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The made-in effect and leapfrogging: A model of leadership change for products with country-of-origin bias

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ABSTRACT

Change in industrial leadership is often explained in terms of technological and costs advantages. However firms in emerging economies not only have to produce high quality, cost-competitive goods, but also win the resistance of consumers in the world market, who are often adverse to purchasing products from countries that yet have to build a reputation. We argue that this country-of-origin bias significantly influences the chances of leadership change. A model that aims at capturing the endogenous dynamics of demand building and leapfrogging is proposed. We show that in sectors with high monopoly power acquiring a superior technology is not sufficient for a latecomer country to become leader, unless a significant share of consumers is aware of the quality of its products. An extension of the model to multiple sectors shows that a latecomer country remains specialized into low-value undifferentiated goods, even after overtaking the technology of the leading country.

1. Introduction

Throughout the history of capitalism, recurrent changes of industrial leadership from the incumbent to the latecomer country have taken place in a variety of sectors (e.g., in shipbuilding, steel, photographic cameras, mobile phones) (Lee and Malerba, 2017). Some authors have related leadership change to technology-driven dynamic comparative advantages. Brezis et al. (1993) show how leapfrogging may occur in technologically progressive sectors that exhibit learning-by-doing and local spillovers. More recent studies have linked leadership changes to city life cycles (Brezis and Krugman, 1997), spillovers between the old and the new technology with capital mobility (Desmet, 2002) and international spillovers (Furukawa, 2015).

In parallel, other authors suggest that the role of demand can be complementary to that of technology in explaining leapfrogging. Motta et al. (1997) argue that differences in internal demand can lead to differentiated investments in product quality among nations. Artige et al. (2004) show that leadership change can occur when increasing wealth in the leading nation generates a change in habits that favors consumption over investment. Giovannetti (2013) shows how a preference for quality can influence technology adoption and, subsequently, catching up or leapfrogging.

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In this paper, we argue that to challenge the established leadership, it may be not enough to produce high-quality or cost-competitive products if consumers have a marked *country-of-origin bias*. Also referred to as the *made-in* effect, this distortion leads consumers to infer quality from the products' country of origin (Dinnie, 2004). The existing literature on the made-in effect finds that such bias is strong, in particular for differentiated durable and luxury consumer goods for which quality is imperfectly observable before purchase (Godey et al., 2012). A few illustrative examples are German cars, American software, Japanese electronics, Swiss watches, Portuguese tiles, Italian clothing, and French wine. A case in point is indeed the catch-up dynamic in the wine industry, where some producers (in emerging countries, such as Chile, and in developed countries, such as Australia) have, in recent years, managed to take a sizable share of the world market. These producers certainly had to learn how to make good wine. However, they also made a huge effort to get consumers to acknowledge that their bottles could compare to those from Italy or France (see Morrison and Rabellotti, 2017). This example suggests that catch-up is also a story of discovery and shifting demand: consumers need to discover that the products from the follower country are just as good as those currently on the market.

In this paper, we develop a simple theoretical 2-country model to evaluate the role of the made-in effect in the dynamics of sectoral leapfrogging. The model initially assumes that the follower produces at lower costs and that informed consumers on world markets find the goods produced in the two countries to be of equal quality. Nonetheless, most consumers are not informed and cannot observe product quality before purchase. Thus, only a minority of pioneering consumers are willing to purchase the follower's products, which are of unknown quality. As these pioneering consumers discover that the follower's products are just as good, a process of information diffusion begins. Other consumers are 'infected' with the information on the quality of goods and become willing – in the next period – to purchase those products. On the production side, firms' entry, growth and exit are driven by profits. Firms in the leader and follower countries increase or decrease in number according to the profits made. We then extend the model to a continuum of tradable goods to assess how the dynamics of leapfrogging influence the pattern of specialization and comparative advantage of the follower and leader countries.

We find that for differentiated goods, acquiring a superior technology is insufficient for the follower to leapfrog the leader, unless there is a sufficiently large share of consumers who are aware of the quality of the follower's products. Further, we observe that in some cases, leapfrogging depends on the dynamics of entry and exit of firms and on the dynamics of information diffusion among consumers. In the general equilibrium, multiple-product case, the follower – because of its late entry into the world market – specializes in low-value, highly substitutable goods, while the leader keeps production on more monopolistic markets. Even when the follower reaches a level of technological sophistication well beyond that of the leader, wages still favor the first comer. Empirical evidence of this specialization pattern is presented in Section 5.

While this work has been inspired by the cases of catching up and leapfrogging of emerging or developing countries such as Korea, Taiwan, India, and Chile, the structure, results and application of the model may be considered more general. They may broadly refer to a follower country seeking to catch up with the leading country in a specific sector. The model may represent competition in a sector in which a follower industry from an advanced country lags behind the leading industry of another advanced country. For the sake of keeping the argument simple and clear, however, in this paper, we will regard the leading country and follower country as an advanced country and an emerging or developing country.

This paper contributes to the several related literatures. Catch-up and leapfrogging dynamics have been modeled in international economics (e.g., Brezis et al., 1993; Desmet, 2002), endogenous growth theory (e.g., Grossman and Helpman, 1991; Artige et al., 2004) and industrial organization (Giovannetti 2001, 2013), with a clear overlap across disciplines. Our findings show how consumers' behavior – the made-in distortion of purchasing decisions – influences the chances of leapfrogging. These results also add to the empirical literature on catching up and industrial dynamics, in which catch-up and leapfrogging have been associated with the supply-side and the learning of skills – through education, technological transfer, imitation, building experience and with social capabilities (Abramovitz, 1986; Lee and Lim, 2001; Malerba and Nelson, 2011). In this paper, we highlight the importance of demand-side learning, which in spite of some exceptions has been overlooked (Posner, 1961; Adner, 2002; Malerba, 2005). Our results also contribute to the literature in international economics addressing how demand influences specialization patterns and trade (Fieler, 2011; Fajgelbaum et al., 2011; Feenstra and Romalis, 2014).

The paper is organized as follows: in Section 2, the baseline model is presented, first when only firms from the leading country are present, then while considering the dynamics triggered by the entry of firms from the catching-up country. In Section 3.1, we show the possible outcomes of the model: leapfrogging, maintained leadership and partial catch-up. We then discuss under which conditions each outcome is attained. First, in Section 3.2, we highlight that under a set of parameters, the dynamics of entry and exit, as well those of demand, do not influence the outcome, and we derive analytically a simple leapfrogging condition. In Section 3.3, we analyze the transitional dynamics of the system and show how dynamic elements of the model, such as the speed of information diffusion or the rate of entry and exit of firms, can – in some circumstances – affect whether leapfrogging occurs. Then, Section 3.4 analyzes how investment in advertising affects leapfrogging and shows how the social planner might improve on the market outcome. In Section 4, we extend the model to multiple products and to a 2-country general equilibrium framework to show that the latecomer country specializes in low-value homogeneous goods, even after overtaking the technology of the leader.

Finally, Section 5 presents suggestive evidence on the empirical relevance of the made-in effect, and Section 6 presents the conclusions.

2. Baseline model

2.1. Static

We start with a static model. The world market for a particular industry is dominated by firms from one country, L (leader). To build a static model that describes the industry before the entry of firms from the follower country, we use a monopolistic competition model (Dixit and Stiglitz, 1977 and Krugman, 1980). All firms in the leading country use a homogeneous technology, which is freely available through imitation to all entrepreneurs in that country. The production uses only labor and has a fixed cost. Formally,

$$l_i = a_L x_i + b_L, \tag{1}$$

where l_i is the amount of labor input used by firm i in country L to produce x_i units of output, and a and b are parameters of the model. The nominal cost of labor (wage) is fixed, as the sector represents only a small portion of the economy of the country. Demand is represented by a CES (constant elasticity of substitution) function:

$$x_i = \frac{P_i^{-\sigma}}{\sum_{k\in L} P_k^{1-\sigma}} E, \tag{2}$$

where P_i is price of the variety i, E is expenditure, the budget consumers in the world market allocate to the products from this sector (exogenous in this version of the model), and σ is the elasticity of substitution. The CES demand implies that goods are horizontally differentiated. This means that, while there is no hierarchy in quality, consumers appreciate differences between varieties, so that a lower price does not cannibalize the entire demand. Firms' profit function is

$$\pi_i = p_i x_i - w_L(a_L x_i + b_L). \tag{3}$$

Given the CES demand function, each firm can choose its own price, as each has a degree of monopolistic power. The price associated with the highest profit is

$$p_i = \frac{\sigma}{\sigma - 1} w_L a_L. \tag{4}$$

The profit-maximizing price is the standard mark-up on variable costs that depends on σ. For σ close to 1 (quasi-monopoly), firms can set high mark-ups. For large σ (highly competitive sectors), only small margins can be made. Denoting the number of firms as n_L, in equilibrium, we have

$$\bar{n}_L = \frac{E}{\sigma w_L b_L}. \tag{5}$$

If n_L is lower than $\bar{n}_L$, the firms in the market will be making positive profits, which attracts new firms to the market. The process continues until it reaches the maximum sustained by the market, that is $\bar{n}_L$. In the opposite case (in which n_L is greater than $\bar{n}_L$), negative profits would drive firms out of the market until the maximum capacity and $\bar{n}_L$ is reached.

Let us now imagine that in another country F (follower), a new efficient method of production becomes available to every entrepreneur in the country. This technology is at least as efficient as that of country L. To operationalize this, in the baseline model, it is assumed that the two countries have identical wages ($w_L = w_F$) and fixed costs ($b_L = b_F$) but different variable costs, with $a_L \geq a_F$. This choice (which we relax in Section 4) does not imply a loss of generality. It is made for exposition purposes (it is convenient in the context of monopolistic competition since the maximum number of firms sustained by the market does not depend on variable costs, see Eq. (5), which simplifies the model slightly) as well to stress one of the main points of the paper: that technological catch-up may not be sufficient for leapfrogging. It is important to highlight that there is no substantial difference (only formal) between the case where the follower has equal wages with the leader, but lower variable costs, and the case where the follower has the same technology, but lower wages. The production technology is then

$$l_i = a_F x_i + b. \tag{6}$$

In contrast to Eq. (1), the subscript of b has been removed here (since we assumed no difference between L and F in this respect). The newly available technology of country F allows for the production goods of identical quality to those of country L, which means that the varieties of the countries are not in a vertical hierarchy (such as in quality ladder models) but are only horizontally differentiated. However, most consumers do not consider products from country F as a possible purchase, as at this initial entry stage they are not aware of these latter products' quality. Only a minority of pioneering consumers who are aware of the quality of the good will purchase it. We assume that expenditure per consumer is equal to one. If there are J aware consumers, the total demand for variety i from country F is

$$x_{i,F} = \frac{P_i^{-\sigma}}{\sum_{k\in L} P_k^{1-\sigma} + \sum_{k\in F} P_k^{1-\sigma}} J. \tag{7}$$

Total demand for variety i from country L is

$$x_{i,L} = \frac{P_i^{-\sigma}}{\sum_{k\in L} P_k^{1-\sigma} + \sum_{k\in F} P_k^{1-\sigma}} J + \frac{P_i^{-\sigma}}{\sum_{k\in L} P_k^{1-\sigma}} (E-J). \tag{8}$$

The first term on the right-hand side (RHS) of (8) is the quantity of goods that a firm in the leading country (L) manages to sell to the J aware consumers. The second term on the RHS is the quantity sold to the $E-J$ unaware customers. Note that since both type of firms sell to the same international market, there is no need to qualify E and J with an index denoting destination.

Firms in country F know that they possess a valid and potentially profitable technology. However they also know that the majority of global consumers $(E-J)$ will not buy their product. Before the first firm from country F sells on international markets, it is not known how many consumers J exist. Thus, potential entrants face a high degree of uncertainty and cannot predict whether they will make positive profits by entering the market. We assume that some potential entrants (pioneering firms) have a high risk propensity and enter the market despite the uncertainty. Assuming this myopic behavior is in our view well justified by the reality of export emergence, where pioneers engage in a process of self-discovery to find out what can be successfully exported (Hausmann and Rodrik, 2003).

2.2. Profit functions

The profits of firms from L and F are, respectively,

$$\pi_{i,L} = (P_i - wa_L)\left[\frac{P_i^{-\sigma}}{\sum_{k\in L} P_k^{1-\sigma} + \sum_{k\in F} P_k^{1-\sigma}} J + \frac{P_i^{-\sigma}}{\sum_{k\in L} P_k^{1-\sigma}} (E-J)\right] - wb \tag{9}$$

$$\pi_{i,F} = (P_i - wa_F)\left(\frac{P_i^{-\sigma}}{\sum_{k\in L} P_k^{1-\sigma} + \sum_{k\in F} P_k^{1-\sigma}}\right) J - wb. \tag{10}$$

There is a number of substitutions we can apply to both profit equations. As shown in Eq. (4), the price chosen by a profit-maximizing firm can be expressed in terms of few model parameters. Second – given that all L firms are identical and the same goes for F firms – L firms choose the same price $P_{i,\,L}$, while F firms choose the same as $P_{i,\,F}$. Third, as $P_i = P_{i,L}$, $\forall i \in L$ and $P_i = P_{i,F}$, $\forall i \in F$, it follows that we can replace the sums in the price index with n_L and n_F. Fourth, to simplify the notation we define $r = a_L/a_F$. Finally, it is convenient to explicitly highlight the difference between parameters and variables that evolve over time (state variables). After substitutions and rearrangements, we have that profits of firms from L and F are, respectively,

$$\pi_{i,L}(t) = \frac{n_L(t)Er^{1-\sigma} + n_F(t)[E-J(t)] - n_L(t)^2 wb\sigma r^{1-\sigma} - n_L(t)n_F(t)wb\sigma}{n_L(t)^2 r^{1-\sigma}\sigma + n_L(t)n_F(t)\sigma} \tag{11}$$

$$\pi_{i,F}(t) = \frac{J(t) - n_F(t)wb\sigma - n_L(t)wbr^{1-\sigma}\sigma}{n_F(t)\sigma + n_L(t)r^{1-\sigma}\sigma}. \tag{12}$$

2.3. Dynamics

The essence of this model is in the dynamics which originate from the setting presented in Sections 2.1 and 2.2. The starting point is that of a market entirely dominated by L, with $n_L(t) = E/wb\sigma$ and $n_F(t) = 0$, for all $t < 0$. Then, at time $t = 0$, an exogenous number of pioneers from the follower country – $n_F(0)$ – enter the market. At that point, the number of pioneering consumers $J(0)$ willing to buy their products is revealed. If the entry is successful and firms from country F make positive profits, new imitators will follow the pioneers. Conversely, if negative profits (losses) are made, firms will exit the market. The law of motion of firms from country F is described by the following differential equation:

$$\dot{n}_F(t) = \alpha n_F(t)\pi_{i,F}(t), \tag{13}$$

where the left-hand side (LHS) is the derivative of number of firms with respect to time, while the RHS is a function of number of firms, $n_F(t)$, and profits. In turn, profits of firm j are a function of $J(t)$, $n_L(t)$ and $n_F(t)$ (see (12)).

The differential equation is a zero profit condition that also allows for dynamics to reflect our interest. This function describes the dynamics of entry by imitation or exit by failure and depends on n_F (more visibility, higher chances of spin-offs) and on profits (which can be negative, driving firms out of the market)[1]. The parameter α captures the speed of entry and exit. An analogous law of motion dictates entry and exit of firms from country L:

$$\dot{n}_L(t) = \alpha n_L(t)\pi_{i,L}(t). \tag{14}$$

[1] An entry/exit differential equation that depends on the current value of the state variable can be seen as having a parallel in reproduction functions in population dynamics (biology, demography).

In the model, the number of aware consumers $J(t)$ changes over time: as the varieties offered by country F experience an expanded presence in world markets, increasing numbers of consumers become aware of their quality. The following endogenous law of motion illustrates this process:

$$\dot{J}(t) = \beta J(t)(E - J(t))(n_F(t) - \tilde{n}). \tag{15}$$

The LHS is the derivative of the number of aware consumers with respect to time. This law of motion is an adaptation of the word-of-mouth information diffusion function $\dot{J}(t) = \beta J(t)(E - J(t))$, where a user contacts a non-user in a given period with probability β (Geroski, 2000). We enrich this function with a multiplication of the term $(n_F(t) - \tilde{n})$. This additional term is included to reflect the fact that the diffusion of information is not independent of the success and market exposure of firms (i.e., other consumers are not the only source of diffusion). In particular, when $n_F(t) = 0$, this function avoids the diffusion of information about a product that is no longer on the market. The parameter $\tilde{n}$ is an arbitrarily small number. Below this (low) threshold, consumers cannot *de facto* purchase the product (for instance, because they do not find in the supermarket) and slowly forget about it.

Eqs. (13), (14) and (15) represent the core of the model. It is a system of nonlinear differential equations in three state variables ($n_F(t)$, $n_L(t)$ and $J(t)$) and cannot be solved in explicit form. Nevertheless, it is possible to derive analytical results that are of considerable interest.

3. Leapfrogging vs maintained leadership

3.1. Steady states and simulations

We derive two main outcomes from our model: leapfrogging and maintained leadership. These two outcomes correspond to the only two stable steady states possible when $r > 1$. We emphasize here an important preamble about the model's dynamics. First, if $J(t) = E$, that is all consumers are aware of the quality of the goods from F, only firms from the country with better technology will survive on the long run. Second, if $J(t) = E$ and $r = 1$ there are infinite combinations of $n_F(t)$ and $n_L(t)$ that are in steady state. This is because firms are identical in this scenario. These premises, which are proven in the appendix in the form of lemmas, suggest that the most interesting case is when $J(0) < E$ and $r > 1$, as there is a trade-off between technology and demand. In this section, we concentrate on this case and present the two main steady states and discuss their stability. To illustrate the process that leads to those steady states, we show a representative numerical simulation. We note, however, that when $r = 1$ and $J(0) < E$, a third economically meaningful stable outcome, partial catch-up, is also possible. For completeness, we also discuss this outcome at the end of this subsection, while – for the rest of the analysis – the emphasis remains on maintained leadership and leapfrogging.

We also note that the system has several other steady states, all of which are uninteresting[2]. The one exception is an interior saddle point. Considerable activity occurs around this saddle point, which we discuss in Section 3.3. Finally we highlight that the case where $r < 1$ and $J(0) < E$ is also uninteresting. Lemma 1 shows that the steady states is maintained leadership for $r < 1$ and $J(0) = E$: it cannot be different for $J(0) < E$.

To simulate the dynamics of leapfrogging, maintained leadership and partial catch-up, a choice of parameters has been made[3].

Leapfrogging

The first outcome, leapfrogging, is shown in Fig. 1. Were it not for the information asymmetries created by the made-in effect, this would be the only outcome. Fig. 1 (where the horizontal axis is iterations/time) shows that, initially, firms from F are making losses, and the 20 pioneering firms are being driven out of the market, although a small fraction survives. The number of aware consumers is, simultaneously, growing – along with demand for products made by the followers. After some time, firms from country F make positive profits. This attracts new entrants from country F, which slowly takes over the whole market. Interestingly, before leapfrogging occurs, there is a long period of coexistence, during which firms in the two countries have relatively stable market shares. This occurs – as we discuss further in Section 3.3 – because for some starting points, the system is attracted to the interior saddle point before being pushed away.

This outcome, leapfrogging, is a steady-state equilibrium. It can be easily verified that when $n_F(t) = E/(wb\sigma)$, $n_L(t) = 0$ and $J(t) = E$, the system is stationary, with $\dot{n}_F(t) = 0$, $\dot{n}_L(t) = 0$, and $\dot{J}(t) = 0$. Moreover, the eigenvalues of the Jacobian are all negatives, giving the steady state asymptotic stability. In the appendix, we prove the following proposition.

Proposition 1. *The leapfrogging outcome is an asymptotically stable steady state of the system, and it is attained when* $n_F(t) = E/(wb\sigma)$, $n_L(t) = 0$ *and* $J(t) = E$.

Maintained leadership

The second outcome, maintained leadership, is shown in Fig. 2. We use here the same set of parameters as in Fig. 2, with the only difference being that now the leader has a smaller cost disadvantage. The figure shows a case in which the follower

[2] Some are inadmissible (i.e., require negative firms), while others are trivial and unstable (see appendix).

[3] For these and all other numerical solutions in the paper, appendix Appendix C specifies the value of parameters.

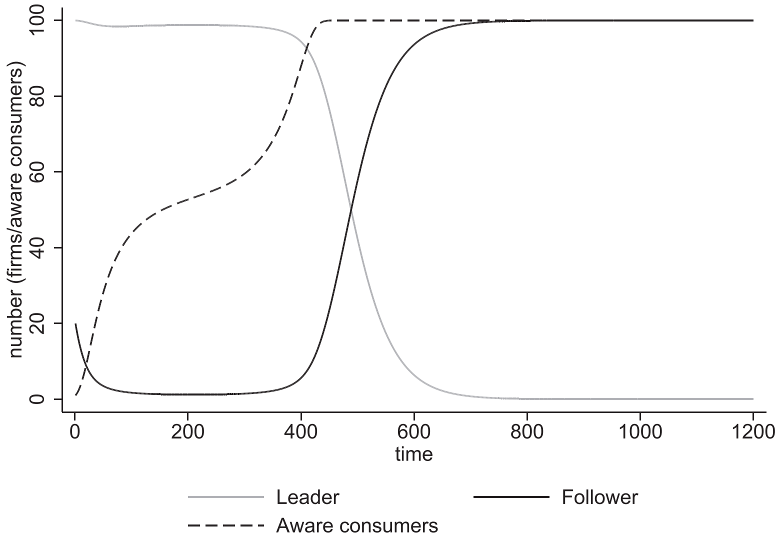

Fig. 1. Leapfrogging.

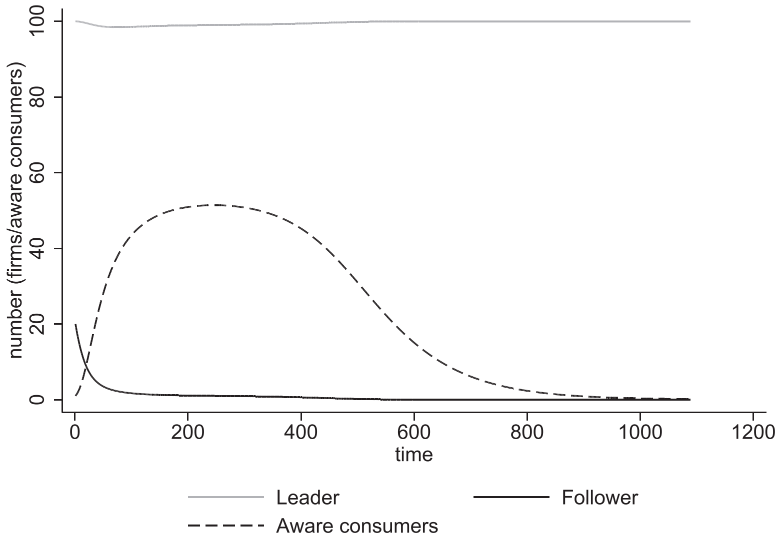

Fig. 2. Maintained leadership.

F is more efficient, and yet the leader dominates the market in the long run. This is because the demand for the products from *F* is too low and firms make negative profits, which forces them to exit gradually. The number of aware consumers is growing too slowly for the 20 pioneering firms from *F*, which all fail before the demand is high enough to result in positive profits. The firms from *L*, initially pressured by the competition, are now making profits, and their number grows until the maximum sustained by the market is reached. As we show in the appendix, this outcome is also asymptotically stable.

Proposition 2. *The maintained leadership outcome is an asymptotically stable steady state of the system, and it is attained when* $n_L(t) = E/(wb\sigma)$, $n_F(t) = 0$ *and* $J(t) = 0$.

Partial catch-up

To close Section 3.1, we illustrate the special case in which firms from the two countries have the same cost structure. In this scenario, it is possible (although it is not the only outcome) that the economy ends up in a situation of partial catch-up, with firms of either type surviving. In Fig. 3, we illustrate this case.

Without dynamics, an equal cost structure allows any division of the market to be a solution (lemma 2). The dynamics instead force the number of firms from country *F* below the number of pioneering firms. This is because we assume that there is a number of pioneers that are willing to take a chance and enter the market without knowing what their profits

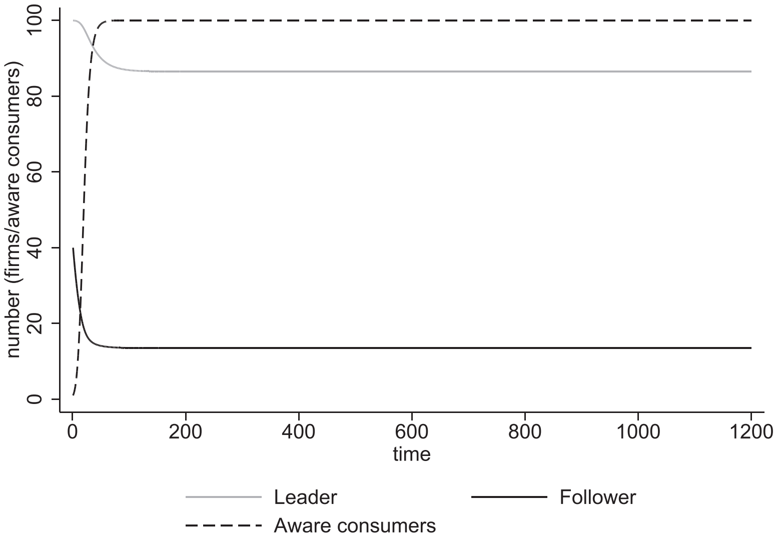

Fig. 3. Partial catch up.

would be. Once profits are revealed to be negative, no other entrepreneurs enter the market. The eventual growth of aware consumers to its maximum level makes the firms from the two countries indistinguishable. Once enough firms have failed and the zero profit condition is met, a few firms from the follower country are still in the market.

3.2. The leapfrogging condition

In the previous section, we showed the possible stable outcomes of the model. Our interest lies in the case in which the follower has lower costs ($r > 1$) because this advantage is countered by the disadvantage created by the made-in effect. We have seen that – in this scenario – there are two outcomes possible: leapfrogging or maintained leadership. The question that naturally follows is, under which conditions will each outcome occur? In this section, we derive a leapfrogging condition, whereby the leadership in the sector would switch from the leader to follower.

To derive this condition, we focus on when firms in different countries make positive profits. We note that the denominators of both profit functions (11) and (12) are always positive, given the domain of variables and parameters. Thus, profits are positive if the numerators are positive. This leads to the following positive profit condition for firms in L and in F:

$$n_F(t) < \frac{n_L(t)Er^{1-\sigma} - n_L(t)^2 wbr^{1-\sigma}\sigma}{J(t) - E + n_L(t)wb\sigma} \tag{16}$$

$$n_F(t) < \frac{J(t)}{wb\sigma} - n_L(t)r^{1-\sigma}. \tag{17}$$

The inequalities imply that firms from F and L make profits for a different combinations of $n_F(t)$, $n_L(t)$, and $J(t)$. It can be easily seen that the larger $J(t)$, the higher the chances firms from F are profitable. The opposite is true for L. The intuition is that the growth of $J(t)$ steals away a protected (by lack of awareness) market for the leader. Larger $n_F(t)$ and $n_L(t)$ make profits less likely for both leader and follower. The economic principle behind it is simply that of competition, which makes individual profits harder to achieve.

To better understand this system, we build a graph that captures the model at a specific time (say $t = t^*$). At t^*, there are $J(t^*)$ consumers and $n_L(t^*)$ and $n_F(t^*)$ firms. In this graph, we keep $J(t)$ in the background, while we assign $n_L(t)$ and $n_F(t)$ to two oriented axes of a Cartesian plot. We then draw the zero profit lines (zero profit loci) taken from Eqs. (16) and (17).

The point x represents the number of firms from both L and F at time $t = t^*$. The curve LL indicates for which combination of $n_L(t)$ and $n_F(t)$ firms from L make positive profits. If x is below LL, firms from L make positive profits and n_L grows in subsequent periods. If x is above LL, firms from L make a loss and decline in number. Similarly, if x is below FF, firms from F make positive profits and n_F grows, while they make a loss and decline in number if x is above FF. The intersection between FF and LL (point e on the graph) is the zero profit point toward which x is moving. In Fig. 4, e is found in a region in which both firms from L and F can exist. It is also possible to propose another set of parameters (and a value for $J(t^*)$) such that e would be found below the n_L axis, a region where only firms from L can survive.

We note that e is a point at which two of three differential equations have their stationary point. However, since $J(t)$ evolves over time and Eqs. (16) and (17) depend on $J(t)$, the two curves, LL and FF, are shifting. Subsequently e, the point of intersection of the two curves, also shifts. How does e shift when $J(t)$ changes? It is sufficient to solve Eqs. (16) and (17) for

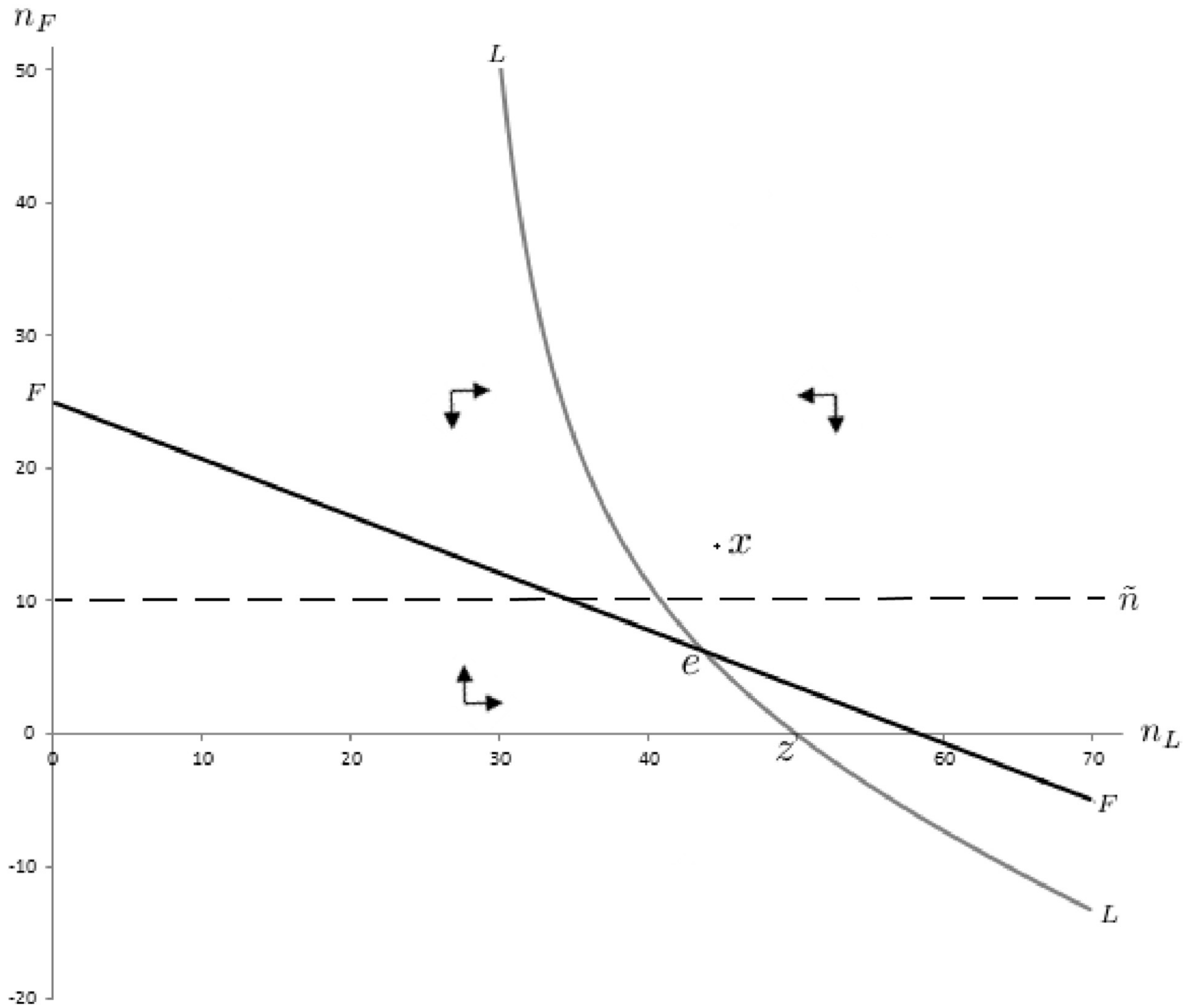

Fig. 4. Zero profit loci (projection on the $n_L - n_F$ plane).

n_L and n_F to find the coordinates of the point *e:* $n_L(t)^e$ and $n_F(t)^e$.

$$n_L(t)^e = \frac{E - J(t)}{wb\sigma\,(1 - r^{1-\sigma})} \tag{18}$$

$$n_F(t)^e = \frac{J(t) - Er^{1-\sigma}}{wb\sigma\,(1 - r^{1-\sigma})}. \tag{19}$$

Since the sign of $J(t)$ is negative in (18) and positive in (19), e can only move north-west (with more firms from F and fewer from L) if $J(t)$ is growing and south-east (with more firms from L and fewer from F) if $J(t)$ is declining. This insight – along with the fact that the LL line crosses the horizontal axis at $E/wb\sigma$ and that $n_L(t) \le E/wb\sigma$ – allows us to identify sufficient conditions for leapfrogging and maintained leadership.

While we explain this in greater detail in the appendix, the intuition is the following: if both e and n_F are below the critical level, $\tilde{n}$, it does not matter whether firms from F are initially making profits or losses. They are pulled toward e, which itself can only shift south–east over time until $J(t) = 0$ and the whole market is again dominated by country L. Setting $n_F(t)^e < \tilde{n}$, we obtain the maintained leadership conditions: $J(t) < Er^{1-\sigma} + \tilde{n}wb\sigma(1 - r^{1-\sigma})$ and $n_F(t) < \tilde{n}$.

Similarly, though not entirely symmetrically, if $n_F > \tilde{n}$ and the FF line is greater than $\tilde{n}$ when $n_L \le E/wb\sigma$, we obtain the leapfrogging condition of $J(t) > Er^{1-\sigma} + \tilde{n}wb\sigma$ and $n_F(t) > \tilde{n}$. As $\tilde{n}$ is an arbitrarily small number, we can collapse the two conditions into a single one by simply setting $\tilde{n} = 0$[4]. With $n_F(t) > 0$, the leapfrogging condition is

$$\frac{J(t)}{E} > r^{1-\sigma}. \tag{20}$$

The expression in (20) captures a core result of this paper. If firms in country F improve their production technology, the RHS of (20) decreases, making leapfrogging more likely (recall that $r = a_L/a_F$). This may prove insufficient if the LHS is not large enough. The latter depends on the share of consumers in the world market that are aware of the quality of products from country F.

Condition (20) is both a sufficient and a necessary condition for leapfrogging: if at $t = t^*$, condition (20) applies, leapfrogging will occur in the model. However, if at time $t = t^*$, condition (20) does not apply, leapfrogging is still possible at time $t = \tilde{t}$, with $\tilde{t} > t^*$.

Proposition 3. *If at any time in the model, the share of aware consumers becomes greater than $r^{1-\sigma}$, the firms from the country F will eventually dominate the entire market. This is both a necessary and sufficient condition.*

The proposition is proven in the appendix. The condition applies for all t. In the particular case in which the condition is valid at the time of entry ($t = 0$), the outcome of the whole model can be assessed without knowing the exact dynamics (for instance, without knowing how large β is, that is, how rapidly information diffuses). Conversely, if at $t = 0$, the condition does not apply, we need to define how the dynamics unfold to determine whether leapfrogging will occur (that is, whether at some point $t > 0$, the condition will apply).

We observe that for low values of σ – when firms have a high degree of monopolistic power – the RHS has larger values, which means that having a large share of aware consumers is more important for leapfrogging. This has interesting economic implications. Competitive markets are characterized by homogeneous goods, where consumers do not perceive a significant difference between the varieties produced by different firms. For this reason, price differences – even if small – are the main driver of consumers' behavior. For differentiated, durable and luxury goods other factors, such as perceived quality, status, identity, play an important role. In terms of our analysis, we model homogeneous goods as those that have higher elasticity of substitution than differentiated goods. It can be easily seen from the demand function (Eq. (2)) that a larger elasticity of substitution implies greater price sensitivity. It follows directly that, when producers from the follower enter the market, leapfrogging is facilitated by price advantage to a larger extent when the goods are homogeneous.

3.3. Dynamics

In the event that neither the leapfrogging condition nor the maintained leadership condition holds at $t = 0$, we cannot say whether leapfrogging occurs unless we solve in explicit form the system of differential equations, which unfortunately we cannot. There are two steps we can take, however, to learn about the property of the system in this case. First, we can use an extremely simplified version of the dynamical system that allows us to obtain an analytical solution. Second, we analyze the transitional dynamics around the interior saddle point, where most of activity occurs if the leapfrogging and maintained leadership conditions do not hold at $t = 0$.

Simplified model

To make the model tractable without losing its interpretative power, we use an extremely simple set of functional shapes that allow us to obtain an analytical solution for the transitional dynamics. The law of motion for firms from countries F and L are, respectively,

$$\dot{n}_F(t) = \begin{cases} \alpha & \text{if } \pi_{i,F}(t) > 0 \\ 0 & \text{if } \pi_{i,F}(t) = 0 \\ -\alpha & \text{if } \pi_{i,F}(t) < 0 \end{cases} \tag{21}$$

$$\dot{n}_L(t) = \begin{cases} \alpha & \text{if } \pi_{i,L}(t) > 0 \\ 0 & \text{if } \pi_{i,L}(t) = 0 \\ -\alpha & \text{if } \pi_{i,L}(t) < 0 \end{cases}. \tag{22}$$

For the diffusion of information among consumers on the quality of goods from F, we have that

$$\dot{J}(t) = \begin{cases} \beta & \text{if } n_F(t) > 0 \\ 0 & \text{if } n_F(t) = 0 \end{cases}. \tag{23}$$

Even with these simple dynamic equations, a few steps are required to reach useful conclusions. Hereafter, we will enunciate these steps in an intuitive manner. In the appendix, we rigorously prove our statements. First, if condition (20) does not apply in $t = 0$, firms from F are making negative profits. This is because the number of firms from L is given in

[4] Note that the main steady states (leapfrogging, maintain leadership, partial catch-up) are still the same in case $\tilde{n} = 0$ (see appendix Appendix B).

$t = 0$ ($n_L(0) = E/wb\sigma$). It follows that the combination of $n_L(0)$ and $n_F(0)$ for every $n_F(0) > 0$ will lead to negative profits for F. The number of firms in F then declines as follows:

$$n_F(t) = n_F(0) - \alpha t, \tag{24}$$

where the above equation is the explicit form of (21). This dynamic holds until either all firms from F are out of the market or profits are made. As long as $n_F(t)$ is positive, then $J(t)$ grows as follows:

$$J(t) = J(0) + \beta t. \tag{25}$$

Next, the dynamics of the model dictate that both the point e and the number of firms, x, are going to cross the n_L axis at the exact same point (that is, point z in Fig. 4, which has coordinates $(E/wb\sigma, 0)$). Thus, to assess whether leapfrogging occurs, we simply need to derive what goes to zero first: if e is in the positive region before $n_F(t)$ becomes zero, then the condition in (20) applies and leapfrogging occurs. Conversely, if $n_F(t)$ goes to zero before e becomes positive, there would be no change in leadership.

The point e becomes positive when $J(t)/E > r^{1-\sigma}$. Given that $J(t) = J(0) + \beta t$,

$$t' = \frac{Er^{1-\sigma} - J(0)}{\beta}. \tag{26}$$

The number of firms from F reaches zero when

$$t'' = \frac{n_F(0)}{\alpha}. \tag{27}$$

We can then easily compute a dynamic leapfrogging condition by imposing that $t' < t''$:

$$\frac{n_L(0)wb\sigma r^{1-\sigma} - J(0)}{\beta} < \frac{n_F(0)}{\alpha}, \tag{28}$$

where we replaced E with $n_L(0)wb\sigma$ to have an expression in which all three initial conditions ($n_L(0)$, $n_F(0)$ and $J(0)$) are made explicit. However, $n_L(0)$ is not a free variable in this model but depends on the size of the market, E, and other parameters.

Proposition 4. *If at time zero, the share of aware consumers is smaller than $r^{1-\sigma}$, leapfrogging is still possible, but it is dependent on how the dynamic unfolds: it depends on the speed of entry and exit of firms (α), on the speed of information diffusion (β) and on the initial conditions of the dynamic system ($n_L(0)$, $n_F(0)$ and $J(0)$).*

The higher the speed of information diffusion, β, the easier it is for country F to leapfrog. Given that for leapfrogging e needs to become positive before all F firms exit the market, the speed of entry and exit, α, works against leapfrogging: a slow exit rate gives more time to F firms to reach a point at which the share of aware consumers is high enough to enable a change in leadership[5].

Although $n_L(0)$ is not a free variable, we can see that for a large market size, leapfrogging is less likely to occur. The opposite is true for the two other initial conditions, $n_F(0)$ and $J(0)$. When their value increases, the chances that the expression in (28) holds are higher.

Dynamics around the saddle point

The saddle point – as we mentioned – is not on the boundaries of the model's admissible region. In fact, the coordinates of this unstable fixed point are $n_L = \frac{E}{wb\sigma} - \tilde{n}$, $n_F = \tilde{n}$ and $J = Er^{1-\sigma} + \tilde{n}wb\sigma(1 - r^{1-\sigma})$ – in the interior. The initial conditions of the model are instead on a boundary. While $J(0)$ and $n_F(0)$ can have any value (although economically we expect them to be small), $n_L(0)$ needs to be equal to $E/wb\sigma$, that is, the maximum number of firms that the market is capable of supporting. This means that model never starts at the saddle point. However, being a saddle point, the system may be attracted to it for some initial values.

The graph in Fig. 5 illustrates the relationship between the initial conditions of the model and the saddle point by drawing a number of representative solution curves in its vicinity. The initial conditions are highlighted with white dots, and all satisfy that $n_L(0) = E/wb\sigma$. In fact, all starting points are on the cube's face that is closer to the observer. The two solid dots, black and gray, indicate the (direction of the) leapfrogging equilibrium and maintained leadership equilibrium, respectively. At the center of the graph, one can notice the solution curves drawing a cross. This cross indicates the saddle point. The system is drawn to it for some initial values and then pushed away in one of the two possible directions: toward leapfrogging or maintained leadership.

As we highlighted above, these dynamics may imply a long period of coexistence of the two types of firms before the system is pushed to one of the stable steady states. It also implies that marginally different initial conditions may have unpredictable consequences for whether leapfrogging occurs.

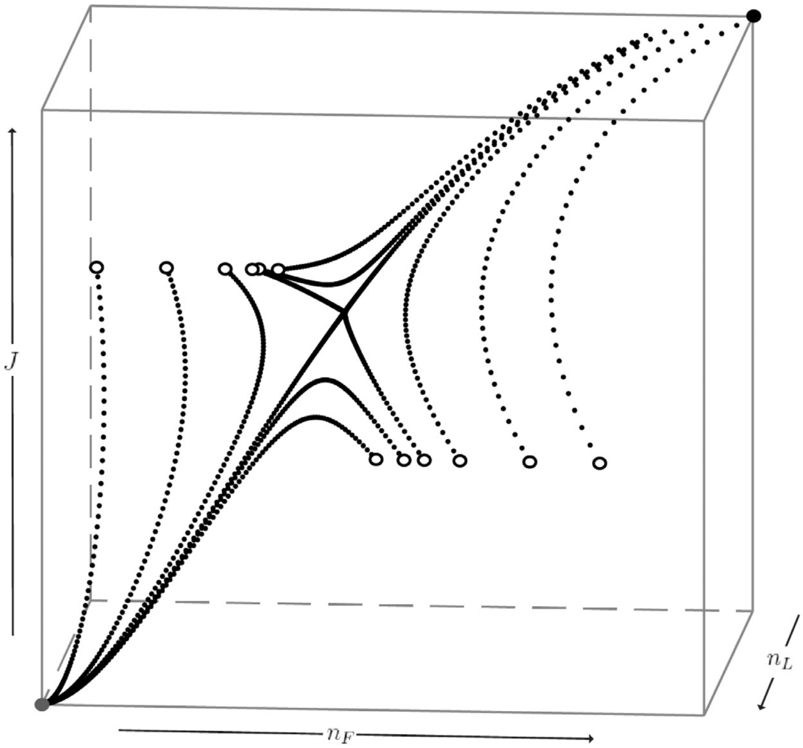

Fig. 5. Solution curves around the saddle point (parallel projection).

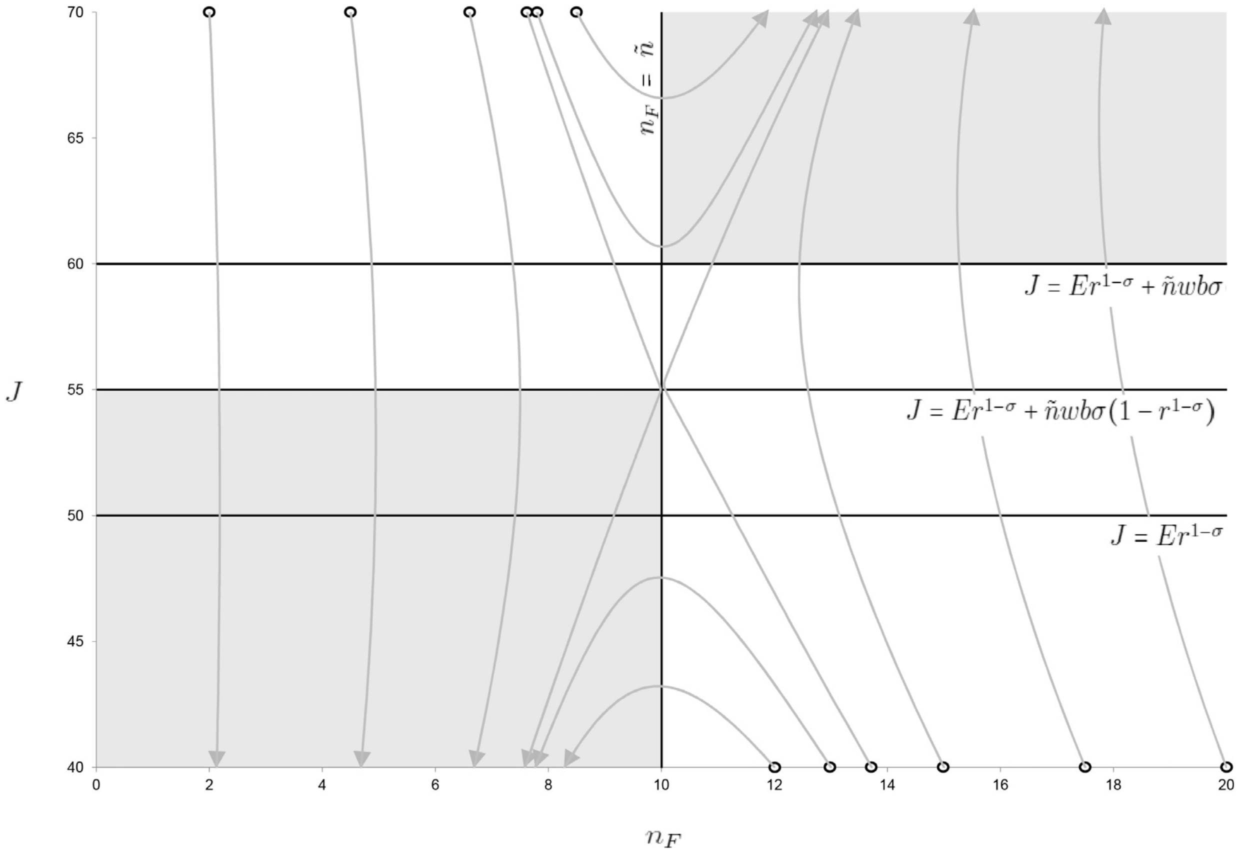

Fig. 6. Solution curves around the saddle point (projection on the $n_F - J$ plane).

Another way to visualize the dynamics around the saddle point is shown in Fig. 6. In this graph, we show the same solution curves as in Fig. 5, although in a projection on the $n_F - J$ plane. This viewpoint also allows us to clearly superimpose the leapfrogging conditions ($J(t) > Er^{1-\sigma} + \tilde{n}wb\sigma$ and $n_F(t) > \tilde{n}$, the gray region to the top-right) and the maintained leadership conditions ($J(t) < Er^{1-\sigma} + \tilde{n}wb\sigma(1 - r^{1-\sigma})$ and $n_F(t) < \tilde{n}$, the gray region to the bottom-left). In the limit case in which $\tilde{n} = 0$, the discriminating region for the conditions becomes $n_F > 0$ and $J > Er^{1-\sigma}$, which (for reference) is also shown in the graph. Again, the white dots are used to highlight the initial conditions of the solution curves.

The graph also underlines the regions in which we are uncertain about the outcome. In the top-left white region, firms from F are making profits, which makes n_F grow. However, the number of aware consumers is below the critical threshold of $\tilde{n}$, and J is declining. Leapfrogging occurs if n_F passes the threshold (and, hence, J begins to grow) before firms from F start making losses – triggered by a growing number of firms from F and declining demand. Similarly in the bottom-right region, firms from F are making losses, but J is growing. Leapfrogging occurs if the growth of demand turns losses into profits, before n_F declines below the critical threshold. Which outcome occurs is a matter of the exact unfolding of the dynamics.

The economic intuition behind the existence of the saddle point steady state can be understood by observing the role of $J(t)$ and $n_F(t)$ in the system. A larger number of aware consumers increases the chances of leapfrogging, as a higher portion of demand is taken away from the leader. Similarly, a larger number of firms from F makes leapfrogging more likely, since diffusion of information ($\dot{J}(t)$), we argued, also depends to some extent on exposure. It follows that when both $J(t)$ and $n_F(t)$ are high, they jointly contribute to leapfrogging. When both are low, they both push for maintained leadership. It follows that, between number of aware consumers and firms from the follower, when one is high and the other is low, they push discordantly towards leapfrogging and maintained leadership. This feature generates a saddle point steady state: when $J(t)$ and $n_F(t)$ are acting in unison, they system is pushed away from it. When they are not, the point becomes an attractor.

3.4. Investment in advertising

An interesting question is how allowing firms to invest in advertising affects leapfrogging. Part of the answer lies in the nature of the made-in effect: it is a form of collective reputation that benefits, to some extent, all firms in the country, which produce a particular good. This type of reputation is not attached to any particular firm, but it is a form of public good. Any investment a firm might commit to advertising is in part appropriated by other producers in the nation. This is not to say that firms cannot invest in brand advertising (which is a private good). However, the aim of this analysis is to explore how the made-in effect influences the dynamics of competition between nations. In this section, then, we extend the model by allowing firms from the follower country to improve their collective reputation. In the model's language, the extension allows investment to change the number of aware consumers J, as well as its law of motion.

Given the complexity of the system, we follow the same methodological structure of the previous subsection on dynamics and we analyze the role of investment first with a simplified model (with myopic firms and a one time investment in $t = 0$), that permits an analytical solution, and then with the full model (with forward looking firms that invest in every period), where we can characterize many aspects, but not the full transitional dynamics. In the interest of brevity, only the salient elements of this extension are reported here, while we leave most details to the appendix.

We denote individual investment with ϕ_i. The advertising effort of a firm compounds with that of others in F. Without loss of generality, we choose the following form:

$$\Phi = \prod_i \phi_i^{\gamma}, \tag{29}$$

where $\gamma n_F < 1$. Advertising has two main effects, a short- and long-run. In the short run, it shifts the number of aware consumers J according to the following law:

$$J_\Phi = J + \Phi(E - J). \tag{30}$$

J_Φ indicates the number of aware consumers after the investment. In the long run, investment also affects the law of motion of J. For the simple version of the model with investment, we use the structure proposed in Section 3.3 and write $\dot{J}(t)$ as

$$\dot{J}(t) = \begin{cases} \Phi(0) & \text{if } n_F(t) > 0 \\ 0 & \text{if } n_F(t) = 0 \end{cases}. \tag{31}$$

[5] We note that this simplification implicitly assumes that $\tilde{n} = 0$. This means that we are only considering one side of the saddle point, where $n_F > \tilde{n}$. We observe that Fig. 6 suggests that the opposite is true on the other side of the saddle point ($n_F < \tilde{n}$): a higher α increases the chances of leapfrogging, while a higher β decreases it.

It can be seen that the simple version of the model assumes that the amount of investment in time zero determines the dynamics for the whole period. This has the simple implication that the leapfrogging condition becomes

$$\frac{n_L(0)wb\sigma r^{1-\sigma} - J(0)}{\Phi(0)} < \frac{n_F(0)}{\alpha}. \tag{32}$$

The question is then: what is the amount of investment chosen by firms in zero ($\Phi(0)$)? Assuming myopic agents, firms are concerned only with the short-run effect of the investment, ignoring the long run. Hence, their maximization problem translates into the first order condition

$$\frac{\partial \pi_{i,F}(\Phi(0))}{\partial \phi_i(t)} = 0, \tag{33}$$

for each firm i in F. The solution to Eq. (33) gives the investment chosen by a single firm. By plugging the value into Eq. (29), one can obtain $\Phi(0)$ and characterize the analytical solution to this system.

Since investment in advertising is only partially appropriated by the firm – in other words there are positive externalities to investment – it is interesting to compare market equilibrium with that reached by a social planner, whose objective is to maximize profits from all firms in F. That is $W = \sum_i \pi_{i,F}$. The first order condition is

$$\frac{\partial W(\Phi(0))}{\partial \phi_i(t)} = 0, \tag{34}$$

for each firm i in F. Were it not for externalities in investment, the conditions in (33) and (34) would be identical. Instead, since investment of firm i enters in the profit function of other firms, the following proposition holds

Proposition 5. *Under externalities in investment, a social planner (S) would allocate a larger sum to advertising than the market (M) does. That is $\phi_i^S(0) > \phi_i^M(0)$ and $\Phi^S(0) > \Phi^M(0)$. As the number of aware consumers grows faster in S compared to M, for a range of initial conditions $n_F(0)$, $n_L(0)$ and $J(0)$ the planner solution leads to leapfrogging, while the market leads to maintained leadership.*

The appendix presents the details of the proof. The economic implication of the proposition is that it may be in the national interest to intervene in emerging sectors where strong made-in effects are present. The complementarities among firms in advertising efforts suggest that the state might take an active part, by (for instance) compensating for sub-optimal investments or by assuming the role of coordinator. It is important to highlight that proposition 5 also implies a role for the state even in case both the planner and market equilibrium lead to leapfrogging, since differences in $\Phi(0)$ translate into different trajectories before the steady state is reached.

The first part of proposition 5 – $\phi_i^S(0) > \phi_i^M(0)$ and $\Phi^S(0) > \Phi^M(0)$ – also holds once the model is augmented to include the complete dynamics (Eqs. (13), (14) and (15)), as well as forward looking firms who can invest in every moment of time t. The problem is one of dynamic optimization in continuous time. While the complexity of the problem is such that we cannot express the transitional dynamics analytically (just like with the model without investment) and therefore to identify the trajectory of $\phi_i(t)$, we can however prove that $\phi_i^S(0) > \phi_i^M(0)$ and $\Phi^S(0) > \Phi^M(0)$ (see appendix). We can also show numerically that – for some initial conditions $n_F(0)$, $n_L(0)$ and $J(0)$ – the planner solution leads to leapfrogging and the market solution to maintained leadership. Moreover, in case both market and planner lead to leapfrogging, we can show the different trajectories of the two solutions. This highlights, once again, that there is a reason for the social planner to intervene, even in case the market solution leads to leapfrogging (see Appendix B).

4. Specialization of leader and follower in general equilibrium

Let us now imagine that the world economy consists of two countries: the leader L and follower F. Suppose that L is a developed country, the firms of which have supplied all tradable goods to both countries for some time. For this reason, consumers in both countries acknowledge the quality of the leader's products. F, instead, has just started exporting to the world market. While domestic consumers know the quality of their products, consumers abroad have yet to be exposed and are therefore biased by the made-in effect[6]. Further, we assume that firms from F can potentially produce all goods but with an inferior technology. While this may appear in contrast with the setting of the partial equilibrium model, this assumption entirely maintains its spirit. The reason is that the main concern of the analysis is whether technological catch-up is sufficient for leapfrogging. For the partial equilibrium model, we translate this into a setting with equal wages and a technology for the follower, which is inferior for $t < 0$ and becomes superior after technological catch-up in $t \geq 0$. For the case in general equilibrium, we model technological catch-up with the follower having an initially inferior technology, and then improving it over time. Wages in this case are free to be endogenously determined.

[6] While we chose not to emphasize it, we note here that, if aware consumers are local and potential consumers are foreign, the size of the domestic market may play a role in leapfrogging opportunities.

To build such a model, we need to first to generalize the leapfrogging condition for a single good (with $\tilde{n} = 0$[7]) to jointly account for differences in wages, fixed costs and variable costs. If we assume that the good g has variable costs $a(g)/T_c$ for country c and fixed costs $b(g)/T_c$, the leapfrogging condition becomes

$$\frac{w_F}{w_L} < \left(\frac{T_F}{T_L}\right)\left(\frac{J(0)}{E}\right)^{1-\rho}. \tag{35}$$

Notice that wages are determined at the country level, as we assume labor mobility across sectors but not across countries. For convenience, we substitute $\sigma = 1/(1-\rho)$.

Eq. (35) is the leapfrogging condition for any given good. For simplicity, here, we abstract from the dynamics: we can simply imagine that only one (infinitesimally small) firm from F attempts to enter, and if the condition is not verified at $t = 0$, there will be no leadership change.

Let us now imagine there is a continuum of goods for $\rho(g) \in (0, 1)$. For each of the goods, a competition between firms of country L and F takes place. This implies that for any given good g, there can be several varieties produced either in F or in L. The dynamics of competition between these varieties follow those we described in Section 3, except that we use the generalized version of the leapfrogging condition (Eq. (35)). Then, for each good g, we assume a constant number of initially aware consumers, $J(0)/E$ (which is below 1, as consumers from L are unaware of the quality of products from F). It is easy to see from (35) that the follower has a higher chance of leapfrogging as goods become more substitutable, as in the standard case. To see what pattern of specialization occurs in general equilibrium, we must introduce demand. This model compares fairly well with a Ricardian model of specialization with 2 countries and multiple products, as in the classic Dornbusch et al. (1977) paper. In Dornbusch et al. (1977), there is a continuum of goods that differ by relative technology. In this case, goods differ by elasticity. We then follow a similar procedure to find the equilibrium wages. As goods here are distinguished by elasticity, and not by relative technological advantage, we order them from the lowest ($\rho(g) = 0$) to the highest ($\rho(g) = 1$). If we assume Cobb-Douglas preferences across goods (with CES preferences for the different varieties of each good), consumers allocate a constant (independent of price) share of their income to good g. If we further assume that each good receives the same spending, independent of the elasticity, ρ, it must hold that

$$L_L w_L = \rho(g)(w_L L_L + w_F L_F), \tag{36}$$

where $\rho(g)$ is the share of goods that are produced by L. F produces 1-$\rho(g)$. The labor forces in the two countries are L_L and L_F, respectively. Rearranging (36), we have

$$\frac{w_F}{w_L} = \frac{1-\rho(g)}{\rho(g)}\frac{L_L}{L_F}. \tag{37}$$

The intersection between (35) and (37) represents an equilibrium. In Fig. 7, the vertical axis represents the wage ratio between the follower and the leader (w_F/w_L).

The horizontal axis is $\rho(g)$, representing the type of goods by elasticity – as well as the share of goods from 0 to 100% – in which L specializes. To draw the curves, we assumed that the labor forces in the two countries are equal. We can see that F ends up specializing in fewer goods, with a higher elasticity of substitution and lower price. The figure also shows what happens in this system if F gradually catches up on technology. While it is the case that with technological growth F increases its market share and its wages, the made-in effect pushes the equilibrium solution far below where is should have been, if there were no such effect. In the extreme examples of the figure, even when F is 50% more productive than L, it only captures 45% of the market and the wages are 3/4 of those of workers in L.

In the next section, we look for the made-in effect in the data. To help guiding this effort, we note that the model in general equilibrium is well suited to provide propositions that can be taken to empirics and tested. To this end, we derive two propositions. The first one can be immediately derived from the characterization of the equilibrium above (proof in the appendix).

Proposition 6. *Production of differentiated products is on average relatively more concentrated in the leading country.*

A second testable proposition is derived to overcome the empirical limits of testing proposition 6. As we note in the empirical section, an analysis of specialization on the cross-section is at risk of omitted variable bias. For instance, leading countries may be rich for their advantageous geographical position, which in turn can have an effect on the specialization of countries. For this reason, we find it convenient to derive a proposition on the dynamics of the model, so that we can use the longitudinal dimension of the data to detect the presence of the made-in effect, while minimizing the risk of bias. In the appendix we derive the following proposition.

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[7] As we do in proposition 3, we assume that, since $\tilde{n} \simeq 0$, equating $\tilde{n}$ to zero is a reasonable assumption for the purpose of identifying the leapfrogging condition. In appendix Appendix B, how this choice affects the leapfrogging condition is thoroughly discussed.

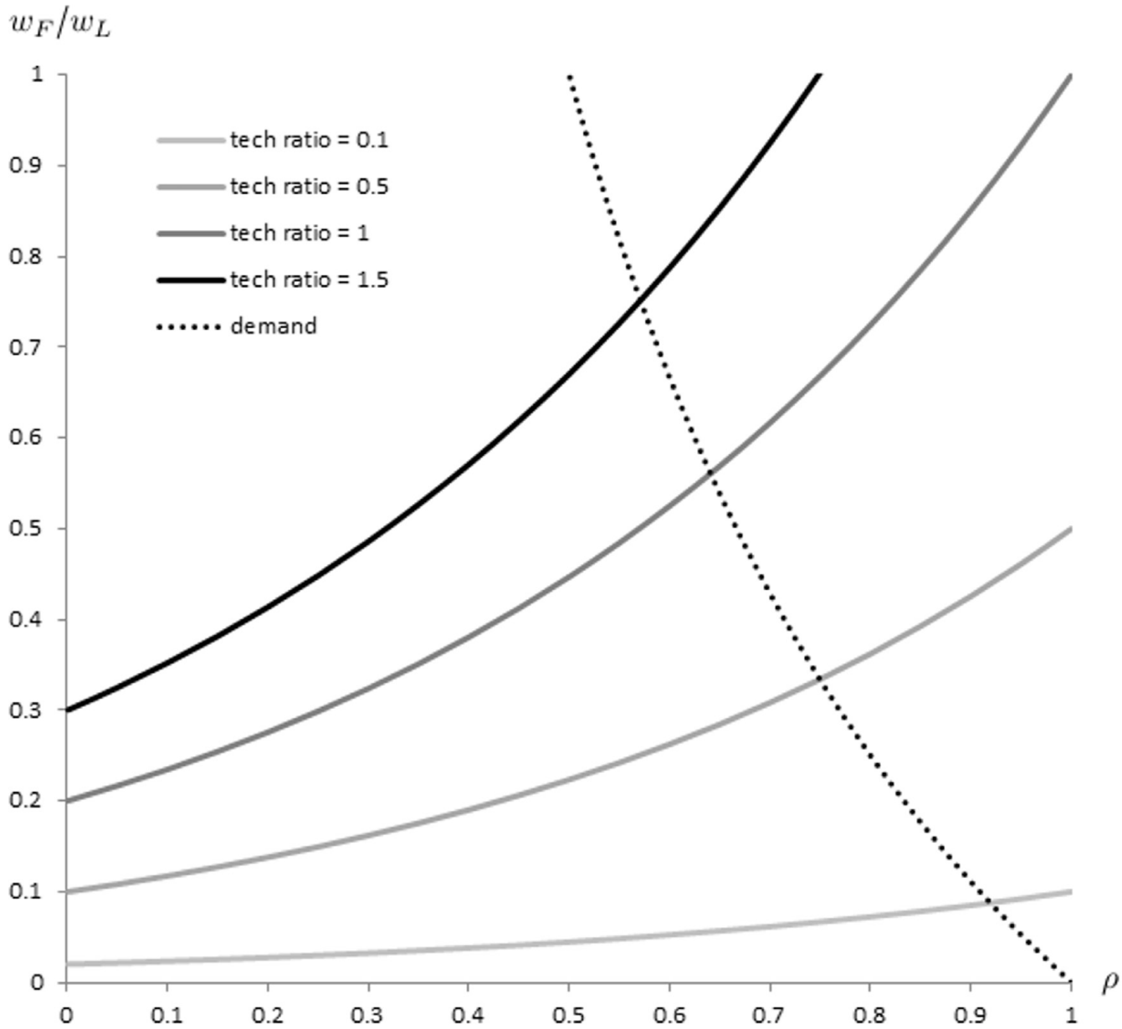

Fig. 7. Equilibrium.

Proposition 7. *With technological growth, catch up countries increase their share of differentiated goods in their export basket. When comparing the process of catch-up between two countries, where one suffers from the made-in effect more than the other, the latter exports larger shares of differentiated goods at every stage of development.*

5. Relevance in empirics

The existence of a distortion deriving from the country-of-origin label has been extensively documented by the literature on customer behavior (Dinnie, 2004). In particular, this literature has stressed the role of reputation for product-country combinations (Heslop and Papadopoulos, 1993). The analysis of the model we propose, however, suggests something stronger: that the made-in effect has direct consequence on world trade, influencing the patterns of specialization of countries. The general equilibrium version of our model – we have shown – can be used to derive predictions on trade that can be taken to the data.

We test whether there is any evidence of the patterns discussed in proposition 6 and 7, using historical world trade data from 1962 to 2000 in Feenstra et al. (2005). We collapse bilateral flows into country-year-product exports at the 4-digit level of the SITC Rev.2 classification. We then select 560 (out of 935) differentiated goods following the classification in Rauch (1999)[8]. Selected examples are cars, tires, watches and clocks, photographic equipment, furniture items such as chairs and

[8] The classification categorizes goods as homogeneous if they possess a reference price quoted on an organized exchange or in trade publications. Rauch (1999) defines a 'liberal' and a 'conservative' classification. As we find only marginally different outcomes under the two classifications, we present here results of the 'conservative', while in the appendix those of the 'liberal' classification.

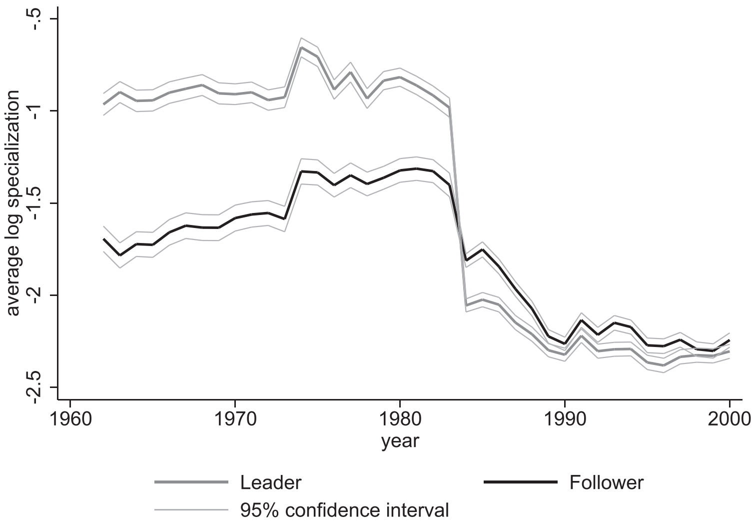

Fig. 8. Average specialization in differentiated goods for the leader and the follower.

tables, footwear, clothing and accessories[9]. In the early 1960s, these goods represented 45% of the value of world trade. By 2000, this share had grown to 67% of trade value. We then identify two groups of nations – leaders and followers – according to their PPP GDP per capita in the year 2000 (data from Penn World Tables 8.1). We classify as leaders countries in the upper quartile and as followers those in the third quartile. The logic is that the former group developed earlier than the latter.

Proposition 6 states that production of differentiated products is on average relatively more concentrated in the leading country. Closely following the proof we give in the appendix, we compute the Balassa index of specialization for every country c and product g as $RCA_{cg} = (x_{cg}/x_g)/(x_c/x)$. The logarithm of RCA index is used to calculate the average specialization in each of the two groups, identified using the leader/follower classification. We denote this average z and the two quantities z_L^{dif}, z_F^{dif}. Fig. 8 plots z_L^{dif}, z_F^{dif} for each year until 2000, together with the 95% confidence interval.

Fig. 8 shows that the leading countries were on average more specialized than the followers in differentiated goods, up until the 80s. This appears to revers in the last 15 years of the data, although by the end of the 90s the difference is no longer significant. As at early stages the leader has significantly larger specialization in differentiated goods, this provides some evidence that proposition 6 holds. We find, however, that testing this proposition has important empirical limits and, therefore, the evidence of Fig. 8 can only in part be trusted. This is because specialization can be affected by country-specific factors that can also be related to development (but unrelated to the made-in effect). For this reason, proposition 7 builds specific prediction for the changes of specialization over time. While looking at the evolution over time – as we do in Fig. 8 – does mitigate the problem, to properly account for country fixed-effects an estimation is required. Imbs and Wacziarg (2003) propose a methodology to estimate how diversification evolves at different stages of development. They argue that a non-parametric method is preferable for the task because it does not impose any previously established shape to the diversification-development link. We find that this methodology is well-suited to take proposition 7 to an empirical test, as it allows, not only to estimate the changes of specialization in differentiated goods accounting for fixed-effects, but also to compare the two groups – leader and follower – at different development stages[10].

We run N (for $n = 1..N$) regressions with different subsamples of the dataset. Each subsample collects all country-year observations for which the GDP per capita (at PPP) is within an interval of $5,000 dollars (data again from Penn World Tables 8.1). The subsample is changed by shifting the midpoint by $250 for each regression, thereby allowing the different samples to overlap. We start with a midpoint of $2,500 and an interval between $0 and $5,000. We run 71 regressions, each time shifting the midpoint by $250 until it reaches $20,000. This limit is chosen to have sufficient observations in all groups. Once we run all the regressions, we compute the predicted value at the midpoint, along with a confidence interval

[9] The analysis is simplified here by considering all differentiated goods, disregarding differences in technology. This is because we are interested in the difference between leaders and latecomers. According to our model, the latecomer exports a differentiated good at a later stage of development compared to the original leader, regardless of the level of technology required by the good.

[10] The theoretical model suggests that the share of differentiated goods increases with technological growth (more efficient use of inputs). Since growth accounting exercises highlight that most economic growth is indeed due to increased efficiency, rather than a greater use of inputs (Jones and Romer, 2010), we believe that economic growth is a reasonable proxy for technological growth. Moreover we note that to fully link the theory to the data we have assumed that countries that developed early suffer less from the made-in bias. This is justified by the fact the leaders developed first and together, and were, hence, not in a strong condition of asymmetry as the followers.

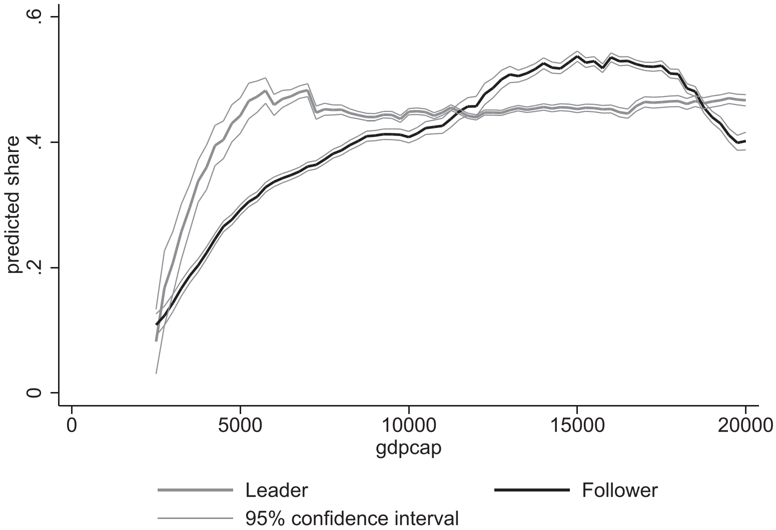

Fig. 9. Economic growth and share of differentiated exports.

of the prediction. The prediction is obtained as

$$\widehat{share}_n = \hat{\beta}^{FE}_{0,n} + \hat{\beta}^{FE}_{1,n} Gdpcap_n. \tag{38}$$

In the regressions, we use the shares of differentiated products that a country has in its export basket in a given year. Other than having a strong link with proposition 7, this measure has the advantage that it does not mechanically increase with economic growth. In the appendix, we show estimates for the share of differentiated goods over the world trade in these goods. To test proposition 7, we run two sets of regressions: one for the group of leaders and one for the followers.

In Fig. 9, the gray line represents the richest quartile, while the black line represents the third quartile. On the vertical axis, we have the predicted values from (38). We can observe that for both groups, the share of differentiated goods increases quickly with development. More interestingly, up to $12,000, the latecomers appear to have lower shares of differentiated goods than what is estimated for the countries that developed early. Between $12,000 and $19,000, the latecomers have larger shares of differentiated products than the incumbents. We show here that this is mostly an effect of selection.

The reason that we use a fixed effects estimator is to control for unobserved country characteristics that might generate both a high share of differentiated products and GDP growth. The non-parametric methodology, however, we employ does not eliminate all the between-country variation. Countries are dropped from (and new ones added to) the sample while shifting to observations with higher GDP per capita. These selections change the estimate of the average fixed effect $\hat{\beta}^{FE}_0$.

We can however use the same methodology to compare the within-estimates of $\hat{\beta}^{FE}_1$, the slope of GDP per capita, of the two groups. In Fig. 10, we plot $\hat{\beta}^{FE}_1$ with 95% confidence intervals for the two groups. This plot confirms the findings in Fig. 9 up to $12,000: at the early stages of development, the share of differentiated goods grows for both groups, but the slope is initially steeper for the most developed quartile. After $6,000, the slope becomes larger for latecomer. For the estimates above $12,000, the within-variation shows different results. There are no signs of a larger share growth for the latecomer, as in Fig. 9. This implies that the temporary overtaking of the latecomers between $12,000 and $19,000 is entirely driven by sample selection (between-variation). In the appendix, we show that this may be due to the inclusion of countries with lower market shares of homogeneous goods.

This evidence is fully in line with proposition 7. It shows that with development, while both the leader and the follower increase their share of differentiated goods in their export basket, the leader does so more easily, and – at every stage – it has a higher share of differentiated goods than the follower. While this evidence is highly suggestive that the made-in effect may be a relevant driver of specialization of countries, it is important to highlight that it is not conclusive. In fact, the adherence of patterns of trade to the model prediction does not exclude that other models may also explain the observed distribution of exports and its evolution over time. To further highlight the relevance in empirics of the made-in effect, we integrate the evidence from specialization patterns with evidence deriving from the detailed knowledge of specific sectors.

We notice that qualitative evidence of the role of the made-in effect on exports in specific sector can already be found in literature. For instance, Artopoulos et al. (2013) explore how Argentina managed to successfully export four types of differentiated goods to developed countries. Among the relevant factors, they identify the made-in effect and conclude: "At early stages in the process of export emergence, firms also have to develop a specific strategy to confront the

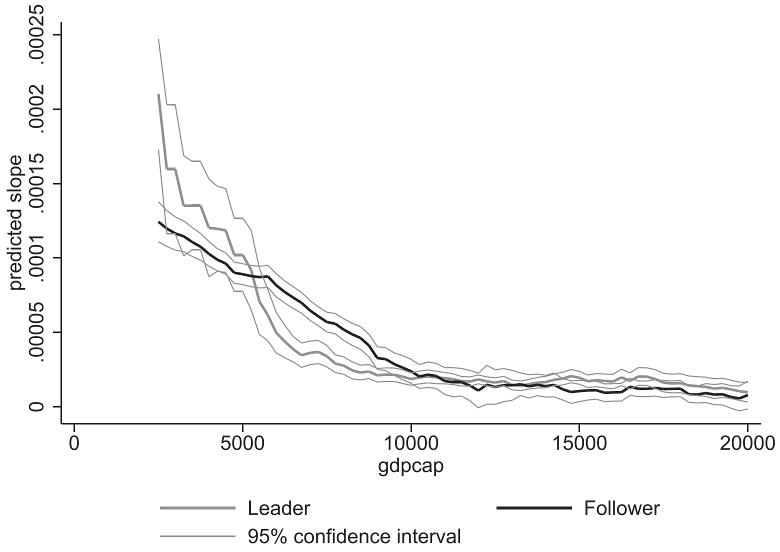

Fig. 10. Magnitude and significance of the slope.

Table 1
Impact of the judgment of Paris on wine export: regression analysis.

	USA	Australia	New Zealand	S. Africa	Chile	Argentina
$treat_c$	0.048	−0.079	0.280	−0.090	0.090	0.350
	(0.042)	(0.054)	(0.126)**	(0.058)	(0.063)	(0.090)***
$treat_c \times post_t$	0.099	0.251	−0.057	0.124	−0.024	−0.328
	(0.059)*	(0.076)***	(0.169)	(0.081)	(0.088)	(0.125)**
R^2	0.46	0.42	0.45	0.36	0.45	0.43
N	87	87	85	87	87	87

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

< <country-of-origin bias> > stemming from the lack of an established reputation in the industry of the country from which they are exporting.” (p.28).

We integrate this qualitative evidence with quantitative evidence from the wine sector. We argue that the history of wine provides a natural experiment to test whether made-in effects, linked to the reputation of the country of origin of wine, have a direct effect on international trade and specialization. A particular event in 1976 is believed to have changed permanently the wine industry. In a blind tasting that became to be known as the *judgment of Paris* a panel of international judges chose a wine from Napa county as best white and – soon after, while trying to avoid it, according to an account from a TIME journalist (Steinmetz, 2016) – another Napa valley wine as the best red. Steinmetz (2016) quotes experts claiming that this shock in reputation put American wine “on the map” as “[p]erceptions among people buying and collecting wine, shifted.” Moreover, it is claimed that “[i]t opened up the doors not only to Napa but other regions in the world” such as “New Zealand, Australia, Oregon, Washington, Chile,” which were producing wine at the time, but were considered inferior.

We exploit this event in a difference-in-difference strategy, where the treatment group is constituted by emerging wine producers and the control group is made by traditional ones. The test is based on the idea that the *judgment of Paris* should have an effect on wine exports on the treatment group after 1976. Denoting s_{ct} the share of wine a country c has in its export basket for year t and g_{ct} as the growth rate of that share ($log(s_{ct}/s_{c,t-1})$), we estimate

$$g_{ct} = \beta_0 + \delta_t + treat_c + \beta_1 treat_c \times post_t + \epsilon_{ct}, \tag{39}$$

where δ_t is the year dummy, $treat_c$ is a dummy equal to 1 if the country is a treatment country, $post_t = 1$ if $year > 1976$ and β_1 is the coefficient we are interested in.

Each column in Table 1 is a separate regression with a different country (as indicated on the top of the table) as treatment. For all regressions France and Italy are selected as the control group. It can be easily seen that we find a positive and statistically significant effect of the judgment of Paris on wine exports of USA and Australia, but not on other nations’. The effect is strong enough that it can be identified visually. In Fig. 11, g_{ct} for USA, Australia, Italy and France are divided by

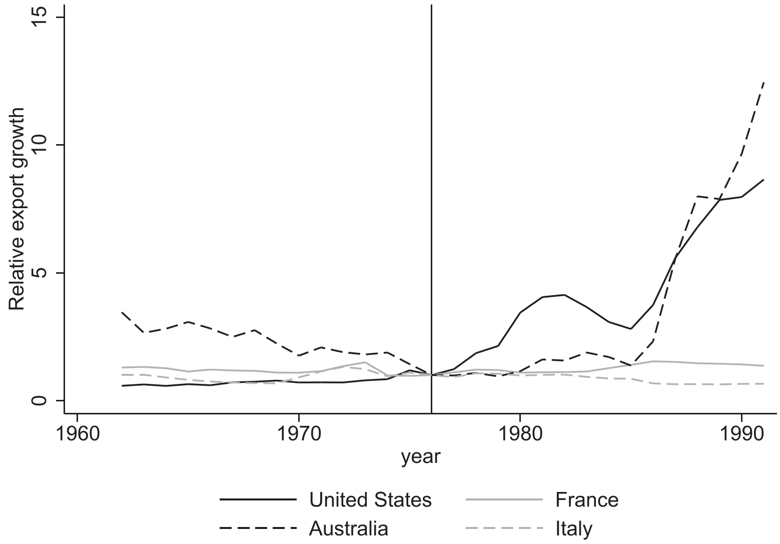

Fig. 11. Impact of the judgment of Paris on wine export: graphical visualization.

$g_{c,\,1976}$ and plotted against time. It is possible to observe a sharp increase in growth of wine exports for the United States right after the judgment of Paris, followed a few years after by Australia.

6. Conclusions

In this paper, we argue that the well-known bias of consumers with respect to the country of origin of traded goods has relevant consequences for leapfrogging. To challenge the established leadership, firms in follower countries not only have to develop a production process that produces high-quality, cost-competitive goods but also have to overcome the resistance of consumers, who are often adverse to purchasing products from countries that have yet to build a reputation.

Our analysis enriches findings on the issues of catch-up and leadership change by proposing the possibility of significant differences across sectors. While indispensable, technological catch-up will not necessarily be the winning factor when the made-in effect is at play. Our sectoral model suggests that the more differentiated the goods of an industry are, the smaller the role of technology and cost efficiency in leapfrogging. With these conclusions, we by no means claim that all historical events of successful or failed leapfrogging in differentiated goods are to be attributed to the defining influence of the made-in effect. Some differentiated goods underwent a radical shift in the technological paradigm (e.g., mobile phones) that is easy to identify as the lead determinant of leadership change. However, we believe that our framework applies to a variety of situations; in particular, it is the most relevant for differentiated durable and luxury goods, final goods and goods for which the technology of production changes at a relatively slow pace and does not have strong and recurring discontinuities. Although the boundaries just drawn may seem to limit the applicability to a narrow portion of the economy, even excluding all intermediates and all technologically progressive products[11], we still find that the made-in effect on leadership change might be applicable to almost 10% of the total value of world trade.

As mentioned in the introduction, our model has been developed for a context in which the leading country is an advanced country and the follower country is an emerging or a developing country. However, the model also holds in situations in which both countries belong to the realm of advanced countries but one of them is a leader in sector while the other is a follower in that sector. Thus, the model can be extended to a broader context of industrial competition.

In terms of policy implications, when the follower country is more efficient, the failure to take over the market, as we described, is a market failure, as it stems from consumers' lack of information. This may justify policy interventions intended to spread information about the quality of the latecomers' products and correcting the made-in bias. Institutions that foster coordination among firms and promote branding and marketing efforts are examples of policy measures that can facilitate overcoming made-in bias. For instance, in the history of the wine industry, such institutions played a prominent role in the catch-up process, through initiatives such as Brand Australia, the Australian Wine and Brandy Corporation, the South African Wine and Brandy Corporation and Vinos de Chile (Morrison and Rabellotti, 2017). Obviously, policymakers

[11] conservatively, hence also excluding mature industries such as automobiles.

should exercise extreme caution, as these measures would only work if the targeted products were already high-quality and cost-efficient.

Acknowledgments

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Appendix A. Additional analysis

By comparing the figures above with Figs. 9 and 10 in the main text, it is possible to verify easily that the choice between a 'liberal' and 'conservative' classification of differentiated goods (Rauch, 1999) only generates small differences in the non-parametric estimates we perform.

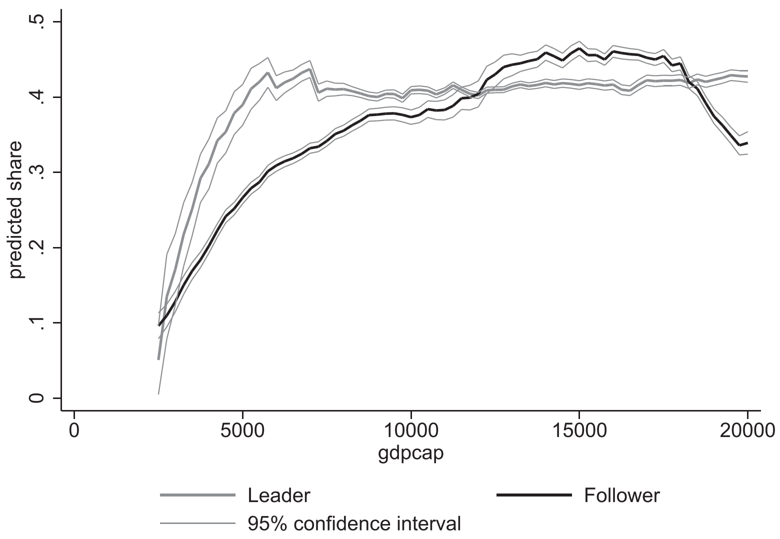

Fig. A.1. Economic growth and share of differentiated exports (Rauch's liberal classification).

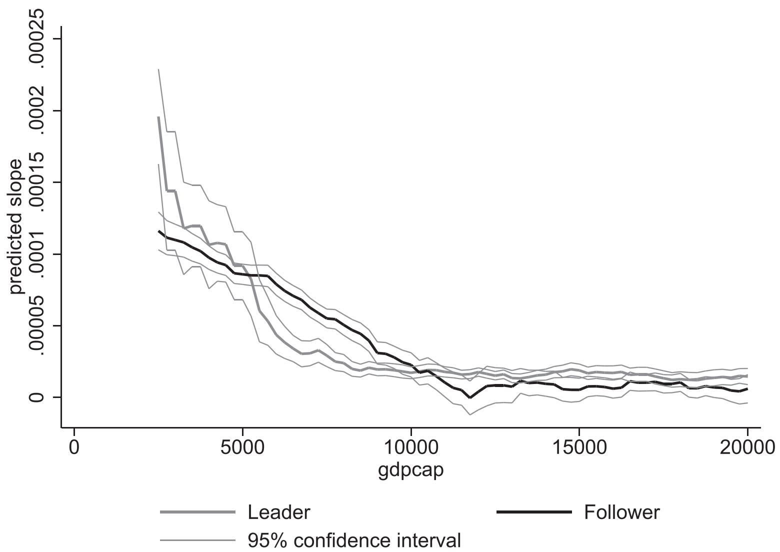

Fig. A.2. Magnitude and significance of the slope (Rauch's liberal classification).

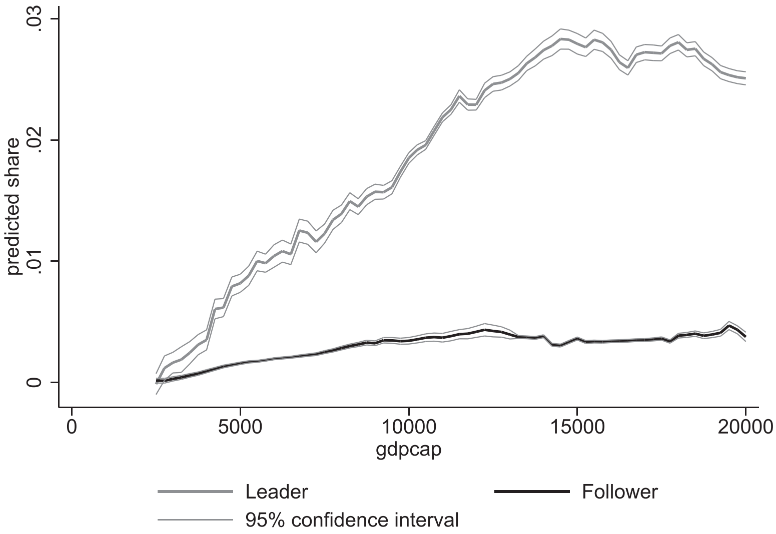

Fig. A.3. Country's differentiated exports over total differentiated exports.

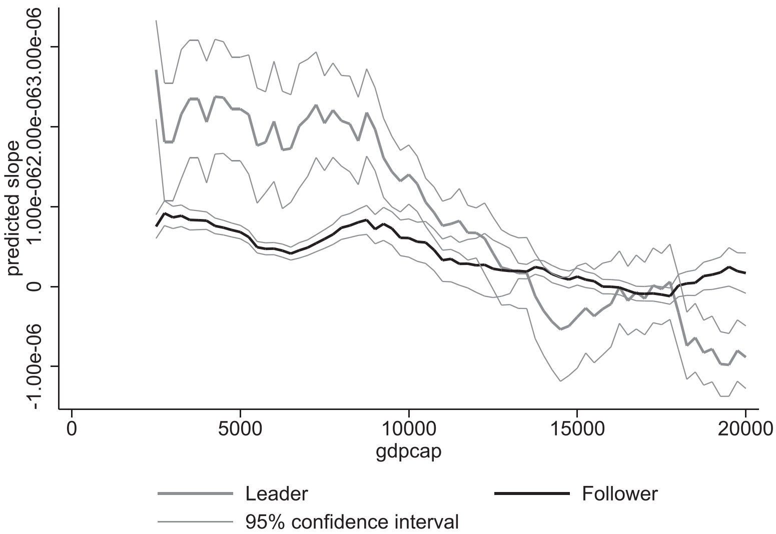

Fig. A.4. Magnitude and significance of the slope.

In the two figures above, we use share of a country's exports in the world trade of differentiated goods (instead of the share of differentiated goods in a country's export basket). Both figures indicate that this share grows in early stages of development, but it grows significantly faster for the upper quartile than for the latecomer.

As a placebo, we re-estimate the model using the share of a country's exports in the world trade of homogeneous goods. We observe that, at early stages of development, there is little difference between the two groups. The leader has slightly larger predicted values, but the estimates of the slope highlight that within-change is actually negative for the leader. After $10,000, there is a split, and the latecomers stabilize to a lower share of homogeneous products. The estimates of the within-effect, however, show that growth should be larger for the latecomer (although the difference is not significant). This implies that the decline in the share of homogeneous goods for the latecomer after $10,000 is mainly due to a selection effect. It is very likely that this selection effect is also behind the overtaking by latecomers in the share of differentiated goods between $12,000 and $19,000 observed in Fig. 9 in the main text.

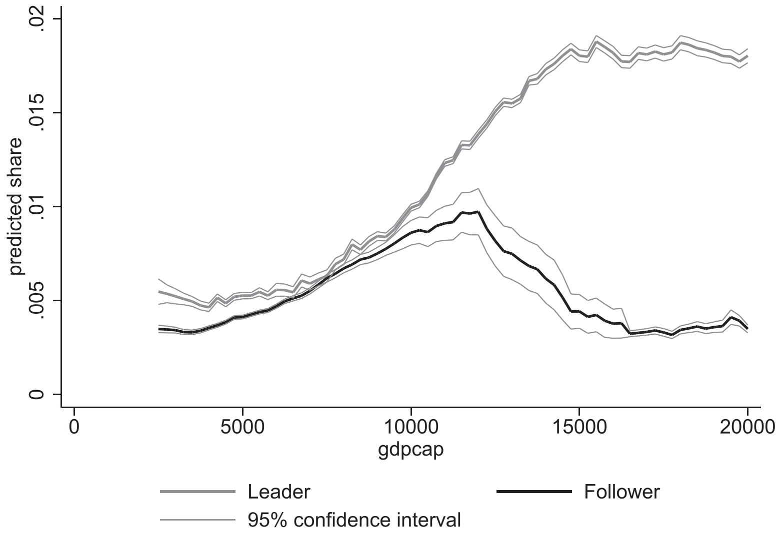

Fig. A.5. Country's homogeneous exports over total homogeneous exports.

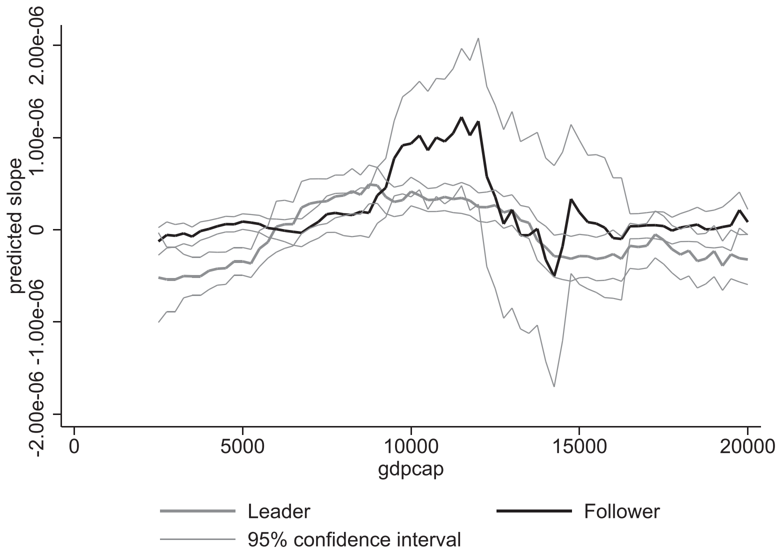

Fig. A.6. Magnitude and significance of the slope.

Appendix B. Proof of propositions

The system of nonlinear differential equations that characterizes this model is

$$\dot{n}_L(t) = \alpha \frac{n_L(t)Er^{1-\sigma} + n_F(t)[E - J(t)] - n_L(t)^2 wb\sigma r^{1-\sigma} - n_L(t)n_F(t)wb\sigma}{n_L(t)r^{1-\sigma}\sigma + n_F(t)\sigma} \tag{B.1}$$

$$\dot{n}_F(t) = \alpha n_F(t)\frac{J(t) - n_F(t)wb\sigma - n_L(t)wbr^{1-\sigma}\sigma}{n_F(t)\sigma + n_L(t)r^{1-\sigma}\sigma} \tag{B.2}$$

$$\dot{J}(t) = \beta J(t)(E - J(t))(n_F(t) - \tilde{n}_F). \tag{B.3}$$

After setting the LHS to zero, we find by substitution all possible vectors, $\mathbf{x} = (n_L, n_F, J)$, that are stationary points of the system. There are multiple possibilities:

$\mathbf{x} = (0, \frac{E}{wb\sigma}, E)$. Leapfrogging (stable)

$\mathbf{x} = (\frac{E}{wb\sigma}, 0, 0)$. Maintained Leadership (stable)

$\mathbf{x} = (\frac{E}{wb\sigma}, 0, E)$. Maintained Leadership (unstable)
$\mathbf{x} = (\frac{E}{wb\sigma} - \frac{n_F}{r^{1-\sigma}}, n_F, E)$. Partial Catch Up (stable). For $n_F \neq 0$, it is a solution only if $r = 1$
$\mathbf{x} = (\frac{E-J}{wb\sigma(1-r^{1-\sigma})}, \frac{J-Er^{1-\sigma}}{wb\sigma(1-r^{1-\sigma})}, J)$. Saddle point
$\mathbf{x} = (0, 0, E)$ and $\mathbf{x} = (0, 0, 0)$. Trivial and unstable
$\mathbf{x} = (n_L, -n_L r^{1-\sigma}, 0)$ and $\mathbf{x} = (-\frac{\tilde{n}_F}{r^{1-\sigma}}, \tilde{n}, J)$. Inadmissible

Lemma 1. *If $J(t) = E$, that is all consumers are aware of the quality of the goods from F, only firms from the country with better technology will survive on the long run.*

Proof. With $J = E$ we have that firms from L make positive profits if

$$n_F(t) < \frac{E}{\sigma wb} r^{1-\sigma} - r^{1-\sigma} n_L(t). \tag{B.4}$$

Firms from F, instead, make positive profit if

$$n_F(t) < \frac{E}{\sigma wb} - r^{1-\sigma} n_L(t). \tag{B.5}$$

The two linear functions are parallel. If F does not have a cost advantage ($r < 1$), the zero profit loci of the leader is above that of the follower. This means that there are combinations of $n_F(t)$ and $n_L(t)$ where firms from L make profit, while those from F do not. In particular when $n_F(t) = 0$, firms from L still make profits. The only stable steady state is $n_F(t) = 0$ and $n_L(t) = E/wb\sigma$.

If ($r > 1$), instead, the zero profit loci of the follower is above that of the leader. When $n_L(t) = 0$, firms from F still make profits. The only stable steady state is $n_F(t) = E/wb\sigma$ and $n_L(t) = 0$. □

Lemma 2. *If $J(t) = E$ and $r = 1$, there are infinite combinations of $n_F(t)$ and $n_L(t)$ that are in steady state.*

Proof. The result of lemma 1 are readily extended to this case by setting $r = 1$ in both zero profit loci. The two inequalities become identical making that any solution to

$$n_F(t) = \frac{E}{\sigma wb} - r^{1-\sigma} n_L(t) \tag{B.6}$$

is a valid steady state of the system. □

Proposition 1. *The leapfrogging outcome is an asymptotically stable steady state of the system, and it is attained when $n_F(t) = E/(wb\sigma)$, $n_L(t) = 0$ and $J(t) = E$.*

Proof. It is straightforward to verify by substitution that leapfrogging – $n_F(t) = E/(wb\sigma)$, $n_L(t) = 0$ and $J(t) = E$ – is a stationary point of the system. To prove stability, we analyze the Jacobian matrix of the partial derivative. We note that, at any stationary point, the numerator of Eqs. (B.1) and (B.2) is zero. The partial derivative of the ratio numerator-denominator N/D is

$$(\frac{N}{D})' = \frac{N'D - D'N}{D^2} = \frac{N'}{D}$$

The denominator is the same for (B.1) and (B.2)

$$D \equiv (n_L r^{1-\sigma} + n_F)(\sigma/\alpha)$$

We can then write the Jacobian at any fixed point as

$$\begin{pmatrix} \frac{Er^{1-\sigma} - 2n_L wb\sigma r^{1-\sigma} - n_F wb\sigma}{(n_L r^{1-\sigma} + n_F)(\sigma/\alpha)} & \frac{E - J - n_L wb\sigma}{(n_L r^{1-\sigma} + n_F)(\sigma/\alpha)} & \frac{-n_F}{(n_L r^{1-\sigma} + n_F)(\sigma/\alpha)} \\ \frac{-n_F wb\sigma r^{1-\sigma}}{(n_L r^{1-\sigma} + n_F)(\sigma/\alpha)} & \frac{J - 2n_F wb\sigma - n_L wb\sigma r^{1-\sigma}}{(n_L r^{1-\sigma} + n_F)(\sigma/\alpha)} & \frac{n_F}{(n_L r^{1-\sigma} + n_F)(\sigma/\alpha)} \\ 0 & \beta J(E - J) & \beta(E - 2J)(n_F - \tilde{n}) \end{pmatrix}$$

For leapfrogging, we have that $\mathbf{x} = (0, \frac{E}{wb\sigma}, E)$. The Jacobian is

$$\begin{pmatrix} -\alpha wb(1-r^{1-\sigma}) & 0 & -\frac{\alpha}{\sigma} \\ -\alpha wbr^{1-\sigma} & -\alpha wb & \frac{\alpha}{\sigma} \\ 0 & 0 & -\beta E(\frac{E}{wb\sigma} - \tilde{n}) \end{pmatrix}$$

The three eigenvalues are $\lambda_1 = -\alpha wb(1-r^{1-\sigma})$, $\lambda_2 = -\alpha wb$ and $\lambda_3 = -\beta E(\frac{E}{wb\sigma} - \tilde{n})$, which are all negative under the model parameters, thus proving asymptotic stability. □

Proposition 2. *The maintained leadership outcome is an asymptotically stable steady state of the system, and it is attained when* $n_L(t) = E/(wb\sigma)$, $n_F(t) = 0$ *and* $J(t) = 0$.

Proof. Again, we easily establish that maintained leadership is a steady state by substitution. The Jacobian is now simply

$$\begin{pmatrix} -\alpha wb & 0 & 0 \\ 0 & -\alpha wb & 0 \\ 0 & 0 & -\beta\tilde{n}E \end{pmatrix}$$

The three eigenvalues are $\lambda_{1,2} = -\alpha wb$ and $\lambda_3 = -\beta\tilde{n}E$, which are all negative under the model parameters. □

Proposition 3. *If at any time in the model, the share of aware consumers becomes greater than* $r^{1-\sigma}$, *the firms from country F will eventually dominate the entire market. This is both a necessary and sufficient condition.*

Proof. We first prove the proposition, which refers to the limit case in which $\tilde{n} = 0$. At the end of the proof, we show how the same steps apply to the general case with $\tilde{n} \neq 0$. The proof of the proposition is in three parts.

Hereafter, we show that if point e is above the n_L axis, while the number of firms from F is greater than zero, e remains above the n_L axis. The point e has the following coordinates:

$$n_L(t)^e = \frac{E - J(t)}{wb\sigma(1-r^{1-\sigma})} \tag{B.7}$$

$$n_F(t)^e = \frac{J(t) - Er^{1-\sigma}}{wb\sigma(1-r^{1-\sigma})}. \tag{B.8}$$

For both $J(t) > 0$ and $n(t) > 0$, it holds that

$$\frac{\partial J(t)}{\partial t} > 0. \tag{B.9}$$

Then, we have

$$\frac{\partial n_L(t)^e}{\partial t} < 0 \tag{B.10}$$

$$\frac{\partial n_F(t)^e}{\partial t} > 0. \tag{B.11}$$

The graphical intuition is that point e can only move north-west, to combinations of $n_L(t)^e$ and $n_F(t)^e$ that have less of the former and more of the latter. Hence – if $n_F(t^*)^e > 0$ – we have that $n_F(t)^e > 0$, $\forall t \geq t^*$.

In the second part of the proof, we need to demonstrate that if point e is above the n_L axis, then point x is attracted to it. This may seem intuitive, but we need to rule out one possibility, which we illustrate in Fig. B.1. In this graph, we show a potential evolution over time of points x and e. The empty dot represents the position of the point at the beginning and the solid dot the position at the end. The line that links them is the path that they take.

It can be seen that, in this case, point e is above the n_L axis at the beginning of the period. Yet, x intersects the n_L axis (hence $n_F(t)$ goes to zero) before it can reach e.

We prove here that this cannot happen in the model. In fact, $n_L(t)$ cannot be larger than $E/wb\sigma$, which is the maximum sustained by the system. At the entry of firms from F, there are exactly $E/wb\sigma$ firms from L. To grow over this limit, it would be required that firms from L make positive profits. This happens if and only if

$$n_F(t) < \frac{n_L(t)Er^{1-\sigma} - n_L(t)^2 wbr^{1-\sigma}\sigma}{J(t) - E + n_L(t)wb\sigma}. \tag{B.12}$$

Substituting $n_L(t) = E/wb\sigma$, we obtain

$$n_F(t) < 0. \tag{B.13}$$

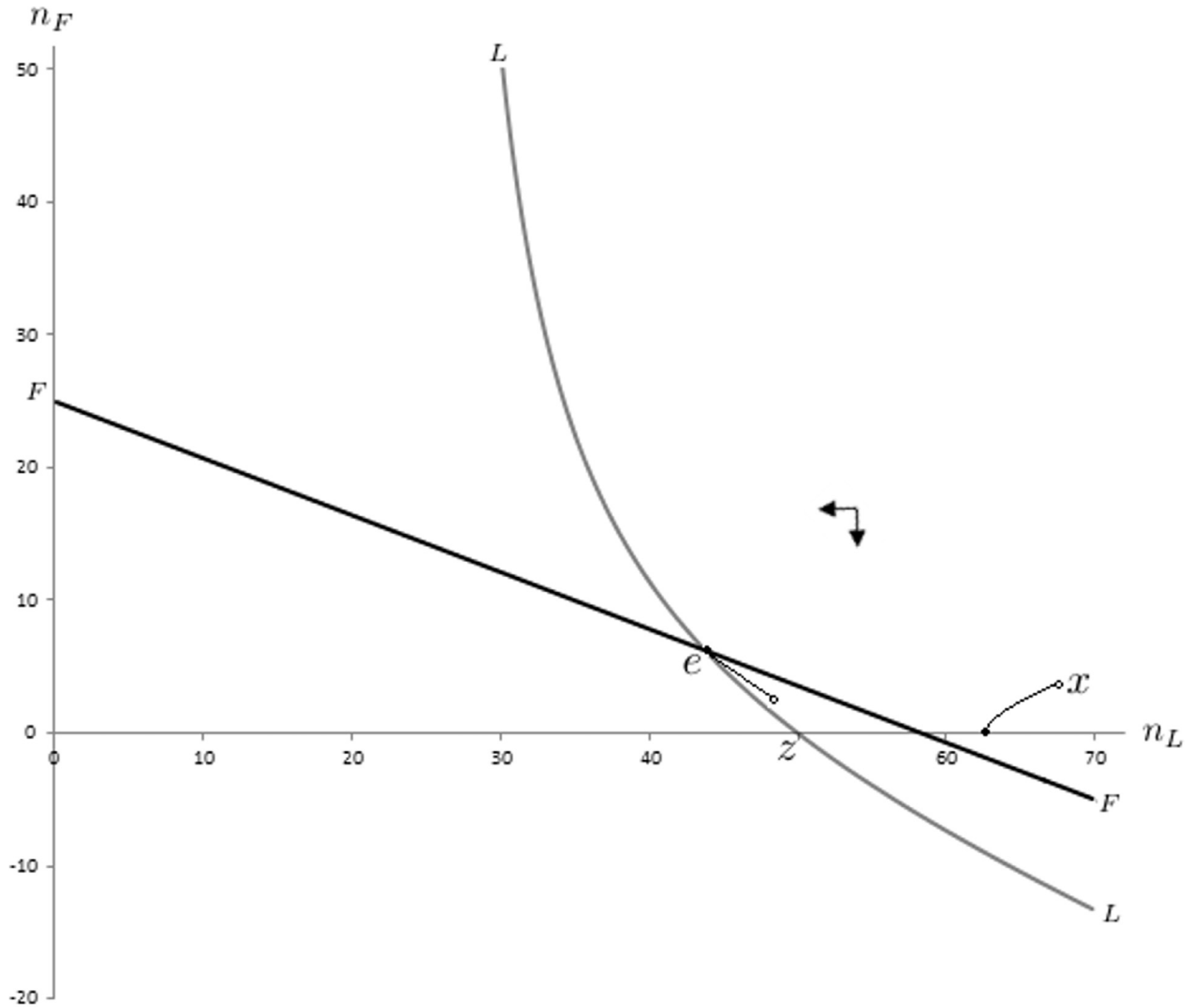

Fig. B.1. The evolution of x and e over time (projection on the $n_L - n_F$ plane).

As long as $n_F(t) > 0$, this condition is never verified and $n_L(t)$ never exceeds $E/wb\sigma$.

Next, we use this fact to show that for each value of $n_L(t)$ with $0 \le n_L(t) \le E/wb\sigma$, the profit line *FF* is above the n_L axis. This is the case if

$$\frac{J(t)}{wb\sigma} - n_L(t) r^{1-\sigma} \ge 0, \tag{B.14}$$

which we can write as

$$\frac{1}{r^{1-\sigma}} \frac{J}{wb\sigma} \ge n_L(t). \tag{B.15}$$

Since point e is above the n_L axis, we know that the smallest value that $1/r^{1-\sigma}$ can assume is E/J. Hence,

$$\frac{E}{wb\sigma} \ge n_L(t). \tag{B.16}$$

It follows that – as we have shown that $n_L(t)$ cannot be greater than $E/wb\sigma$ – the *FF* line is always above the n_L axis for $n_F(t)^e > 0$. In summary, for feasible values of $n_L(t)$, if e is above the n_L axis, the *FF* line is also positive, and $n_F(t)$ cannot reach zero without encountering the *FF* line.

The third and final step of the proof is the easiest. We have shown that if e is above the n_L axis, x is moving toward it. To complete the proof, we only need to show the final position of e. We know now that there are firms from F in the market, as x is above the n_L axis. Hence, $J(t)$ grows until it reaches the maximum value, that is, E. We, therefore, solve the equations that identify the position of point e for $J(t) = E$ to obtain

$$n_L(t)^e = 0, n_F(t)^e = E/wb\sigma. \tag{B.17}$$

Which is the leapfrogging stable stationary point. □

The same type of proof applies for the general case in which $\tilde{n} > 0$. In this case, however, we have a distinct maintained leadership condition and leapfrogging conditions that are not entirely symmetric.

For maintained leadership, it is sufficient that both points x and e are below $\tilde{n}$ to ensure this outcome (use Fig. 4 for reference). In this case, n_F cannot grow larger than $\tilde{n}$, as point x moves toward e. Moreover, since $n_F < \tilde{n}$, $J(t)$ declines and point e moves south–east. It can only stop at the stationary point where $n_L(t)^e = E/wb\sigma$, $n_F(t)^e = 0$ and $J_(t) = 0$. The maintained leadership condition is then

$$\begin{aligned} &n_F(t) < \tilde{n} \\ &J(t) < Er^{1-\sigma} + \tilde{n}wb\sigma(1 - r^{1-\sigma}) \end{aligned} \tag{B.18}$$

For leapfrogging, we need – similarly – that both points x and e are above $\tilde{n}$. However, the second step of the previous proof (when $\tilde{n} = 0$) is no longer valid in the general case, as point x can cross the $\tilde{n}$ line while e is above $\tilde{n}$ (again, use Fig. 4 for reference). An equivalent, although more restrictive, condition in the general case demands that the *FF* line be above $\tilde{n}$ for $0 \le n_L(t) \le E/wb\sigma$.

The leapfrogging condition is

$$\begin{aligned} &n_F(t) > \tilde{n} \\ &J(t) > Er^{1-\sigma} + \tilde{n}wb\sigma \end{aligned} \tag{B.19}$$

Proposition 4. *If at time zero, the share of aware consumers is smaller than $r^{1-\sigma}$, leapfrogging is still possible, but it is dependent on how the dynamic unfolds: it depends on the speed of entry and exit of firms (α), on the speed of information diffusion (β) and on the initial conditions of the dynamic system ($n_L(0)$, $n_F(0)$ and $J(0)$).*

Proof. If the share of aware consumers is smaller than $r^{1-\sigma}$, this means that point e is below the n_L axis, as illustrated in Fig. B.2.

The proof uses the previous proposition. In fact, proposition 3 states that if at any time in the model point e is above the n_L axis – while $n_F > 0$ – leapfrogging occurs.

When the system is in a state in which – as in Fig. B.2 – e is below the n_L axis and $n_F > 0$, leapfrogging occurs if and only if e crosses the horizontal axis before x does. In this case, the leapfrogging condition of proposition 3 is verified and leapfrogging occurs. Conversely, if x crosses the horizontal axis (and n_F becomes equal to zero) while e remains below the axis, the final outcome will be that of maintained leadership.

We then want to know whether the n_F component of e reaches the horizontal axis before the n_F component of x. With the simplified model, we can solve the differential equations in explicit form. With respect to x, the number of firms in F then declines as

$$n_F(t) = n_F(0) - \alpha t. \tag{B.20}$$

With respect to e, as the number of aware consumers grows according to the law $J(t) = J(0) + \beta t$, we have that

$$n_F(t)^e = \frac{J(0) + \beta t - Er^{1-\sigma}}{wb\sigma(1 - r^{1-\sigma})}. \tag{B.21}$$

Point e reaches zero at time t'.

$$t' = \frac{Er^{1-\sigma} - J(0)}{\beta}. \tag{B.22}$$

The number of firms from F reaches zero at time t''.

$$t'' = \frac{n_F(0)}{\alpha}. \tag{B.23}$$

The dynamic leapfrogging condition is then obtained by requiring that $t' < t''$.

$$\frac{Er^{1-\sigma} - J(0)}{\beta} < \frac{n_F(0)}{\alpha}. \tag{B.24}$$

Substituting E, we obtain

$$\frac{n_L(0)wb\sigma r^{1-\sigma} - J(0)}{\beta} < \frac{n_F(0)}{\alpha}, \tag{B.25}$$

where we can see that leapfrogging – if $J(0)/E < r^{1-\sigma}$ – is still possible but depends on the speed of entry and exit, α, on the speed of information diffusion, β, and on the initial conditions, $n_L(0)$, $n_F(0)$ and $J(0)$. □

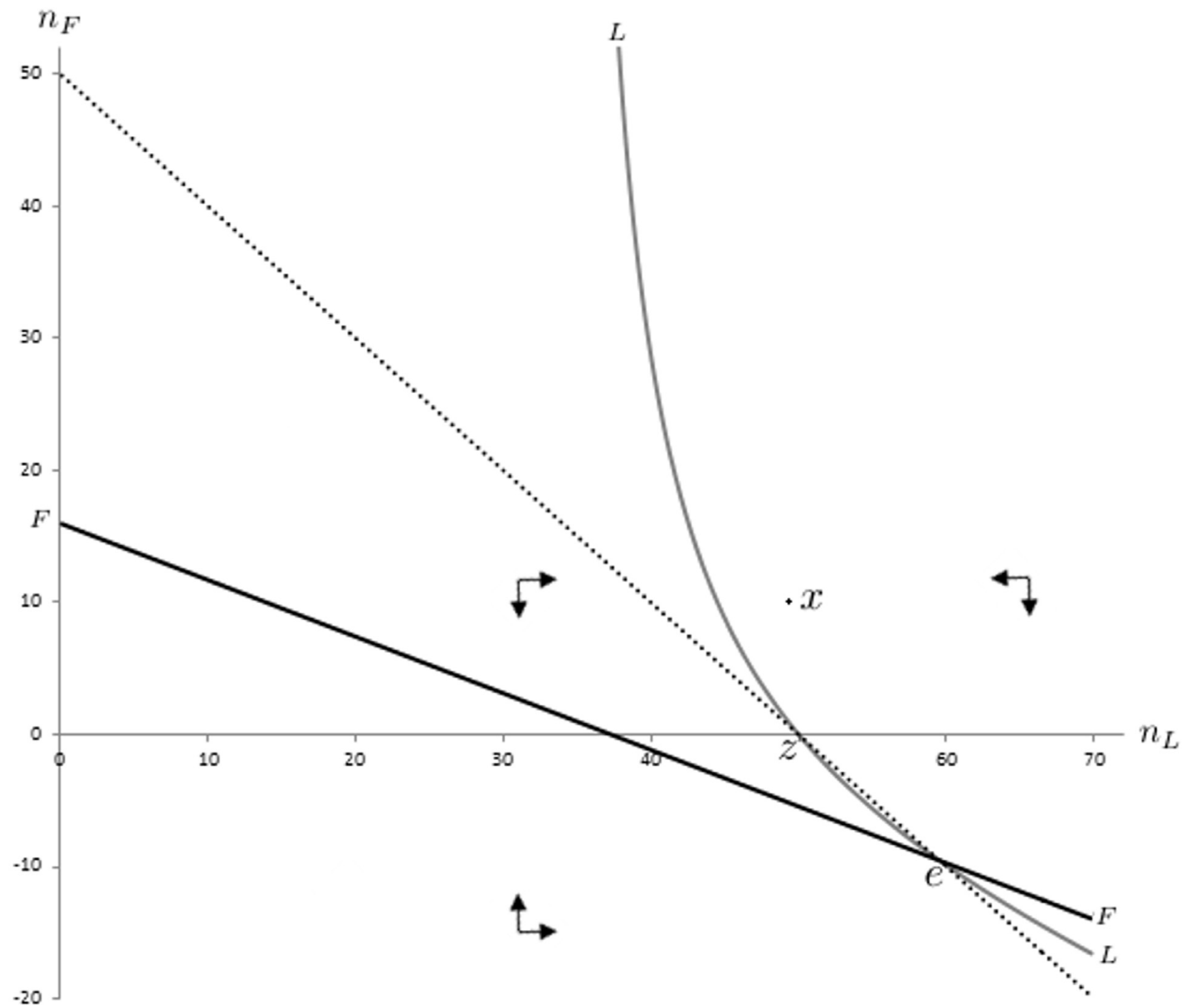

Fig. B.2. Zero profit loci if $J(0)/E < r^{1-\sigma}$ (projection on the $n_L - n_F$ plane).

We can also use Eq. (B.24) to draw the basin of attraction of this simple system. The gray region in Fig. B.3 depicts the basin of attraction of the leapfrogging outcome.

Proposition 5. *Under externalities in investment, a social planner (S) would allocate a larger sum to advertising than the market (M) does. That is $\phi_i^S(0) > \phi_i^M(0)$ and $\Phi^S(0) > \Phi^M(0)$. As the number of aware consumers grows faster in S compared to M, for a range of initial conditions $n_F(0)$, $n_L(0)$ and $J(0)$ the planner solution leads to leapfrogging, while the market leads to maintained leadership.*

Proof. We first provide the proof for the case with simple dynamics and myopic firms that invest only in $t = 0$. Under Eqs. (29) and (30), we can write the profit function from a firm from F as

$$\pi_{i,F}(t) = \frac{J(t) + \Phi(t)(E - J(t)) - n_F(t)wb\sigma - n_L(t)wbr^{1-\sigma}\sigma}{n_F(t)\sigma + n_L(t)r^{1-\sigma}\sigma} - \phi_i(t). \tag{B.26}$$

By writing $D \equiv n_F(t)\sigma + n_L(t)r^{1-\sigma}\sigma$ and $\chi_i(t) \equiv \partial\Phi(t)/\partial\phi_i(t)$, we obtain that

$$\frac{\partial\pi_{i,F}(t)}{\partial\phi_i(t)} = \frac{\chi_i(t)(E - J(t))}{D} - 1. \tag{B.27}$$

The derivative of $\Phi(t)$ with respect to $\phi_i(t)$ equals

$$\chi_i(t) = \gamma\phi_i(t)^{\gamma-1}\prod_{k\neq i}\phi_k(t)^{\gamma}. \tag{B.28}$$

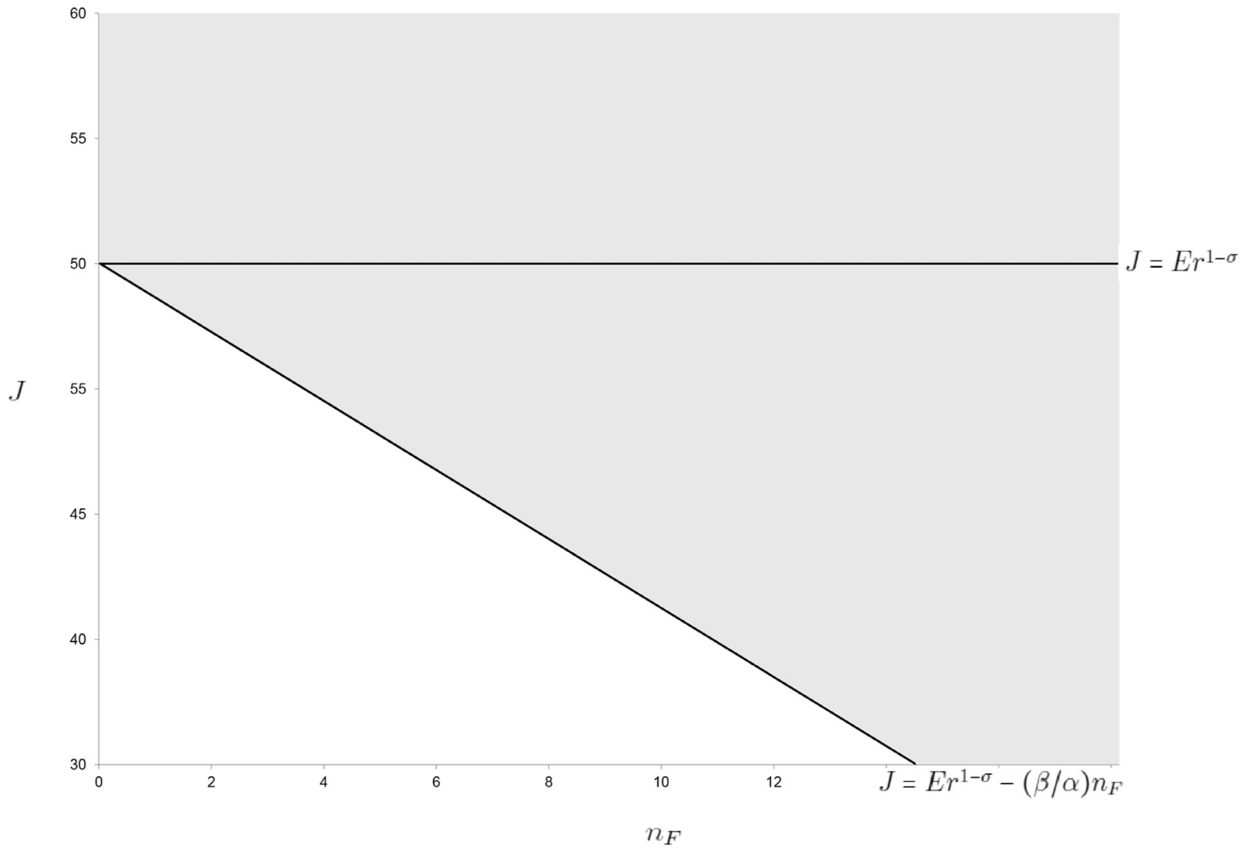

Fig. B.3. Basin of attraction of the simple system.

By symmetry, all firms are equal. We get that

$$\chi_i(t) = \gamma\phi_i(t)^{\gamma-1}\phi_i(t)^{\gamma(n_F(t)-1)} = \gamma\phi_i(t)^{\gamma n_F(t)-1}. \tag{B.29}$$

By equating $\partial\pi_{i,\,F}(t)/\partial\phi_i(t)$ to zero, we obtain optimal investment for the market solution:

$$\phi_i^M(t) = \left(\frac{\gamma(E - J(t))}{D}\right)^{1/(1-\gamma n_F(t))} \tag{B.30}$$

The social planner solution is found in an equivalent manner. The objective function is now, however, $W = \sum_i \pi_{i,F}$. This leads to the following optimal investment for the planner.

$$\phi_i^S(t) = \left(\frac{n_F(t)\gamma(E - J(t))}{D}\right)^{1/(1-\gamma n_F(t))} \tag{B.31}$$

By allowing investment only in $t = 0$ and by comparing Eqs. (B.30) and (B.31), it is easy to verify that – for $\gamma n_F(t) < 1$ and $n_F(t) > 1$ – we have that $\phi_i^S(0) > \phi_i^M(0)$ and $\Phi^S(0) > \Phi^M(0)$.

Moreover, the leapfrogging condition in (32) shows that the larger $\Phi(0)$ the easier it is to leapfrog. Consequently, for the same set of initial conditions $n_F(0)$, $n_L(0)$ and $J(0)$, it is possible that the leapfrogging condition is verified for the planner, but not for the market solution. □

The first part of proposition 5[12] can also be proven in the extended case, with complete dynamics, forward looking expectations, and investment in every t.

Proof. Both firms and the social planner now have to take into account future profits in their decisions. Assuming a discount rate ρ, the objective function for a firm is

$$W^M = \int_0^\infty e^{-\rho t}\pi_{i,F}(t)\,dt \tag{B.32}$$

[12] that is: under externalities in investment, $\phi_i^S(0) > \phi_i^M(0)$ and $\Phi^S(0) > \Phi^M(0)$.

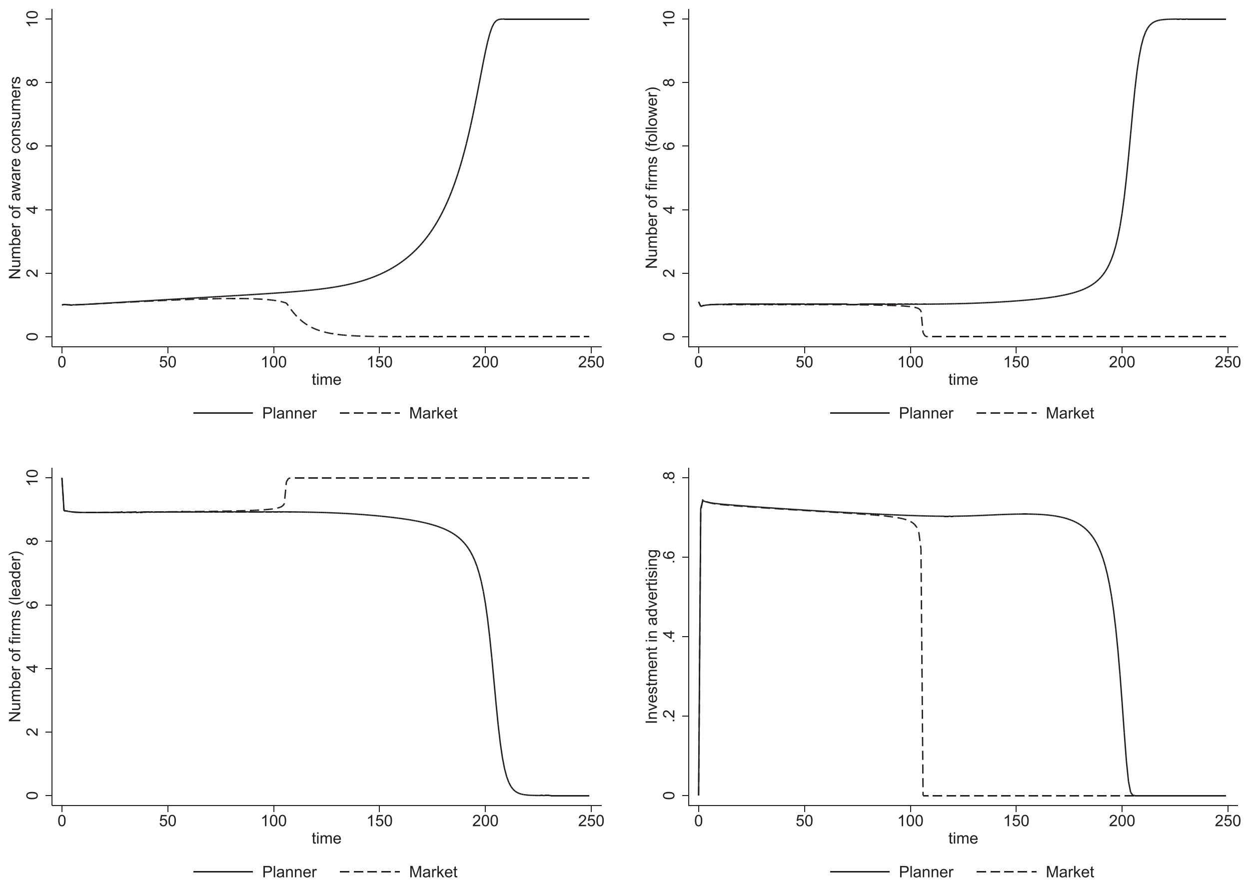

Fig. B.4. Case 1: planner and market solution in complete model: the former leads to leapfrogging, the latter to maintained leadership.

Equivalently, the objective function for the social planner is

$$W^S = \int_0^\infty e^{-\rho t} \sum_i \pi_{i,F}(t)\, dt \tag{B.33}$$

Both the firm and the social planner are subject to the same dynamic constraints

$$s.t. := \begin{cases} \dot{n}_F(t) = \alpha n_F(t) \pi_{i,F}(t) \\ \dot{n}_L(t) = \alpha n_L(t) \pi_{i,L}(t) \\ \dot{J}(t) = \beta (J(t) + \Phi(t))(E - J(t))(n_F(t) - \tilde{n}) \end{cases}. \tag{B.34}$$

Note that profits, $\pi_{i,F}(t)$ and $\pi_{i,L}(t)$, are adjusted for investment according to the following law $J_\Phi = J + \Phi(E - J)$, as they are in Eq. (B.26). The system has one control variable per firm and period ($\phi_i(t)$) and three state variables per period ($n_F(t)$, $n_L(t)$ and $J(t)$). Using control theory, we solve this optimization problem in continuous time by writing the Hamiltonian function. With $Y \in \{M, S\}$, we have that

$$H^Y(t) = V^Y(t) + \lambda_1(t)\dot{J}(t) + \lambda_2(t)\dot{n}_F(t) + \lambda_3(t)\dot{n}_F(t), \tag{B.35}$$

Where $V^M = \pi_{i,F}(t)$ and $V^S = \sum_i \pi_{i,F}(t)$. By equating the derivative of the Hamiltonian with respect to $\phi_i(t)$ to zero, we find optimal investment for the firm and the social planner. The last three terms are identical in the two cases

$$\frac{\partial \lambda_1(t)\dot{J}(t)}{\partial \phi_i(t)} = \lambda_1(E - J(t))(n_F(t) - \tilde{n})\chi_i(t) \tag{B.36}$$

$$\frac{\partial \lambda_2(t)\dot{n}_F(t)}{\partial \phi_i(t)} = \frac{\lambda_2(t)\alpha n_F(t)\chi_i(t)(E - J(t))}{D} - \lambda_2 \alpha n_F(t) \tag{B.37}$$

$$\frac{\partial \lambda_3(t)\dot{n}_L(t)}{\partial \phi_i(t)} = -\frac{\lambda_3(t)\alpha n_F(t)\chi_i(t)(E - J(t))}{D} \tag{B.38}$$

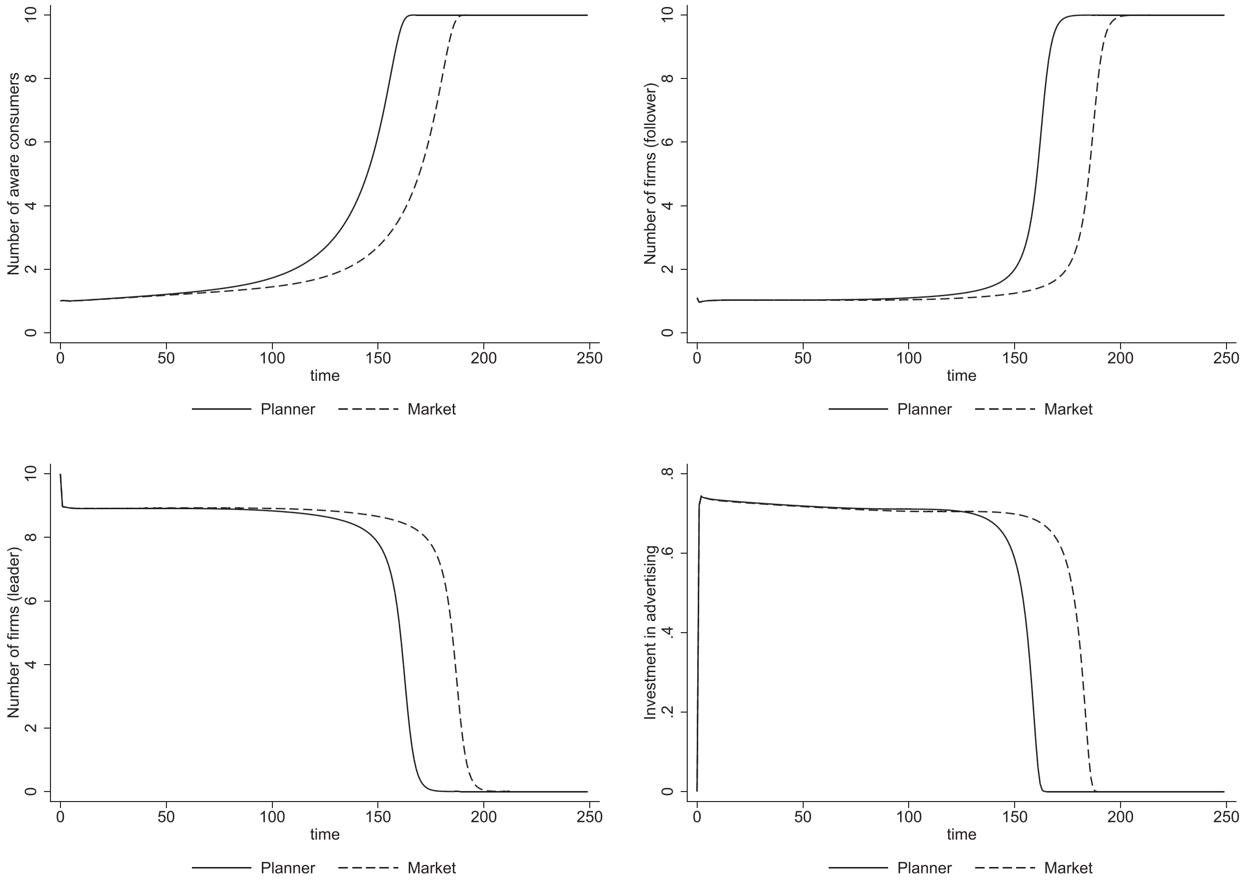

Fig. B.5. Case 2: planner and market solution in complete model: leapfrogging occurs in both cases.

The first term of the Hamiltonian differs for firms' choice compared to the social planner.

$$\frac{\partial V_M(t)}{\partial \phi_i(t)} = \frac{(E - J(t))\chi_i(t)}{D} - 1 \tag{B.39}$$

$$\frac{\partial V_S(t)}{\partial \phi_i(t)} = \frac{(E - J(t))n_F(t)\chi_i(t)}{D} - 1 \tag{B.40}$$

This leads to two different choice of investment. Recalling that

$$\phi_i(t) = \left(\frac{\gamma}{\chi_i(t)}\right)^{1/(1-\gamma n_F(t))} \tag{B.41}$$

The solutions are

$$\chi_i^M(t) = \frac{1 + \lambda_2(t)\alpha n_F(t)}{(E - J(t))/D + \kappa} \tag{B.42}$$

$$\chi_i^S(t) = \frac{1 + \lambda_2(t)\alpha n_F(t)}{((E - J(t))n_F(t))/D + \kappa} \tag{B.43}$$

With

$$\kappa = \lambda_1(t)(E - J(t))(n_F(t) - \tilde{n}) + (\lambda_2(t) - \lambda_3(t))\frac{\alpha n_F(t)(E - J(t))}{D} \tag{B.44}$$

While it is impossible to know which of the two quantity is larger for every t without solving the system in explicit form, it is easy to use Eqs. (B.41), (B.42) and (B.43) to prove that $\phi_i^S(0) > \phi_i^M(0)$ and $\Phi^S(0) > \Phi^M(0)$, for $\gamma n_F(0) < 1$ and $n_F(0) > 1$, since the initial conditions in the two systems are identical. □

It has to be noted that the proof for the complete model is somewhat less meaningful because – given that firms are allowed to invest in every period of time t – proving that $\phi_i^S(0) > \phi_i^M(0)$ gives us only a partial understanding on how the dynamics unfold. That is, in fact, the reason why the second part of proposition 5 is a direct consequence of $\phi_i^S(0) > \phi_i^M(0)$ in the simple model, while it is not the case for the extended one. However, by running two selected numerical solutions, we can show (though not prove) here that the second part of proposition 5 seems to be holding also in the complete model. In particular, a first numerical simulation shows that – with the same set of initial conditions $n_F(0)$, $n_L(0)$ and $J(0)$ – it is possible that leapfrogging occurs for the planner solution, but not for the market solution. A second numerical simulation shows that, even when leapfrogging happens for both the market and the social planner, the trajectories are markedly different, therefore highlighting that also in this case there is a reason for the social planner to intervene. While, we cannot provide formal proof it appears that the planner invests earlier, anticipating diffusion of information (growth of J), profits , and (ultimately) leapfrogging.

Proposition 6. *Production of differentiated products is on average relatively more concentrated in the leading country.*

Proof. The level of differentiation of any given good g is a value on a continuum which is given by $\rho(g) \in (0.1)$. For each good in a country, it is possible to compute a specialization/concentration index, such as the Balassa index of revealed comparative advantage (*RCA*). Since, in the general equilibrium model each good type has a separate elasticity, we denote ρ omitting the index g. Moreover, we write the equilibrium ρ – the intersection between Eqs. (35) and (37) – as ρ^*. We have that

$$RCA_L(\rho) = \frac{x_L(\rho)/x(\rho)}{x_L/x} = \begin{cases} 1/\rho^* & if \quad \rho < \rho^* \\ 0 & if \quad \rho > \rho^* \end{cases}. \tag{B.45}$$

Equivalently, we have that

$$RCA_F(\rho) = \frac{x_F(\rho)/x(\rho)}{x_F/x} = \begin{cases} 1/(1-\rho^*) & if \quad \rho > \rho^* \\ 0 & if \quad \rho < \rho^* \end{cases}. \tag{B.46}$$

Let us dichotomously divide goods in differentiated and non-differentiated, according to a critical (arbitrary) level $\bar{\rho}$. We want to know whether differentiated goods concentrate more often in F or L. Two cases are distinguished: $\bar{\rho} > \rho^*$ and $\bar{\rho} \leq \rho^*$.

If $\bar{\rho} > \rho^*$, we write the average *RCA* of the leader in differentiated goods as:

$$z_L^{dif} = \frac{1}{\bar{\rho}} \int_0^{\rho^*} \frac{1}{\rho^*} d\rho = \frac{1}{\bar{\rho}}. \tag{B.47}$$

For the follower, we have

$$z_F^{dif} = \frac{1}{\bar{\rho}} \int_{\rho^*}^{\bar{\rho}} \frac{1}{1-\rho^*} d\rho = \frac{1}{\bar{\rho}} \frac{1}{1-\rho^*} (\bar{\rho} - \rho^*). \tag{B.48}$$

It is easy to see that $z_L^{dif} > z_F^{dif}$ for $\bar{\rho} < 1$. A similar reasoning applies when $\bar{\rho} \leq \rho^*$.

$$z_L^{dif} = \frac{1}{\bar{\rho}} \int_0^{\bar{\rho}} \frac{1}{\rho^*} d\rho = \frac{1}{\rho^*} \tag{B.49}$$

and

$$z_F^{dif} = 0 \tag{B.50}$$

which immediately establishes that $z_L^{dif} > z_F^{dif}$. □

Proposition 7. *With technological growth, catch up countries increase their share of differentiated goods in their export basket. When comparing the process of catch-up between two countries, where one suffers from the made-in effect more than the other, the latter exports larger shares of differentiated goods at every stage of development.*

Proof. We first establish that with technological growth, catch up countries increase their share of differentiated goods in their export basket.

The process of technological growth in a catch up country can be described as an increase over time of the ratio T_F/T_L. An equilibrium in this model is found at the intersection between Eqs. (35) and (37). There are two unknown: the wage ratio w_F/w_L and the equilibrium elasticity ρ^*. A solution exists with $0 < \rho^* < 1$ and $w_F/w_L > 0$. This is established by analyzing the supply Eq. (35) and the demand (37). For supply we have $w_F/w_L = (J(0)/E)(T_F/T_L)$ when $\rho = 0$ and $w_F/w_L = (T_F/T_L)$ when $\rho = 1$. For $0 < \rho^* < 1$, the supply function is continuous and has positive derivative. For demand we have that $\lim_{\rho \to 0} w_F/w_L = \infty$, while $w_F/w_L = 0$ for $\rho = 1$. For $0 < \rho^* < 1$, the demand function is continuous and has a negative derivative. This establishes that there is solution such that $0 < \rho^* < 1$ and $w_F/w_L > 0$.

Comparative statics can be used to analyze the impact of changes in the technological ratio T_F/T_L. As the demand has negative slope ($\partial(w_F/w_L)/\partial\rho < 0$) while supply has a positive one ($\partial(w_F/w_L)/\partial\rho > 0$), a growth of the technological ratio (which implies a shift of the supply schedule upward), increases the equilibrium wage ratio w_F/w_L and decreased the equilibrium elasticity ρ^*. As result, a number of goods with lower elasticity are added to export basket of the follower.

We prove, then, the second part of the proposition. That is: when comparing the process of catch-up between two countries, where one suffers from the made-in effect more than the other, the latter exports larger shares of differentiated goods at every stage of development. Let us imagine two scenarios. In one the catch up country faces initial shares of aware consumers equal to $\psi_1 = J(0)_1/E$. In the second scenario, the catch up country is affected less by the made in effect, and faces initial shares of aware consumers equal to $\psi_2 = J(0)_2/E > \psi_1$. By the same principles of comparative statics outlined above, it is possible to establish that, everything else equal, $\rho_1^* > \rho_2^*$. That is, in the first scenario the catch up country exports lower shares of differentiated products. The conclusion holds for every dynamics of technological catch up. For instance if we assume that technological catch up follows the law:

$$\frac{T_F}{T_L} = \frac{1}{1+e^{-t}} \tag{B.51}$$

at every single time period t it holds that $\rho_1^* > \rho_2^*$. □

Appendix C. Simulation parameters

Figs. 1, 2 and 3

Common parameters			Variable parameters		
E=100	w=1	b=0.5	Fig. 1	a_L=1.9	$n_F(0)$= 20
a_F=1	σ=2	$\tilde{n}$=1	Fig. 2	a_L=1.89	$n_F(0)$=20
α=0.09	$\beta = 10^{-4}$	$J(0)$=1	Fig. 3	a_L=1	$n_F(0)$=40

Figs. 5 and 6

Parameters				
E=100	w=1	b=0.5	a_F=1	a_L=2
σ=2	$\tilde{n}$=10	α=0.09	$\beta = 10^{-4}$	

Figs. B.4 and B.5

Common parameters				Variable parameters	
E=10	w=1	b=0.5	a_F=1	Fig. B.4	a_L=1.462
σ=2	$\tilde{n}$=1	α=2	$\beta = 0.011$	Fig. B.5	a_L=1.463
$J(0)$=1	$n_F(0)$=1.1	ρ=0.005	γ=0.09		

Supplementary material

Supplementary material associated with this article can be found, in the online version, at 10.1016/j.euroecorev.2017.10.010.

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