n} < \tilde{n} < \hat{n}$. Case II unfolds into two intervals which gives rise to the following result.

Result 2 *i)Under Case II.1,* $0 \leq (a - \hat{m}) < \frac{\hat{\sigma}^2}{2N\tau}$, *it occurs that* $n_I^c < n_I^*$, *unless both are zero or both are equal to* n_f,
ii)Under Case II.2, $\frac{\hat{\sigma}^2}{2N\tau} \leq (a - \hat{m}) < \frac{(N+1)^2\hat{\sigma}^2}{2N\tau(n_h+1)^2}$, *it occurs that* $n_I^c \leq n_I^*$ *for* $\frac{G}{\gamma} \geq \Psi(\bar{n})$ *whereas* $n_I^c \geq n_I^*$ *for* $0 < \frac{G}{\gamma} < \Psi(\bar{n})$.

[Figure 3 about here]

Under Case II the incentives to invest may be stronger or weaker under uncertainty and informational asymmetry than those under the certainty equivalent *depending on the number of investors.* If this number is small enough, i.e. $n_I < \bar{n}$ then the incentives are stronger, otherwise they are weaker. With mild pessimistic beliefs the two above mentioned effects have opposite sign. Uncertainty and informational asymmetry will result in more FDI when the strategic learning effect dominates the conjecture effect. This happens when the equilibrium number of investors is low and then the informational oligopolistic rent is not shared among too many firms (see Figure 3).

Note that Case II.1 arises when $n_f < \bar{n}$ and, therefore, it follows that the incentives to invest are always stronger under uncertainty and informational asymmetry, as in Case I. The strategic learning effect is lower the larger the number of informed firms. However the size of the foreign oligopoly is relatively small so that the reduction in the strategic learning effect is not sufficient to reverse the sign of $\Omega(n_I) - \Psi(n_I)$ even if all n_f firms engaged in FDI. We conclude from Case II that, although uninformed firms are pessimistic about the market, there are conditions under which uncertainty and informational asymmetry do not discourage FDI with respect to the certainty equivalent. These conditions are either low values of n_f or large enough adjusted set-up costs values when n_f is rather large.

Finally, we study Case III which we will call the heavily pessimistic beliefs case.

Result 3 *Under Case III,* $\frac{(N+1)^2\hat{\sigma}^2}{2N\tau(n_h+1)^2} \leq (a - \hat{m})$, *it occurs that* $n_I^* < n_I^c$, *unless both are zero or both are equal to* n_f.

[Figure 4 about here]

In this case the intersection point, $\bar{n}$, becomes negative, and therefore $\Psi(n_I)$ always lies above $\Omega(n_I)$ for nonnegative n_I (see Figure 4). It implies that the incentives to invest are stronger under the certainty environment. That is, the conjecture effect always prevails upon the strategic learning effect.

The combination of Results 1-2-3 above allows us to answer the research question posed in the introduction, which can be summarized as follows: *the presence of uncertainty and informational asymmetry does not necessarily discourage FDI as compared with an environment of certainty.*

The analysis identifies the specific conditions on the parameter space that ensure whether the incentives to invest abroad are stronger under the certainty environment. The export decision will be favoured under uncertainty and informational asymmetry when uninformed firms are heavily pessimistic about the market demand, that is, a negative conjecture effect is a necessary but not a sufficient condition. However, the investing decision may be favoured without necessarily imposing a specific sign on the conjecture effect. If positive, no further restrictions on the parameters are required to guarantee that FDI will never be discouraged relative to the certainty equivalent. The intuition behind is simply based on an optimistic view of the market. Alternatively, if the conjecture effect is negative, i.e. firms do not view the market as good as it actually is, the equilibrium number of investors can still exceed that under an environment of certainty. This will happen either when the foreign oligopoly size is small regardless the size of the adjusted set-up costs, or when both the adjusted set-up costs and oligopoly sizes are large enough. These two conditions will ensure a small number of equilibrium investors under the uncertainty with informational asymmetry environment and, therefore, a large strategic learning effect. Therefore, the negative conjecture effect is offset by a large enough strategic learning effect. We would like to stress that either the optimistic or pessimistic beliefs scenarios can be reached regardless the relationship between priors and the true value of the demand intercept, i.e. the results do not depend on the choice of priors. To sum up, whether uninformed firms are optimistic or pessimistic, is not determinant in having $n_I^* > n_I^c$. Rather, it is the fact that beliefs are sufficiently disperse and/or a small enough number of investors which makes information acquisition more valuable and strengthens the strategic learning effect. Finally, we would like to draw attention to Case II.2, the mild pessimistic beliefs case (see Figure 3). It yields a testable implication in that FDI may be stimulated or depressed depending on the size of adjusted set-up costs, the number of investors and the dispersion of beliefs. These economic fundamentals might help explain some observed behaviour of multinationals.

To further highlight the role played by asymmetric information, suppose that all firms are uncertain about the demand intercept. Straightforward computations will leave us solely with the conjecture effect. Therefore, the comparison with the certainty equivalent is always univocal and barely surprising in that n_I^* exceeds n_I^c for optimistic beliefs; the opposite, otherwise. One of the arguments employed to explain foreign investment is that it is a way to avoid tariffs and/or transportation costs if these are too high. Differently, if the additional export costs were zero then no FDI would come about. This statement holds true regardless that firms are certain or uncertain about host demand. However, it can be contradicted by resorting to asymmetric information. In other words, there may be justifications for FDI other than tariff-jumping, one of them being the incentives for information acquisition on demand. In fact, if τ is set equal to zero, then the conjecture effect does not exist and since the strategic learning effect is positive, we will unambiguously find more investors under uncertainty and informational asymmetry than under an environment of certainty.

Our setting can be related with previous literature. Apart from the informational assumptions, the presence of a foreign oligopoly allows us to partially endogenize the market structure, as in Motta (1994), although other authors, such as Horstmann and Markusen (1992) and Markusen and Venables (1998), have also studied the strategic interaction between potential multinationals. Motta (1994) considers vertical differentiation and a historical host and foreign duopolistic structure. However, some results are remarkably similar if we look at the certainty case. If the quality gap is not too large, that is, we move towards product homogeneity, then host firms are active producers; the choice of FDI relative to exports is favoured by lower adjusted set-up costs and higher exporting costs. Furthermore, "bunching investments", where both foreign firms invest abroad, will occur for large enough market size. Such a possibility also arises in our model, with the qualification that the required market size will be larger the higher the oligopoly sizes. With uncertainty and informational asymmetry, "bunching investments", i.e. $n_I^* = n_f$, also show up when, in addition to the aforementioned conditions, beliefs are more disperse. This fact emphasizes the importance of the strategic learning effect. A sufficiently large updated variance makes it such that, even if the informational oligopolistic rent is shared among all the foreign firms, the adjusted set-up costs can be dealt with; (ex ante) symmetry is restored and all firms, host and foreign, enjoy the same market share. More interesting is the fact that, if foreign oligopoly size is small enough, it is possible to find "bunching investments" under uncertainty and informational asymmetry whereas no firm would invest under an environment of certainty. Then the strategic learning effect, which is absent in the certainty case, is very significant because the informational rent is distributed among very few firms and allows all foreign firms to invest and choose the technology with lower marginal costs.

5 Summarizing comments

The received literature on FDI suggests that firms become multinationals in order to exploit some specific advantages. The basis of recent formal theoretical work is implicitly an application of cost benefit analysis, that explains why FDI opportunities occur by alluding to the trade off between incurring on the trade costs of exports or the set-up costs of building a plant. In addition, this paper addresses the observation of FDI based on learning arguments. We have developed a simple oligopoly model, where due to the presence of uncertainty and informational asymmetry, foreign direct investment takes place in order to acquire information about host market demand. In fact, foreign direct investment may be the equilibrium choice even if foreign uninformed firms are pessimistic or exporting does not entail any additional costs.

Compared to the certainty equivalent, we have identified conditions under which the equilibrium number of investors is higher under uncertainty and informational asymmetry: either uninformed firms hold optimistic beliefs about the host market, or, if they hold pessimistic beliefs, the (positive) strategic learning effect outweighs the (negative) conjecture effect. Key to the results is the fact that uninformed firms hold sufficiently disperse beliefs rather than their view, optimistic or pessimistic, about demand in the host market. It is worth noting that the results here obtained would not arise had we considered just an uncertainty environment

We have emphasized the strategic role of information in the FDI versus exports decision a) by identifying and showing the relevance of the strategic learning effect, b) by providing an information acquisition rationale for investment apart from the standard tariff-jumping argument, and c) by suggesting some economic fundamentals for testing FDI behaviour in a context of oligopoly where some firms have superior information about market demand. The model proves useful to draw some insights about the observer behaviour of multinational enterprises. The results suggests that there is still much to be done considering asymmetric information in firms' internationalization decisions. Future research may be directed to study different oligopoly models with product differentiation and to examine other types of learning methods.

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A Appendix: complete characterization of equilibria

We first establish an intermediate result that states the relationship between n_f and $\hat{n}$; it uses the restriction that ensures positive equilibrium outputs in the certainty environment. Firstly, note that $\hat{n} = \frac{a-c}{\tau} - (\frac{n_h - n_f}{2})$. Secondly note that in the certainty environment, the equilibrium output of an exporter provided that $n_f - 1$ firms invest is positive iff $a - c - (n_h + n_f)\tau > 0$, or equivalently $(n_h + n_f) < \frac{a-c}{\tau}$. The condition for $\hat{n} < n_f$ (i. e. $(n_h + n_f) > \frac{2(a-c)}{\tau}$) and that of positive outputs cannot be simultaneously satisfied, therefore it follows that $n_f < \hat{n}$.

Consider Case I, that is, $(a - \hat{m}) < 0$ and therefore $\Omega(n_I) > \Psi(n_I)$ for all n_I. Then, it is verified that $\Omega(0) > \Psi(0)$ and $\hat{n} < \tilde{n}$. The equilibrium depends both on the foreign oligopoly size, n_f, and the $\frac{G}{\gamma}$ values. Let us define n^o as the number which satisfies $\Omega(n^o) = \Psi(0)$; it follows that $0 < n^o < \hat{n} < \tilde{n}$. We will next distinguish several subcases attending to the relative position of n_f with respect to the ranking $n^o < \hat{n} < \tilde{n}$. Subcase I.1 corresponds to the case where $0 < n_f < n^o$, whereas subcase I.2 corresponds to $n^o < n_f < \hat{n}$.

The next lemma characterizes the equilibria for subcase I.1:

Lemma 1 *Suppose* $(a - \hat{m}) < 0$ *and* $0 < n_f < n^o$. *Then the number of investors at equilibrium is a function of* $\frac{G}{\gamma}$ *as follows:*
i) $n_I^c = n_I^* = 0$ *if* $\frac{G}{\gamma} \geq \Omega(0)$,
ii) $n_I^c = 0$ *and* $0 < n_I^* < n_f$ *if* $\Omega(n_f) \leq \frac{G}{\gamma} < \Omega(0)$,
iii) $n_I^c = 0$ *and* $n_I^* = n_f$ *if* $\Psi(0) \leq \frac{G}{\gamma} < \Omega(n_f)$,
iv) $0 < n_I^c < n_f$ *and* $n_I^* = n_f$ *if* $\Psi(n_f) \leq \frac{G}{\gamma} < \Psi(0)$,
v) $n_I^c = n_I^* = n_f$ *if* $0 \leq \frac{G}{\gamma} < \Psi(n_f)$.

The next lemma displays the equilibria for subcase I.2 (see Figure 2):

Lemma 2 *Suppose* $(a-\hat{m})<0$ *and* $n^o<n_f<\hat{n}$. *Then the number of investors at equilibrium is a function of* $\frac{G}{\gamma}$ *as follows:*
i) $n_I^c=n_I^*=0$ *if* $\frac{G}{\gamma}\geq\Omega(0)$,
ii) $n_I^c=0$ *and* $0<n_I^*<n_f$ *if* $\Psi(0)\leq\frac{G}{\gamma}<\Omega(0)$,
iii) $0<n_I^c<n_I^*<n_f$ *if* $\Omega(n_f)\leq\frac{G}{\gamma}<\Psi(0)$,
iv) $0<n_I^c<n_I^*=n_f$ *if* $\Psi(n_f)\leq\frac{G}{\gamma}<\Omega(n_f)$,
v) $n_I^c=n_I^*=n_f$ *if* $0\leq\frac{G}{\gamma}<\Psi(n_f)$.

Since in Case I $\Omega(n_I)$ always lies above $\Psi(n_I)$, then for any given $\frac{G}{\gamma}$ the crossing point between $\frac{G}{\gamma}$ and $\Psi(n_I)$ is reached at a smaller n_I value than that of $\frac{G}{\gamma}$ and $\Omega(n_I)$. Remind that these crossing points identify the equilibrium number of investors under uncertainty and informational asymmetry and under certainty, respectively. Therefore $n_I^c<n_I^*$ (items ii, iii and iv in lemmas 1 and 2). The other situations arise because the number of investors is nonnegative and cannot exceed n_f. Thus, for $\frac{G}{\gamma}$ large enough, that is $\frac{G}{\gamma}>\Omega(0)>\Psi(0)$, no crossing points occur and therefore we conclude that $n_I^c=n_I^*=0$ (which are items i in the above lemmas). Furthermore, if $\frac{G}{\gamma}$ is small enough, that is if $\frac{G}{\gamma}<\Psi(n_f)<\Omega(n_f)$ then the crossing points are reached at a number of investors greater than n_f and, therefore, we conclude that the equilibrium number of investors is equal to n_f under both environments. It corresponds to items v in lemmas 1 and 2. Result 1 in the text follows from the combination of lemmas 1 and 2.

Now consider Case III, that is, $\frac{(N+1)^2\hat{\sigma}^2}{2N\tau(n_h+1)^2}\leq(a-\hat{m})$ which implies that $\Psi(n_I)>\Omega(n_I)$ for all n_I. Then it is verified that $\Psi(0)>\Omega(0)$ and $\tilde{n}<\hat{n}$. Let us define n^p as the number which satisfies $\Omega(0)=\Psi(n^p)$. It follows that $0<n^p<\tilde{n}<\hat{n}$. As in Case I several subcases are distinguished attending to the relative position of n_f with respect to the ranking $n^p<\tilde{n}<\hat{n}$. These are: subcase III.1 for $0<n_f<n^p$, subcase III.2 for $n^p<n_f<\tilde{n}$ and finally subcase III.3 for $\tilde{n}<n_f<\hat{n}$. Note that Case III is similar to Case I but with the reversed conclusion that $n_I^* \leq n_I^c$ and a parallel reasoning as above applies.

The next lemma presents the equilibria for subcase III.1:

Lemma 3 *Suppose* $\frac{(N+1)^2\hat{\sigma}^2}{2N\tau(n_h+1)^2} \leq (a-\hat{m})$ *and* $0 < n_f < n^p$*. Then, the number of investors at equilibrium is a function of* $\frac{G}{\gamma}$ *as follows:*

i) $n_I^* = n_I^c = 0$ *if* $\frac{G}{\gamma} \geq \Psi(0)$,

ii) $n_I^* = 0$ *and* $0 < n_I^c < n_f$ *if* $\Psi(n_f) \leq \frac{G}{\gamma} < \Psi(0)$,

iii) $n_I^* = 0$ *and* $n_I^c = n_f$ *if* $\Omega(0) \leq \frac{G}{\gamma} < \Psi(n_f)$,

iv) $0 < n_I^* < n_f$ *and* $n_I^c = n_f$ *if* $\Omega(n_f) \leq \frac{G}{\gamma} < \Omega(0)$,

v) $n_I^* = n_I^c = n_f$ *if* $0 \leq \frac{G}{\gamma} < \Omega(n_f)$.

The equilibria corresponding to subcase III.2 appear in the next lemma (see Figure 4):

Lemma 4 *Suppose* $\frac{(N+1)^2\hat{\sigma}^2}{2N\tau(n_h+1)^2} \leq (a-\hat{m})$ *and* $n^p < n_f < \tilde{n}$*. Then, the number of investors at equilibrium is a function of* $\frac{G}{\gamma}$ *as follows:*

i) $n_I^* = n_I^c = 0$ *if* $\frac{G}{\gamma} \geq \Psi(0)$,

ii) $n_I^* = 0$ *and* $0 < n_I^c < n_f$ *if* $\Omega(0) \leq \frac{G}{\gamma} < \Psi(0)$,

iii) $0 < n_I^* < n_I^c < n_f$ *if* $\Psi(n_f) \leq \frac{G}{\gamma} < \Omega(0)$,

iv) $0 < n_I^* < n_I^c = n_f$ *if* $\Omega(n_f) \leq \frac{G}{\gamma} < \Psi(n_f)$,

v) $n_I^* = n_I^c = n_f$ *if* $0 \leq \frac{G}{\gamma} < \Omega(n_f)$.

The equilibria corresponding to subcase III.3 appear in the next lemma:

Lemma 5 *Suppose* $\frac{(N+1)^2\hat{\sigma}^2}{2N\tau(n_h+1)^2} \leq (a-\hat{m})$ *and* $\tilde{n} < n_f < \hat{n}$*. Then, the number of investors at equilibrium is a function of* $\frac{G}{\gamma}$ *as follows:*

i) $n_I^* = n_I^c = 0$ *if* $\frac{G}{\gamma} \geq \Psi(0)$,

ii) $n_I^* = 0$ *and* $0 < n_I^c < n_f$ *if* $\Omega(0) \leq \frac{G}{\gamma} < \Psi(0)$,

iii) $0 < n_I^* < n_I^c < n_f$ *if* $\Psi(n_f) \leq \frac{G}{\gamma} < \Omega(0)$, *iv)* $0 < n_I^* < n_I^c = n_f$ *if* $0 \leq \frac{G}{\gamma} < \Psi(n_f)$.

The combination of lemmas 3 to 5 leads to result 3 in the text.

Next consider case II.1, that is, $0 \leq (a - \hat{m}) < \frac{\hat{\sigma}^2}{2N\tau}$ which implies that $\Omega(n_I) > \Psi(n_I)$ for all $n_I < \bar{n}$ whereas $\Psi(n_I) > \Omega(n_I)$ for all $n_I > \bar{n}$. Therefore, it is satisfied that $\Omega(0) > \Psi(0)$ and $\tilde{n} < \hat{n}$. Note that $(a - \hat{m}) < \frac{\hat{\sigma}^2}{2N\tau}$ implies $\bar{n} > n_f$ and also recall that $n_f < \hat{n}$. This allows us to distinguish two subcases depending on the size of n_f. These are subcase II.1.1 where $0 < n_f < n^o$ and subcase II.1.2 where $n^o < n_f < \bar{n}$.

The next lemma displays the equilibria for subcase II.1.1:

Lemma 6 *Suppose* $0 \leq (a - \hat{m}) < \frac{\hat{\sigma}^2}{2N\tau}$ *and* $0 < n_f < n^o$. *Then the number of investors at equilibrium is a function of* $\frac{G}{\gamma}$ *as follows:*
i) $n_I^c = n_I^* = 0$ *if* $\frac{G}{\gamma} \geq \Omega(0)$,
ii) $n_I^c = 0$ *and* $0 < n_I^* < n_f$ *if* $\Omega(n_f) \leq \frac{G}{\gamma} < \Omega(0)$,
iii) $n_I^c = 0$ *and* $n_I^* = n_f$ *if* $\Psi(0) \leq \frac{G}{\gamma} < \Omega(n_f)$,
iv) $0 < n_I^c < n_f$ *and* $n_I^* = n_f$ *if* $\Psi(n_f) \leq \frac{G}{\gamma} < \Psi(0)$,
v) $n_I^c = n_I^* = n_f$ *if* $0 \leq \frac{G}{\gamma} < \Psi(n_f)$.

The next lemma displays the equilibria for subcase II.1.2:

Lemma 7 *Suppose* $0 \leq (a - \hat{m}) < \frac{\hat{\sigma}^2}{2N\tau}$ *and* $n^o < n_f < \hat{n}$. *Then the number of investors at equilibrium is a function of* $\frac{G}{\gamma}$ *as follows:*
i) $n_I^c = n_I^* = 0$ *if* $\frac{G}{\gamma} \geq \Omega(0)$,
ii) $n_I^c = 0$ *and* $0 < n_I^* < n_f$ *if* $\Psi(0) \leq \frac{G}{\gamma} < \Omega(0)$,
iii) $0 < n_I^c < n_I^* < n_f$ *if* $\Omega(n_f) \leq \frac{G}{\gamma} < \Psi(0)$,
iv) $0 < n_I^c < n_I^* = n_f$ *if* $\Psi(n_f) \leq \frac{G}{\gamma} < \Omega(n_f)$,
v) $n_I^c = n_I^* = n_f$ *if* $0 \leq \frac{G}{\gamma} < \Psi(n_f)$.

These two lemmas are similar to those of subcases I.1 and I.2.

Consider case II.2, that is, $\frac{\hat{\sigma}^2}{2N\tau} \leq (a-\hat{m}) < \frac{(N+1)^2\hat{\sigma}^2}{2N\tau(n_h+1)^2}$ which implies that $\Omega(n_I) > \Psi(n_I)$ for all $n_I < \bar{n}$ whereas $\Psi(n_I) > \Omega(n_I)$ for all $n_I > \bar{n}$. Therefore, it is satisfied that $\Omega(0) > \Psi(0)$ and $\tilde{n} < \hat{n}$. In this case, since $(a-\hat{m}) > \frac{\hat{\sigma}^2}{2N\tau}$ then $n_f > \bar{n}$. Two subcases can be distinguished: subcase II.2.1 where $\bar{n} < n_f < \tilde{n}$ and subcase II.2.2 where $\tilde{n} < n_f < \hat{n}$.

The next lemma summarizes the equilibria for subcase II.2.1:

Lemma 8 *Suppose* $\frac{\hat{\sigma}^2}{2N\tau} \leq (a-\hat{m}) < \frac{(N+1)^2\hat{\sigma}^2}{2N\tau(n_h+1)^2}$ *and* $\bar{n} < n_f < \tilde{n}$. *Then the number of investors at equilibrium is a function of* $\frac{G}{\gamma}$ *as follows:*
i) $n_I^c = n_I^* = 0$ *if* $\frac{G}{\gamma} \geq \Omega(0)$,
ii) $n_I^c = 0$ *and* $0 < n_I^* < n_f$ *if* $\Psi(0) \leq \frac{G}{\gamma} < \Omega(0)$,
iii) $0 < n_I^c < n_I^* < n_f$ *if* $\Psi(\bar{n}) \leq \frac{G}{\gamma} < \Psi(0)$,
iv) $0 < n_I^* < n_I^c < n_f$ *if* $\Psi(n_f) \leq \frac{G}{\gamma} < \Psi(\bar{n})$,
v) $0 < n_I^* < n_I^c = n_f$ *if* $\Omega(n_f) \leq \frac{G}{\gamma} < \Psi(n_f)$,
vi) $n_I^* = n_I^c = n_f$ *if* $0 \leq \frac{G}{\gamma} < \Omega(n_f)$.

The next lemma summarizes the equilibria for subcase II.2.2 (see Figure 3 in the text):

Lemma 9 *Consider* $\frac{\hat{\sigma}^2}{2N\tau} \leq (a-\hat{m}) < \frac{(N+1)^2\hat{\sigma}^2}{2N\tau(n_h+1)^2}$ *and* $\tilde{n} < n_f < \hat{n}$. *Then the number of investors at equilibrium will be a function of* $\frac{G}{\gamma}$ *as follows:*
i) $n_I^c = n_I^* = 0$ *if* $\frac{G}{\gamma} \geq \Omega(0)$,
ii) $n_I^c = 0$ *and* $0 < n_I^* < n_f$ *if* $\Psi(0) \leq \frac{G}{\gamma} < \Omega(0)$,
iii) $0 < n_I^c < n_I^* < n_f$ *if* $\Psi(\bar{n}) \leq \frac{G}{\gamma} < \Psi(0)$,
iv) $0 < n_I^* < n_I^c < n_f$ *if* $\Psi(n_f) \leq \frac{G}{\gamma} < \Psi(\bar{n})$,
v) $0 < n_I^* < n_I^c = n_f$ *if* $0 \leq \frac{G}{\gamma} < \Psi(n_f)$.

Lemmas 6 to 9 lead to the statement of result 2 in the text.

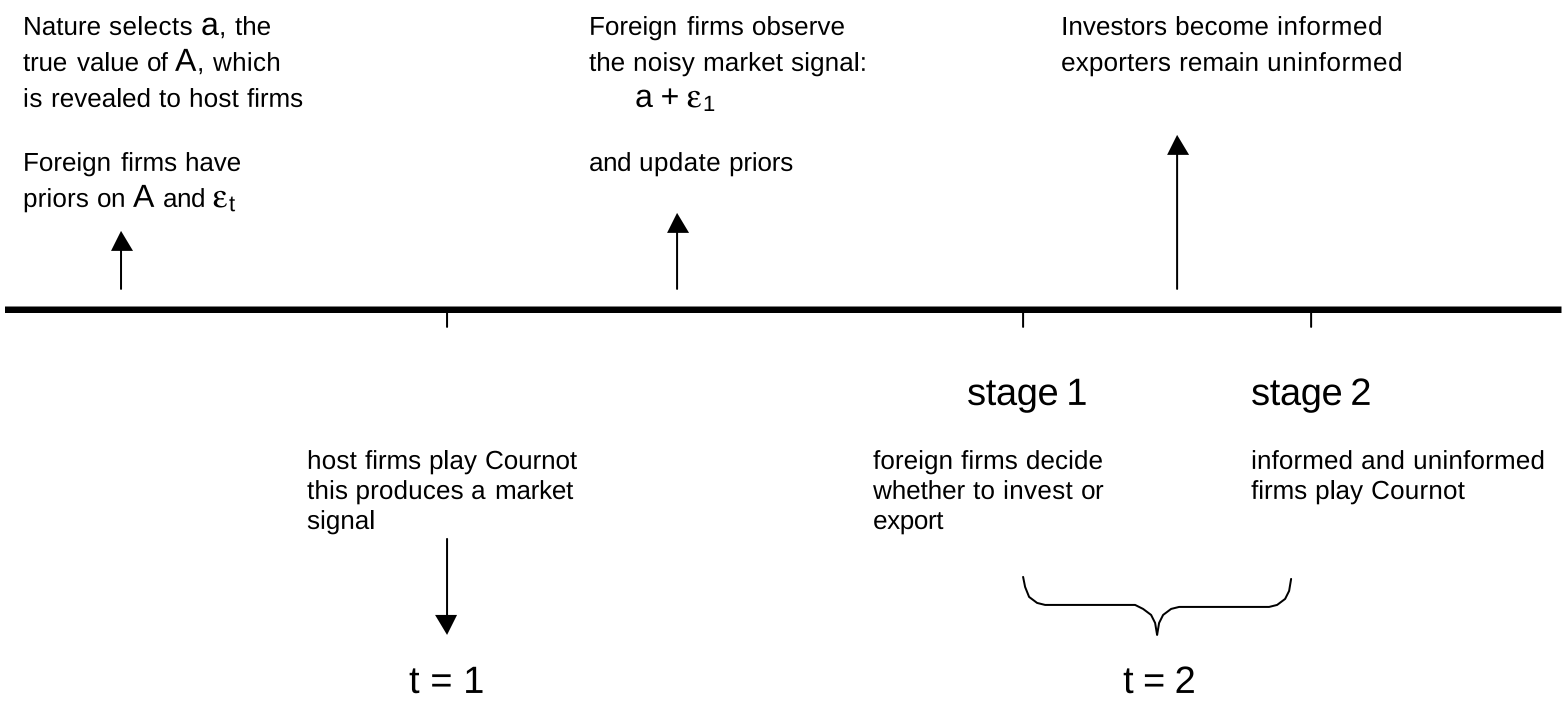

Figure 1: Timeline of decisions and information flow

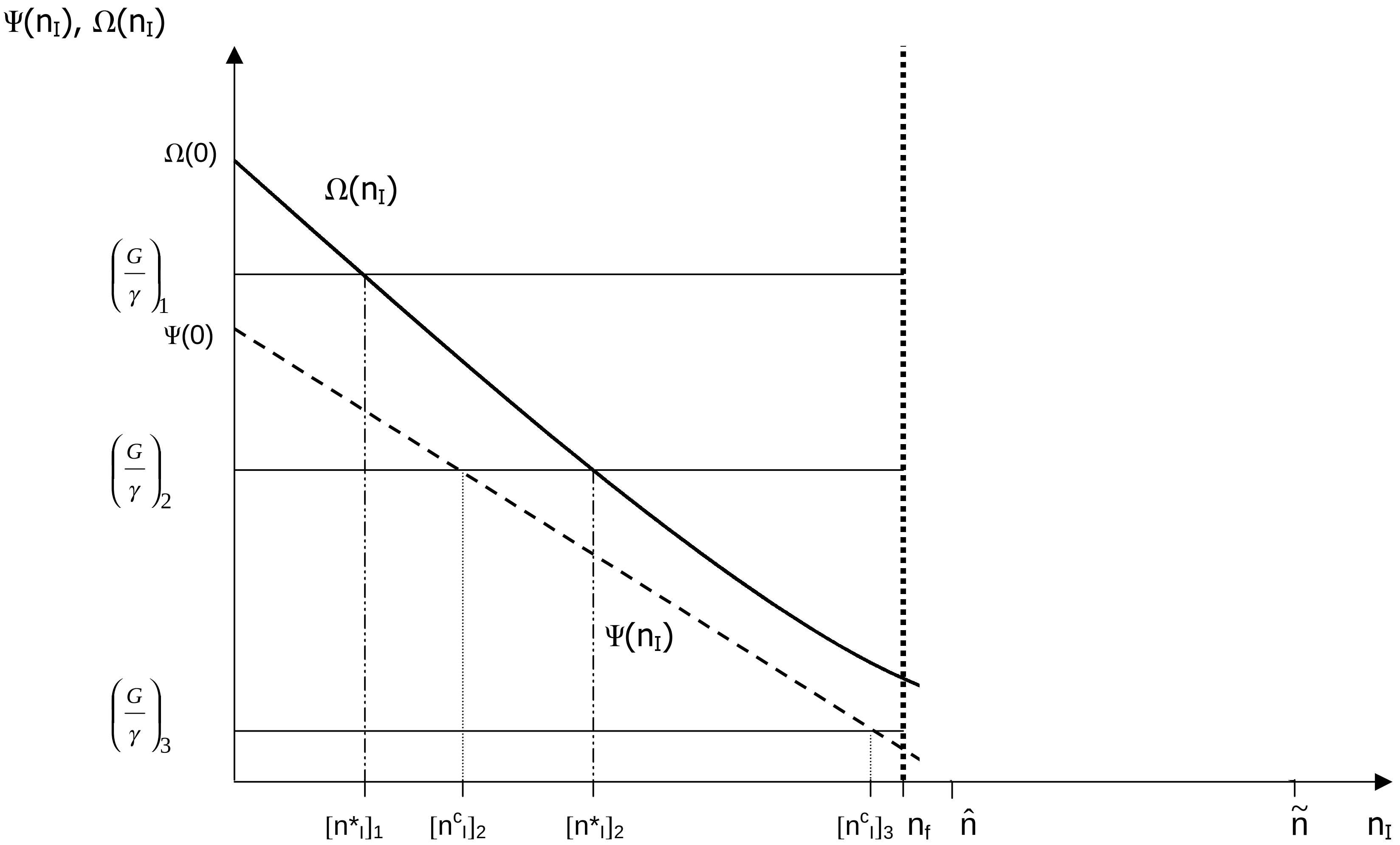

Figure 2: An example for Case I: $n_f < \hat{n} < \tilde{n}$

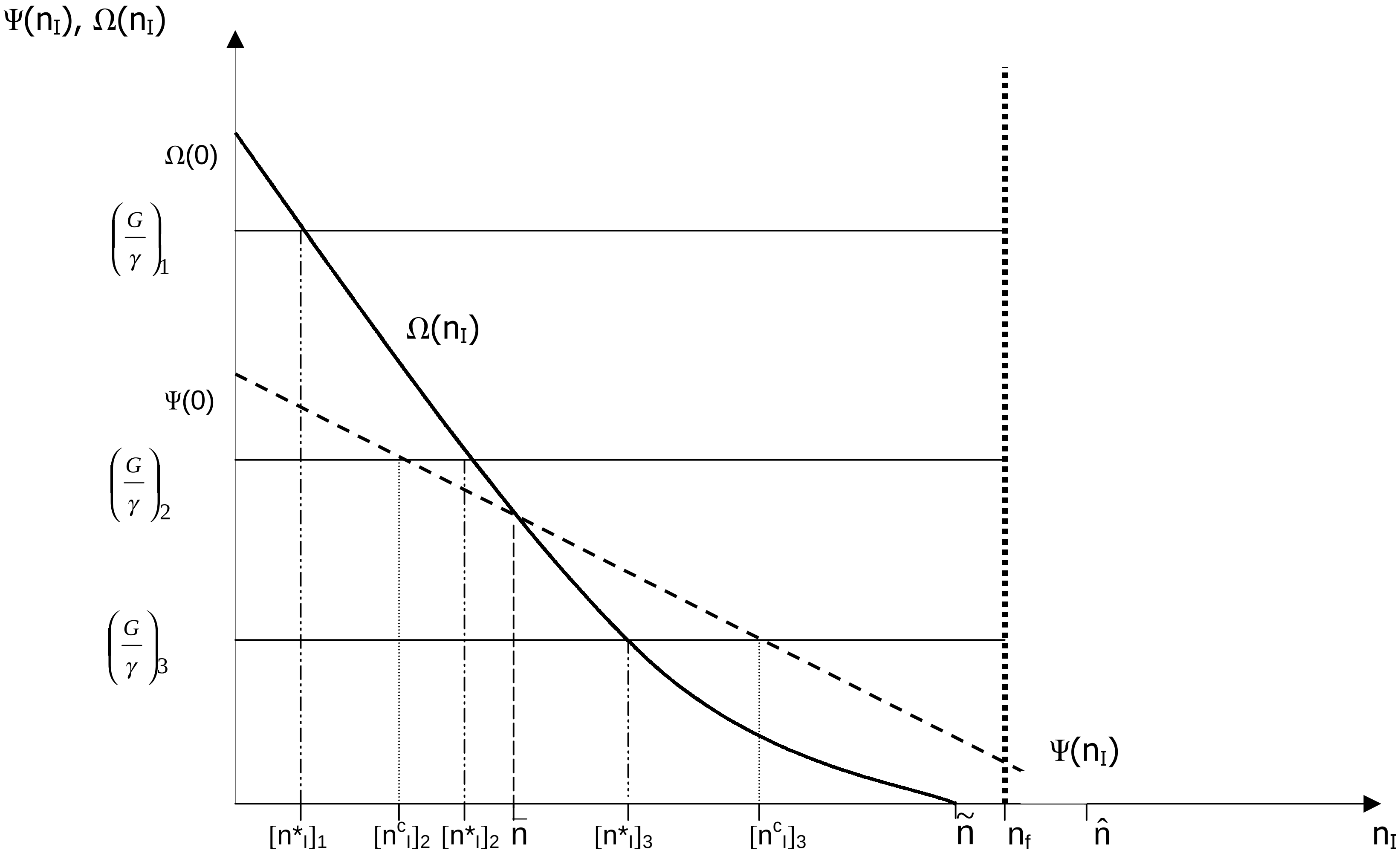

Figure 3: An example for Case II.2: $\tilde{n} < n_f < \hat{n}$

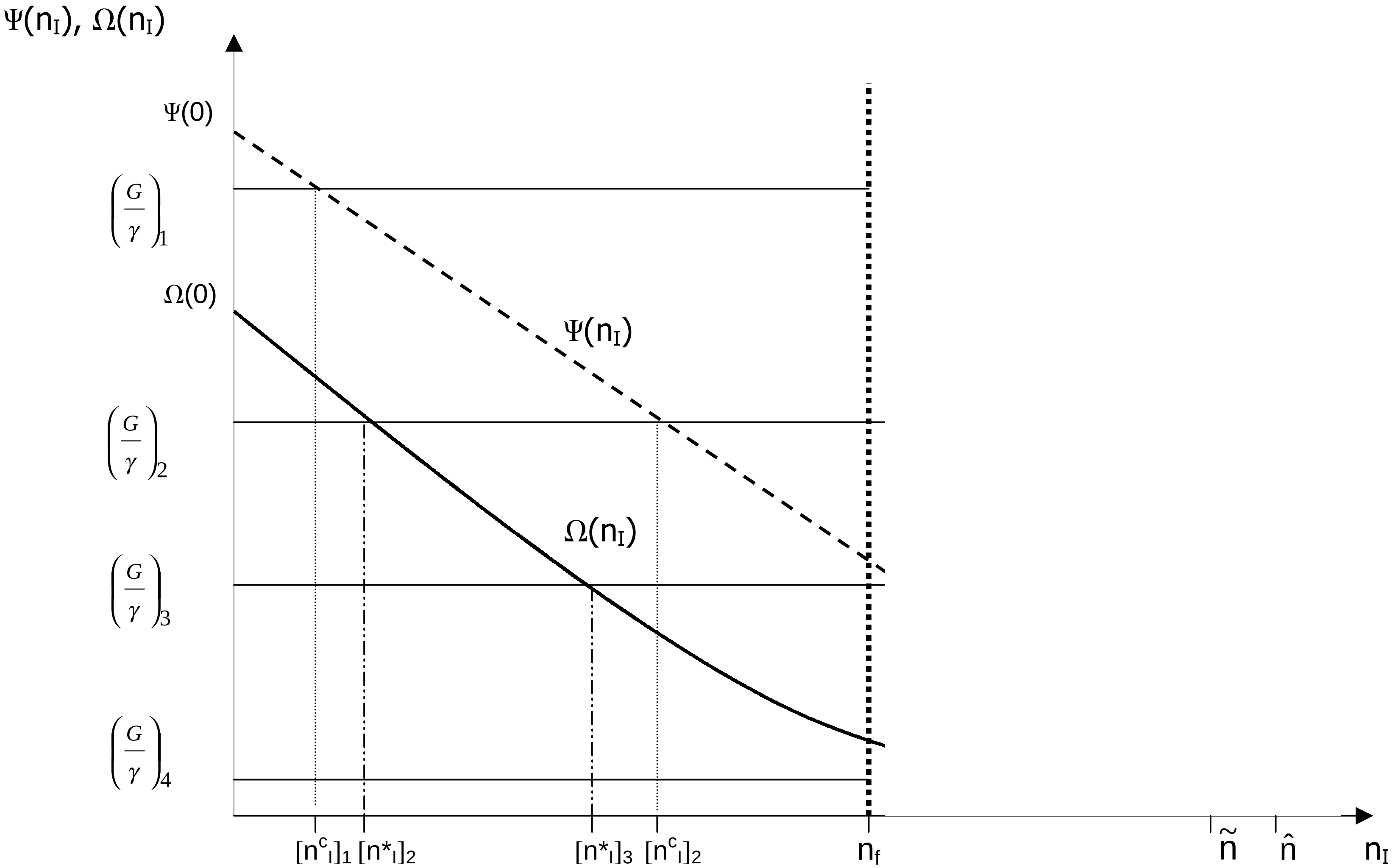

Figure 4: An example for Case III: $n_f < \tilde{n} < \hat{n}$