Paper to be presented at the DRUID Academy conference in Rebild, Aalborg, Denmark on January

21-23, 2015

Industrial Leadership and Sectoral Catch-up: the Role of the Demand Side

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Abstract

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PhD start date: June 2013. Expected end date: May 2016
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abstract
1) State-of-the-art. Some nations hold a solid and long-lasting leadership in the production and exports of certain products, which makes changes in industrial leadership a rare event. Nevertheless, sometimes it does happen that a latecomer nation enters into a long established market and manages to become market leader (Lee and Jeehoon, 2011). If one looks at the literature that examined those cases of sectoral catch-up, he or she would find stories of learning: the latecomer country had to learn a variety of complex skills, which were necessary to compete in the world markets. (Abramovitz, 1986; Lee and Lim, 2001; Malerba and Nelson, 2011).
2) Research gap. In many sectors (if not all), learning an efficient production technology is crucial for catching up. This paper, however, suggests an alternative or complementary explanation, which comes from the demand side of the economy. It is argued that for firms in a developing or emerging country to catch up with incumbents, the effort of

creating a demand for their own products can be just as crucial as learning an efficient production technique. We contribute to the growing literature on changes in industrial leadership by highlighting the importance of the demand side in triggering the catch-up process.
3) Theoretical arguments. For many products, consumers put substantial weight for their decisions to the reputation that a country and its firms have accumulated over time. This perspective suggests that sectoral catch-up might be not only a story of learning technology, but also a story of discovery and shifting demand: consumers need to discover that the products from the catch-up country are just as good as those currently on the market. Two indicative examples of sectoral catch-up that were at least in part influenced by this type of demand shift are Chilean wine and Korean cars.
4) Methods. This paper proposes a simple 2-country model to evaluate the role played by demand in the dynamics of sectoral catch-up. We first present a model that abstracts from differences in technology in the two countries, to keep the focus strictly on demand. This is achieved by assuming that the production in the catch-up country is at least as good, in quality and efficiency, to that of the incumbent. Nonetheless, when pioneering firms in the catch-up country enter in the world markets, only a minority of pioneering consumers are willing to purchase their products. As these consumers discover that products from the catch-up country are just as good, a process of diffusion of information takes off. Other consumers are 'infected' with the information of the quality of goods and they become willing - in the next period - to purchase those products. The model is driven by the endogenous dynamics of (1) the number of firms in the catch-up country, (2) the number of firms in the leading country and (3) the number of consumers in the world markets that are aware of the quality of products sold by the entrants. The model is, then, extended to allow for increasing complexity. First, technology is made a dynamic variable that improves over time through learning-by-doing. Second, investment is made endogenous: firms can choose to spend profits in marketing or to increase efficiency. Third, the role of local demand is explored by making wages endogenous.
5) Results. The baseline model finds that catching up can only occur if the entrants have a better technology than the incumbents. However, a better technology does not guarantee catching up: the model shows that important determinants of catch-up are speed of entry and exit of firms, speed of diffusion of information among consumers, firms' monopolistic power, as well as the initial conditions, in terms of number of pioneering consumers and pioneering firms.

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Jelcodes:O14,F12

Industrial Leadership and Sectoral Catch-up: the Role of the Demand Side

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December 12, 2014

Abstract

Literature on sectoral catch-up put much emphasis on the role of supply-side factors, such as learning a technology or increasing efficiency. However some authors highlight that an important role is also played by factors on the demand side. In this paper, it is argued that demand is a decisive determinant of catch-up when consumers need to discover the quality of products of a latecomer country. A model that aims to capture the endogenous dynamics of demand building and catch-up is proposed. It is found that industrial catch-up of a latecomer country is determined by a strong interplay between demand and supply factors. Acquiring a superior production technology is not sufficient for the latecomer to catch-up, especially in sectors where firms have a high degree of monopolistic power. The model also shows that catch-up often, but not always, depends on dynamic factors, such as rate of entry and exit of firms or speed of diffusion of information among consumers.

1 Introduction

Looking back to economic history one can clearly see that the concentration and distribution of economic activities around the world is subject to complex dynamics. It is possible, nonetheless, to observe two important regularities. First, some nations hold a solid and long-lasting leadership in the production and exports of certain products. Second, changes in industrial leadership are, in some sectors, not that infrequent: sometimes it does happen that a latecomer nation enters into a long established market and manages to outcompete the incumbents to become market leader (Lee and Jeehoon, 2011). Often, but it is not always the case, the entrant firms come from a developing or emerging economy, while the incumbents are from a developed one. Given that the latecomers can benefit from a cost advantage, a convincing explanation for the often-observed failure to catch up is the lack of technology. The incumbents possess a better production technology, which firms in developing economies cannot outcompete, in spite of the cost advantage. In fact, if one looks at the literature that examined those cases of sectoral catch-up, he or she would find stories of learning through education, technological transfer, imitation, building experience and social capabilities: the bottom line is that the latecomer country had to learn a variety of complex skills, which were necessary to compete in the world markets. (Abramovitz, 1986; Lee and Lim, 2001; Malerba and Nelson, 2011).

It is not the purpose of this paper to question these conclusions. In many sectors (if not all), learning an efficient production technology is crucial for catching up. This paper, however, suggests an alternative or, perhaps, complementary explanation, which comes from the demand side of the economy. In focusing on the role of demand in the process of catching-up in industries we contribute to the growing literature on changes in industrial leadership. Many authors have suggested that demand can influence catching up in various ways. Posner (1961) notices that the changing nature of demand along the product life cycle can shift production towards low income countries. Mathews (2005) proposes that demand fluctuations caused by the business cycle can create windows of opportunity to catch up. Adner (2002) and Malerba (2006) link demand conditions to innovation. Morrison and Rabellotti (2013) argue that changing consumers taste, as well as the entry of new consumers from emerging countries can substantially impact the dynamics of catching up.

In this paper it is argued that for firms in a developing or emerging country to catch up with the incumbents, the effort of creating a demand for their own products can be just as crucial as learning an efficient production technique. In fact, for many products, consumers put substantial weight for their decisions to the reputation that a country and its firms have accumulated over time. A few examples of this are German cars, American software, Japanese electronics, Swiss watches, Portuguese tiles, Italian clothing, French wine. The leaders in these sectors did not become such overnight. Not only was it necessary for them to learn a cost-efficient process of production that could result in output of high quality, but they also had to get known and appreciated in the world markets. Similarly, for firms in an emerging country to challenge the established leadership, it may be insufficient to produce high quality, cost-competitive products, if consumers are unaware of their value. A key point we highlight in this paper is that getting your products known and having their quality recognized requires time and effort. This perspective suggests that sectoral catch-up might be not only a story of learning technology, but also a story of discovery and shifting demand: consumers need to discover that the products from the catch-up country are just as good as those currently on the market.

We make a case that, for catch-up, the demand side of the story is all the more important when the sector under scrutiny is a traditional one, such as food products, textile and furniture. In these sectors which are typically labeled as low tech or supplier-dominated (Pavitt, 1984) the state-of-the-art technology is relatively more accessible and its rate of change is typically slow. At the same time, consumers can be rather critical in their demand for quality and are not easily persuaded that new products meet their needs. A case in point is the catch-up dynamic of the wine industry, where some producers in emerging countries, such as Chile, Argentina and South Africa, as well as in developed countries like the U.S., Australia and New Zeeland managed to take a sizeable share of the world market. It certainly was indispensable for these producers to learn how to make good wine, but it also required an effort to get consumers to acknowledge that their bottles could compare to those coming out of Italy and France (see Morrison and Rabellotti 2013).

This paper proposes a simple theoretical 2-country model to evaluate the role played by demand in the dynamics of sectoral catch-up. In this first working paper version of our analysis, we present a simple baseline model. We then plan to extend the current model by adding layers of increasing complexity. We present here a model that abstracts from a potential technological gap of the latecomer country, to keep the focus strictly on demand. This is achieved by assuming that a) the production process in the catch-up country is at least as efficient as that of incumbent firms in the leading country and b) consumers in the world markets find the goods produced in the two countries of equal quality. Nonetheless, when pioneering firms in the catch-up country enter in the world markets, only a minority of pioneering consumers are willing to purchase their products. As these consumers discover that products from the catch-up country are just as good, a process of diffusion of information takes off. Other consumers are 'infected' with the information of the quality of goods and they become willing in the next period to purchase those products. On the side of production, firms in the catch-up country also follow a process of diffusion of information. The entry of the pioneering firms reveals to other potential imitators if selling these products to the world market is profitable. In case it is, new firms will follow. If pioneering firms suffer a loss, some firms will exit the market. The same applies for firms in the leading country, which will grow or decrease in number, according to the profit they make. The model, hence, is driven by the endogenous dynamics of 1) the number of firms in the catch-up country, 2) the number of firms in the leading country and 3) the number of consumers in the world markets that are aware of the quality of products sold by the entrants.

The model we propose contributes to the literature on sectoral catch-up in two ways. First, it highlights the importance of the demand side in triggering the catch-up process and eventually in leading to changes in industrial leadership. Second, it shows that key dynamic factors behind the catch-up process can be captured by a relatively simple dynamic model.

The baseline model allows us to reach a number of interesting conclusions. When consumer awareness has an important role on demand, industrial catch-up of a latecomer country is determined by a strong interplay between demand and supply factors. We find that acquiring a superior production technology is not enough for the latecomer country to catch-up, unless there is a sufficiently large share of consumers who are aware of the quality of their products. This is even more relevant in markets where firms have a high degree of monopolistic power. For highly competitive markets, instead, the competition is mostly played on price. This implies that catch-up might be possible even for small cost advantage and for small share of aware consumers.

We also find that, for a set of conditions (such as high cost advantage or high initial shares of aware consumers), catch-up will occur independently from the dynamics of entry and exit of firms or the dynamics of diffusion of information among consumers, as well as independently from the initial number of firms from the catch-up country. However, if these conditions do not hold, it is still possible for the latecomer country to catch-up. In this case dynamics play a crucial role into determining whether catch-up will occur.

The content of the paper is organized as follows: section 2 details the baseline model, first in its static characteristics, when there are only firms from the leading country, then in its dynamics, triggered by the entry of pioneering firms from the catch-up country. In section 3 two simulations are displayed to show the model dynamics and outcomes. In section 4 we derive analytically a simple catch-up condition, which is independent of dynamics. In section 5 we discuss catch-up when it depends on the dynamics of entry, exit and the evolution of demand. In section 6, we briefly discuss the planned extensions of the model. Lastly, in chapters 7 one can find the conclusions.

2 Baseline Model

2.1 The Status Quo

At beginning the model is entirely static. The world market of a particular industry has been long dominated by firms of one country, which will be named country L (leader). To construct a static model that describes the situation of the industry before the entry of firms the catch-up country, we use the frame of monopolistic competition (Dixit and Stiglitz, 1977 and Krugman, 1979). All firms in this country use an homogeneous technology, freely available through imitation to all entrepreneurs in that country. The production uses only labor, but requires firms to incur in fixed costs. 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 outputs, while a and b are parameters of the model. It is highlighted that this particular technology implies increasing returns to scale. The nominal cost of labor (wage) is fixed: as the sector under analysis represents only a minor portion of the economy in country L, anything that happens in this sector does not have a perceivable effect on wages. The choice of consumers preference is a crucial one in this paper. A CES (constant elasticity of substitution) demand function is taken

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

Where P_k is price of the k variety, E is expenditure, the budget consumers in the world market allocate to the products of this sector (exogeneous in this model) and σ is the elasticity of substitution. The reasons to choose a CES demand are many. First, it allows the coexistence of firms with different efficiency. Consumers with CES preferences perceive a qualitative difference among goods produced by different firms and are willing to spend a positive amount of their budget also on more expensive goods. The coexistence of different types of firms is important when companies from the catch-up country will make their entry into the market. Second, it allows to build dynamics of entry and exit in an elegant and consistent way. Firms that deal with CES demand have a degree of monopolistic power, so they are able to set a price. This price (together with the prices set by other firms) determines the demand for each producer, a demand that clears the market. If a producer with a specific cost structure makes larger profits, it will not cannibalize the market in the next period, but new imitating firms will enter the market. Third, it allows to vary the parameter σ and analyse different market forms, from monopolistic (σ close to one) to highly competitive (σ goes to infinity). Back to the static model. 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, since each has a degree of monopolistic power. The price associated with the highest profit is

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

It is interesting to notice that the profit maximizing price is a mark-up on variable costs and that the mark-up depends on σ. For σ close to 1 (quasi-monopoly) firms can set sizable mark-ups. For instance, with σ=1.5, the price is three times the variable costs. For large σ (highly competitive sectors), only small margins can be made. If σ were equal to 101, firms would be making a

1% margin. On the long run this system can support a maximum number of firms

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

If n_L is lower than $\bar{n}_L$, the firms in the market will be making positive profits. It is assumed in this model that all entrepreneurs in country L have free access to the technology. New firms, subsequently, enter the market to take a portion of these profits. Evidently, the process continues until reaches the maximum sustained by the market, that is $\bar{n}_L$. In the opposite case (when n_L is greater than $\bar{n}_L$), negative profits would drive firms out of the market until the maximum capacity, $\bar{n}_L$, is reached.

2.2 New Entries

The situation described in section 2.1 is that of a market entirely dominated by firms in country L. Let us now imagine that in an other 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 the one of country L. To operationalize this, in this paper it is assumed that the two countries have identical wages ($w_L = w_F$), same fixed costs ($b_L = b_F$), but different variable costs, with $a_L \geq a_F$. This choice 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 equation 5). This implies that, whether the market is dominated by L or F, the maximum number of firms is the same. The production technology is then

$$l_j = a_F x_j + b \tag{6}$$

Where, compared to equation 1, the subscript of F has been removed (since we assumed no difference between L and F in this respect). The index j is used instead of i for firms in country F.

Next to an efficient production method, it is important to specify that the newly available technology of country F allows to produce goods of identical quality to those of country L. Aware consumers are indifferent about consuming 1 unit of goods produced in country L or 1 unit coming from country F. However a main point made in this paper is that consumers in the world markets are not aware, at this initial entry stage, of the quality of goods produced by country F. For this reasons, the vast majority of consumers in the world market are not considering products of country F as a possible purchase. Only a minority of pioneering consumers are aware of the quality of the good. Budget constraint is standardized to 1 for each consumer. If there are J aware consumers, we have that total demand for variety j of country F is

$$x_j = \frac{P_j^{-\sigma}}{\sum_{k\in L} P_k^{1-\sigma} + \sum_{h\in F} P_h^{1-\sigma}} J \tag{7}$$

Total demand for variety i of country L is

$$x_i = \frac{P_i^{-\sigma}}{\sum_{k\in L} P_k^{1-\sigma} + \sum_{h\in F} P_h^{1-\sigma}} J + \frac{P_i^{-\sigma}}{\sum_{k\in L} P_k^{1-\sigma}} (E - J) \tag{8}$$

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, that do not consider the goods of country F as a possible option in their basket. Firms in catch-up country F know that they possess a valid and potentially profitable technology. However they also know that the majority of the world market $(E - J)$ will not buy their product. Before the first firms from country F try to sell to international markets, it is not known how many consumers J exist. Thus, potential entrants face a high degree of uncertainty and they cannot predict whether they will be making positive profits by entering the market. In this paper, it is assumed that some potential entrants (pioneering firms) have a high risk propensity and attempt to enter the market in spite of the uncertainty.

2.3 Dynamics

The essence of this model is in the dynamics which originate from the setting presented in section 2.1 and 2.2. The starting point is that of section 2.1. The market is entirely dominated by L, with $n_L(t) = \bar{n}_L$ and $n_F(t) = 0$, for all $t < 0$. Then, at time $t = 0$, an exogeneous number of pioneers from the catch-up country $n_F(0)$ enters 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 of country F is described by the following differential equation

$$\dot{n}_F(t) = f(\pi_j(t)) \tag{9}$$

Where the LHS is the derivative of number of firms with respect to time, while the RHS is a function (f) of profits. In turn, profits of firm j are a function of $J(t)$, $n_L(t)$ and $n_F(t)$ (see section 4). At this stage, we impose little structure into the function f other than $f > 0, \forall \pi > 0$, $f = 0$ for $\pi = 0$ and $f < 0, \forall \pi < 0$. An analogous law of motion dictates entry and exit of firms from country L

$$\dot{n}_L(t) = f(\pi_i(t)) \tag{10}$$

Also profits of firm i depend on $J(t)$, $n_L(t)$ and $n_F(t)$. The same structure on f is imposed, in fact f is the same function, as in this model we treat entry and exit in the two country symmetrically. We notice that equations 9 and 10 are in substitution of the commonly used zero profit condition. This reflects our interest in the dynamics.

Last, but not least important, in the model of this paper also the number of aware consumers $J(t)$ changes over time. As the varieties of country F expand their presence in the world markets, more and more consumers become aware of their quality. For the model in this paper, the following endogeneous law of motion has been chosen.

$$\dot{J}(t) = g(n_F(t)) \tag{11}$$

The LHS is the derivative of the number of aware consumers with respect to time. This number grows over time according to the number of firms from country F in the market . This choice is derived from the assumption that a larger presence in the market translates into greater visibility, thus speeding up the process of diffusion of information. We notice, however, that we could have measured presence in other ways, such as with total output or sales of firms from country F. Fortunately, this choice has only a marginal impact on the model dynamics, as in a model of monopolistic competition firms choose a constant mark-up on variable costs and output per firm is bound by their monopolistic power. For this reason we opt for the simple specification in 11, which capture the link between presence and visibility, while keeping the model tractable. As with entry and exit dynamics, at this stage we do not impose a particular structure to the function g, other than $g > 0, \forall n_F(t) > 0$ and $g = 0$, for $n_F(t) = 0$. The asymmetry in this structure reflects the assumption that, once the information on the quality of products made in F has reached a consumer, he or she won't forget (moreover, it is meaningless to think about a negative number of firms). It is also worth to highlight that $J(t)$ cannot be greater than E, so there is a limit to how much it can grow.

Equations 9, 10 and 11 represent the core of the model. It is a system of nonlinear dynamic equations. We cannot solve the model in explicit form, for any given shape of f and g. For this reason, to analyze the properties of this dynamic model, we employ a mix of analytical tools and simulations. In the next section (section 3), two simulations are used to get an understanding of the dynamics of the model and its possible outcomes. In section 4, the profit function of firms from both countries are studied analytically in order to derive a simple, meaningful catch-up condition that is independent of dynamics. In section 5 we study catch-up when it is dependent on dynamics. For this we rely on both analytical tools and simulations.

3 Simulation Results

In this section the results of two distinct simulation runs will be displayed. The reason for which in this section only two simulation runs are shown is that the model has only two possible outcomes: in the first case, firms from the catch-up country fail to expand in the world market. The demand for their products, although is growing, is insufficient. Eventually all firms from the catch-up country that entered the market fail, and the market is once again entirely dominated by firms from the leading country. In the second case, catching-up occurs. The growth of demand generated by the pioneering firms is enough to eventually generate positive profits. New firms from the catch-up country enter the market, further increasing the demand for their products. Eventually the firms from the catch-up country take over the whole market. In brief

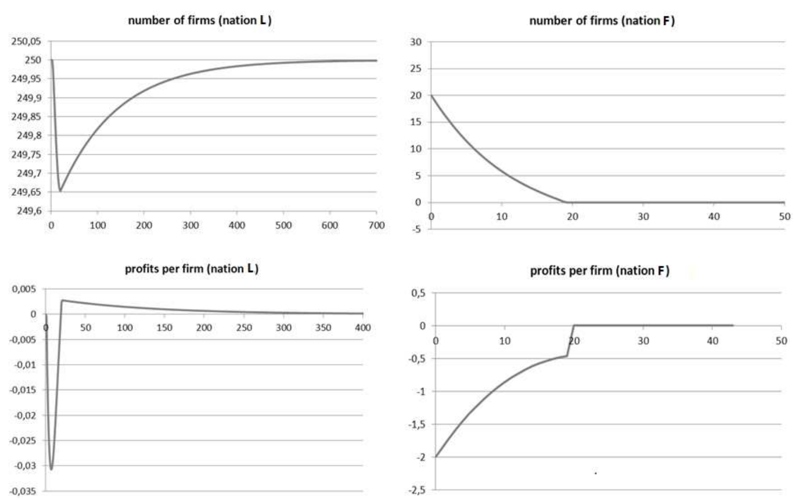
Proposition 1. *In the long run, the market is dominated either by the firms from country L, or by the firms of country F. Intermediate solutions are not possible.*

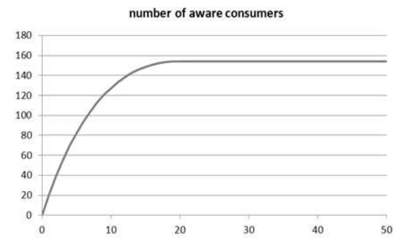
Proposition 1 is proven in the appendix. Since there are only two long run outcomes possible, two simulation runs are sufficient for the aim of the current section of providing and understanding of the working of the model. More simulations are explored in a later section of the paper.

3.1 Catch-up Does Not Occur

The first simulation shows a case in which catch-up does not occur. Figure 1 reports the evolution over time of five important indicators: number of firms in country L, number of firms in country F, profits of firms from L, profits of firms from F and, lastly, number of aware consumers. The horizontal axis for all five indicators represents time, which is in discrete steps in the simulation. In the bottom-right corner of the figure, one can find the values of the parameters used in the simulation. We notice that, for the simulations, a choice of a functional form for equations 9, 10 and 11 had to be made. In the runs of this section, we use $\dot{n}_F(t) = \alpha\pi_j(t)$, $\dot{n}_L(t) = \alpha\pi_i(t)$ and $\dot{J}(t) = \beta n_F(t)$ respectively.

Figure 1. *Simulation 1: catch-up does not occur*





Parameters' values

$E = 1000$	$\alpha = \beta = 1$
$\overline{n} = 250$	$w = 2$
$J(0) = 1$	$b = 1$
$n_F(0) = 20$	$a_L = 2.5$
$\sigma = 2$	$a_F = 0.5$

The story of this simulation goes as follows: initially nation L is the undisputed market leader. The demand can sustain 250 firms, all of which at this moment come from L. Then, 20 pioneering firms from country F attempt to enter the market. These pioneering firms are very efficient, their variable costs are five times smaller than those of firms in country L. Yet, the reputation of firms from F is very limited, and so it is the demand for their products. In this simulation, there is only 1 pioneering consumer out of a 1000, that is only 1 consumer is willing to buy the products of country F, at time 0. For this reason, the 20 pioneering firms are making losses at time 0, and some of them start to exit the market. In the subsequent periods, the number of firms from F keeps decreasing. However, because of their presence in the market, the number of aware consumers is rapidly growing. The sales of firms from nation F are getting better, and so are the profits, which - albeit still with negative sign - are rapidly approaching positive values. In this simulation, however, these rapid improvements are not sufficient to guarantee the survival of firms from F, the catch-up country. Once the last of the 20 pioneering firms fails (around $t = 20$), firms from F are still making negative profits. At this point, and from this point onward, the number of firms from country F is zero, as zero is the profit made by these firms (since they are no longer in the market). Without firms from F selling their product, the number of aware consumers stops its growth. In this simulation, it happens when only around 15% of consumers are aware of the quality of goods produced by country F.

It is clear from this simulation that sectoral catch-up may fail to occur, even when the catch-up country masters a better technology than the leader.

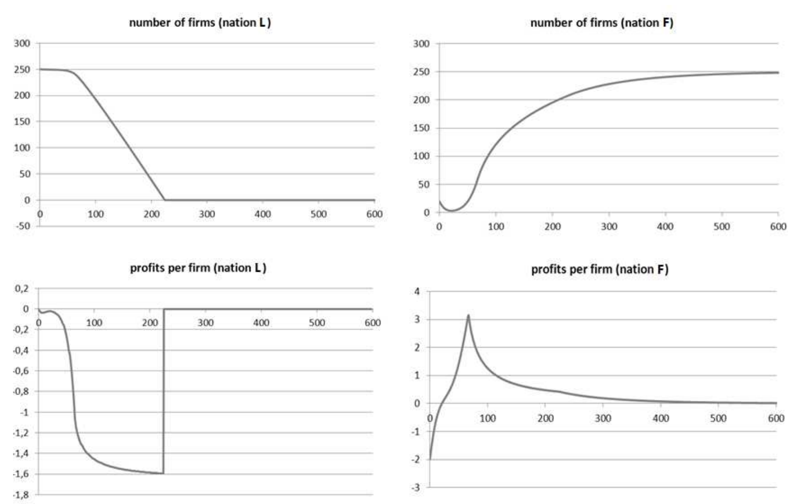
The last remarks concerning this simulation are about firms from country L, the leader. With the entry of firms from F, also firms from country L make negative profits and start exiting the market. However, by the time the last of firms of pioneering firms from country F failed, there are still more than 249 firms from L. These firms, at this point, start operating at profit again. Their number, then, slowly grows again until the original maximum number of firms (250) is reestablished.

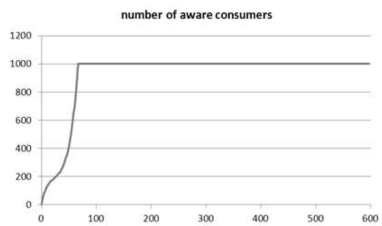
3.2 Catch-up Occurs

In the second simulation in this section, firms from nation F manage to catch-up and take over the whole market. Figure 2 provides a graphical display. For this experiment, the same values from simulation 1 in section 3.1 are used, with the exception of a_L the variable costs of firms in country L, which are set to 3,

hence 6 times higher than those of country F (in simulation 1 they were 5 times higher).
As in simulation 1, at the beginning the market is saturated by 250 firms from country L. Then, at $t = 0$, 20 pioneering firms from country F enter the market. Initially they make negative profits, and their number starts declining. At the same time, though, the number of aware consumers grows, gradually increasing the profits of the pioneering firms. Unlike in simulation 1, this time the profits become positive before the last firm from F exits the market, which means that $n_F(t)$, the number firms from F, can grow again. This is a turning point in the model. As $n_F(t)$ grows, the number of aware consumers grows even faster, eventually reaching 100% of the market. As the number of aware consumers grows, the profits of firms from country L sharply decline. These firms sell products of equal quality to those from F for 6 times the price. Thus, as the knowledge of the quality of products from F diffuses, more and more consumers shift their purchasing habits in favor of the catch-up country. The presence of companies from L declines steadily until none of them remains in the market (in the simulation, around period 200). At this point there are only firms from F, which have not saturated the market yet. Since the whole consumer base has been informed (in $t = 67$), profits are no longer growing. They are, nonetheless, still positive. Entry continues until the number of firms from the catch-up country reaches the maximum supported by the market (250 in this simulation). In this experiment we notice that catching up is possible even if initially there are a very limited number of pioneering consumers (0.1% in the simulation).
Naturally, a follow up question of great interest is: under which circumstances catching up occurs and under which it does not? Section 4 and 5 dedicated to this question.

Figure 2. *Simulation 2: catch-up occurs*





Parameters' values

$E = 1000$	$\alpha = \beta = 1$
$\overline{n} = 250$	$w = 2$
$J(0) = 1$	$b = 1$
$n_F(0) = 20$	$a_L = 3$
$\sigma = 2$	$a_F = 0.5$

4 Catch-up Condition

The model presented in this paper, as briefly discussed in section 2, cannot be solved in explicit form, for any given shape of f and g; that is we cannot find a way to express which value will be assumed by (say) n_F at any given t, unless a simulation is run. Notwithstanding, it is possible to derive analytical results of great interest. In fact, it is possible to derive results that are independent of the dynamic component of the model and, hence, they can be obtained without solving the system of differential equations in explicit form. This concept of independence of dynamics is rather relevant here and we wish to define it carefully.

Definition 1. *Take a model with N variables x_n and M dynamic functions $f_m(\boldsymbol{x})$. We say that a proposition is independent of dynamics (i.o.d.) if its validity does not rely on the specific functional form of the dynamic functions, but only on the sign of $f_m(\boldsymbol{x})$ in different regions of the domain of $\boldsymbol{x}$.*

The intuition behind this definition is that, under some conditions, the conclusions of the model (on whether country F manages to catch-up) depends on how fast is entry and exit of new firms, compared to the speed of diffusion of information among consumers. Under some other conditions, instead, catch-up is independent of the relative speed dictated by the dynamic functions, but only depends on whether profit implies entry, loss implies exit and presence implies information diffusion. In fact, in the model of this paper there are three main dynamic functions: 9, 10 and 11. All three have been written without specifying a functional form. All we need to know, for a result to be *i.o.d.*, is that: in 9 and 10 the function f is positive if profits of firms in F and L (respectively) are positive; f is zero if profits are zero and f is negative if profits are negative. Similarly, in 11, the function g is positive if number of firms from F is positive and it is zero otherwise. Given this definition, we can get interesting results that are *i.o.d.* by analyzing the profit function of firms in country F and L.

4.1 Profit Functions

In this section we derive the profit functions of firms in both countries. The profits of firms from L are

$$\pi_i = (P_i - wa_L)[\frac{P_i^{-\sigma}}{\sum_{k\in L} P_k^{1-\sigma} + \sum_{h\in F} P_h^{1-\sigma}} J + \frac{P_i^{-\sigma}}{\sum_{k\in L} P_k^{1-\sigma}} (E - J)] - wb \quad (12)$$

While profits in country F are

$$\pi_j = (P_j - wa_F)(\frac{P_j^{-\sigma}}{\sum_{k\in L} P_k^{1-\sigma} + \sum_{h\in F} P_h^{1-\sigma}}) J - wb \quad (13)$$

There is a number of substitutions we can apply to both profit equations. First, as shown in equation 4, the price chosen by a profit-maximizing firm can be expressed in terms of few model's parameters. Second - given that all firms from L are identical to each other and the same goes for firm from F - firms in L choose the same price as P_i, while those in F choose the same as P_j. Third, as $P_i = P_k$, $\forall k$ and $P_j = P_h$, $\forall h$, it follows that we can substitute the sums ($\sum_{k\in L}$ and $\sum_{h\in F}$) with n_L and n_F. Fourth, to simplify the notation we define $r = a_L/a_F$. Lastly, it is convenient to explicitly differentiate parameters from variables that evolve over time. After these substitutions and some rearrangements, we have that profits of firm i from L are

$$\pi_i(t) = \frac{n_L(t)Er^{1-\sigma} + n_F(t)[E - J(t)] - n_L(t)^2 wbr^{1-\sigma} - n_L(t)n_F(t)wb\sigma}{n_L(t)^2 r^{1-\sigma}\sigma + n_L(t)n_F(t)\sigma} \quad (14)$$

While profits of firm j from F are

$$\pi_j(t) = \frac{J(t) - n_F(t)wb\sigma - n_L(t)wbr^{1-\sigma}\sigma}{n_F(t)\sigma + n_L(t)r^{1-\sigma}\sigma} \quad (15)$$

There is a great deal of information that we can extract from the profit functions. In this section, we aim to focus uniquely on conclusions we can reach without specifying the functional forms of equations 9, 10 and 11 (that are i.o.d.). We can however employ the simple structure we imposed on these equations. In essence: $J(t)$ grows if there are firms of F in the market, $n_F(t)$ grows if profits of firms from F are positive and $n_L(t)$ grows if firms from L make positive profits. The situation is rather straightforward with respect to the evolution of $J(t)$. At $t = 0$ there is a positive number of aware consumers $J(0)$. Also $n_F(0)$ is positive, hence $J(t)$ grows. This happens for as long as the model reaches one of the two possible solutions (either F takes over or cath-up fails) We, therefore, focus on when firms in different countries make positive profits.

We notice that the denominators of both 14 and 15 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

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

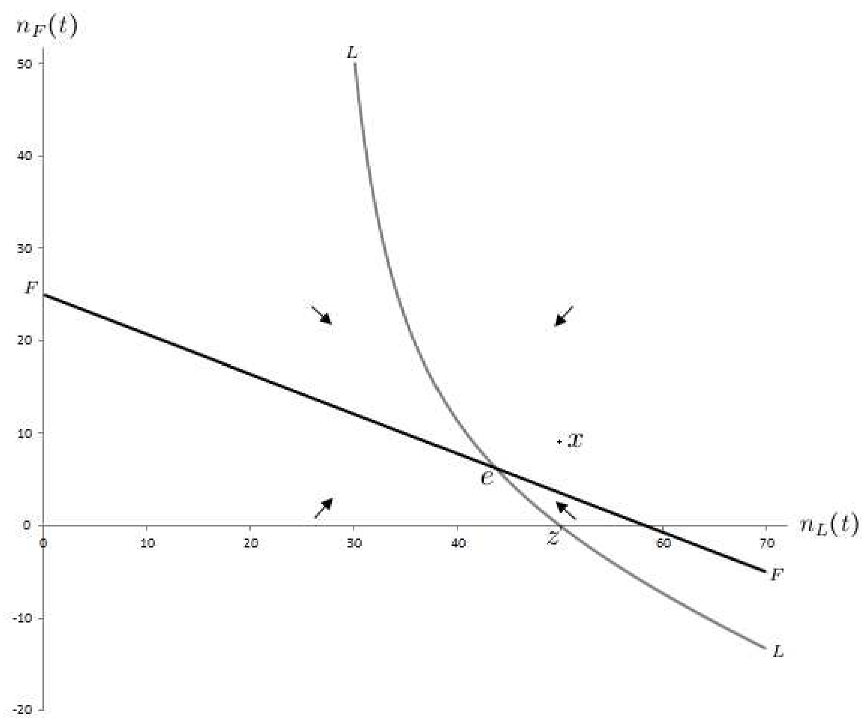
The positive profit condition for firms in F is

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

4.2 Catch-up Condition

The best way to grasp how the model evolves over time is graphically. Let us build a graph that capture the model in a static specific time (say $t = t^*$). At this time t^*, there are be $J(t^*)$ 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 lines of zero profit (zero profit loci) taken from equations 16 and 17.

Figure 3. *Zero profit loci. Graphical representation of dynamics*



The point x represents the number of firms of 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 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 profits and n_F grows, while they make a loss and decline in number if x is above FF. The direction in which the point x will move over time is indicated by the arrows in the graph. It is easy to see that the intersection between FF and LL (point e in

the graph) is an attractor towards which x is moving. In figure 3, the attractor is found in a region, in which both firms from L and F can exist. Nonetheless it is possible to come up with another set of parameters (and a value for $J(t^*)$) such that the attractor would be found below the $n_L(t)$-axis, a region where only firms from L can survive.
This would be all we needed to know to determine whether catch-up occurs in case $J(t)$ were not a dynamic variable. Since $J(t)$ evolves over time and equations 16 and 17 depend on $J(t)$, the two curves, LL and FF, are shifting, as $J(t)$ grows. Subsequently also the attractor (the point of interesection of the two curves) is shifting. The question we then ask is: how does the attractor shift, when $J(t)$ grows?
It turns out that we can answer to this question precisely. It is sufficient to solve (for n_L and n_F) equations 16 and 17 to find the coordinates of the attractor $n_L(t)^e$ and $n_F(t)^e$

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

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

On the evolution of $J(t)$, we said that it can either grow or stay constant. Since the sign of $J(t)$ is negative in 18 and positive in 19, the only direction the attractor can move is North-West (with more firms from F and less from L). This insight allows us to identify a sufficient condition for catch-up. In fact if the attractor is above the $n_L(t)$-axis, it does not matter whether firms from F are making losses initially. They are eventually caught by the attractor, which will then shift North-West over time until the whole market is dominated by country F. To find the expression of this catch-up condition, we just need to impose that $n_F(t)^e > 0$. This leads to the following simple condition

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

The expression in 20 captures the essence of the claim of this paper: catch-up is a process that happens both on the demand side and on the supply side. If firms in country F make an effort to improve their production technology, the RHS of 20 decreases, making more likely that catch-up occurs (we recall that $r = a_L/a_F$). On the other hand, this may prove insufficient if LHS is not large enough. This depends on the share of consumers in the world market that are aware of the quality of product coming from country F.
An important clarification is in order. The condition in 20 is both a sufficient and a necessary condition for catch-up to occur. It implies that if at a certain $t = t^*$ condition 20 applies, then catch-up will occur in the model. However, if at time $t = t^*$ condition 20 does not apply, it could still be that at time $t = \tilde{t}$, with $\tilde{t} > t^*$, $n_F(\tilde{t})^e > 0$ (and catch-up occurs).

Proposition 2. *If at any time in the model, the share of aware consumers becomes greater than* $r^{1-\sigma}$*, the firms from the catch-up country* F *will eventually dominate the entire market. This is both a necessary and sufficient condition and it is i.o.d.*

The proposition is proven in the appendix. As we said, the condition applies for all t. In the particular case where the condition is valid at the time of entry ($t = 0$), the outcome of the whole model can be assessed without ever specifying the form of the three dynamic functions 9, 10 and 11. Conversely, if in $t = 0$ the condition does not apply, we then need to define how the dynamics unfold to determine whether catch-up will occur (that is whether at some point $t > 0$ the condition will apply). The fact that the expression in 20 represents a necessary and sufficient condition for catch-up allows us also to extract some other interesting conclusions. First we notice that, in the limit case, $J(t) = E$. It implies that r must be greater than 1 for catch-up to occur, that is the latecomer country must have a cost advantage to catch-up. Second, 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 a large share of aware consumers is more important for catch-up. On the other hand for high values of σ - when firms compete mostly on price - a smaller share of aware consumers is required to trigger the catch-up process. This suggests that the demand side of catch-up holds higher relevance for many traditional sectors, where not only the cost advantage is less relevant (since demand is often highly critical, the cost advantage are attenuated by low σ), but also the rate of change of the production technology (here captured by r) is very low.

5 Dynamics and Initial Conditions

As we said in the previous section, in case the condition in 20 does not apply at $t = 0$ we cannot say whether firms from country F are able to catch-up unless we define a specific form for the dynamic functions 9, 10 and 11. In this section we analyze this case. We highlight that according to the arguments we proposed in this paper to motivate the model, this case is not a peculiar one, but it is very likely to be what happens in many instances of sectoral catch-up. In fact, if it is true that consumers in the world markets need to become aware of the quality of products made in country F before considering to include them in the consumption basket, the value of $J(t)$ at $t = 0$ is expected to be very low. This in turn makes it more likely that the condition in 20 does not hold.
The issue with introducing a functional form and analyzing the dynamics is that the model becomes intractable, if one wishes to have functions with credible shapes, even if rather simple ones. We deal with this problem in the following way. We first use (in section 5.1) an extremely simple set of functional shapes that allow us to have analytical solution. These functions can be justified, as they capture the essence of the dynamics. Nevertheless they clearly are an over-simplification of how the dynamics are expected to look like. To overcome this,

we then use (in section 5.2) more realistic dynamic functions. A set of simulations gives us suggestive evidence that the analytical results obtained with the simple functions can be extended to more realistic ones.

5.1 Simple Dynamic Functions and Analytical Results

We now define the following simple dynamic functions. The law of motion for firms from country F is

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

Equivalently, for country L we have

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

As for the diffusion of information among consumers on the quality of goods from F we write

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

Even with these simple dynamic equations, a few steps are required to reach useful conclusions. Hereafter we are going to enunciate these steps in an intuitive manner. In the appendix we are going to prove our statements rigorously. First, we need to know that if the condition in 20 does not apply in $t = 0$, then firms from F are making negative profits. This is because the number of firms from L is given in $t = 0$ ($n_L(0) = E/wb\sigma$). 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. (See figure 6 in the appendix, where $n_L(0) = E/wb\sigma$ is given at the intersection between the LL line and the $n_L(t)$-axis. The point x lies above the FF line and firms from F make negative profits). The number of firms in F then decline as follows

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

Where the above equation is the explicit form of 21. This dynamic happens until either all firms from F are out of the market or profits are made. For as long as $n_F(t)$ is positive, Then $J(t)$ grows

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

Next, the dynamics of the model dictate that both the attractor $e(n_L(t)^e, n_F(t)^e)$ and the number of firms $x(n_L(t), n_F(t))$ are going to cross the $n_L(t)$-axis, in the exact same point (that is point z in figure 3, which has coordinates $(E/wb\sigma, 0)$). This implies that to assess whether catch-up occurs, we just need to derive what

gets to the zero first: if the attractor is in positive territory before $n_F(t)$ becomes zero, then the condition in 20 applies and catch-up occurs. Conversely, if $n_F(t)$ goes to zero before the attractor becomes positive, catch-up fails.
The attractor e reaches zero 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 catch-up 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 substituted E with $n_L(0)wb\sigma$. This is to have an expression where all three initial conditions ($n_L(0)$,$n_F(0)$ and $J(0)$) are made explicit. We highlight though that $n_L(0)$ is not a free variable in this model, it depends on the size of the market E and other parameters.

Proposition 3. *If at time zero, the share of aware consumers is smaller than $r^{1-\sigma}$, catch-up is still possible, but dynamic dependent. It depends on the speed of entry and exit of firms (α), on the speed of diffusion of information (β) and on the initial conditions of the dynamic system ($n_L(0)$,$n_F(0)$ and $J(0)$).*

The larger the speed of diffusion of information β, the easier it is for country F to catch-up. Given that to catch-up the attractor needs to become positive before all firms from F exit the market, the speed of entry and exit α works against catch-up: slow exit rate gives more time to firms from F to reach a point, in which the share of aware consumers is high enough to enable catch-up. Even though $n_L(0)$ is not a free variable, we can see that for large values of it (hence, for large size of the market) catch-up 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 chances that the expression in 28 holds are higher.

5.2 Realistic Dynamic Functions and Simulation Results

In this section, we want to get a sense that the results we obtained using the simple dynamic functions in 21, 22 and 23 are also valid for more realistic functional shapes. As discussed, by increasing even marginally the complexity of dynamics, the model becomes intractable. We, therefore, rely on simulation methods.
We first define the three dynamic functions.

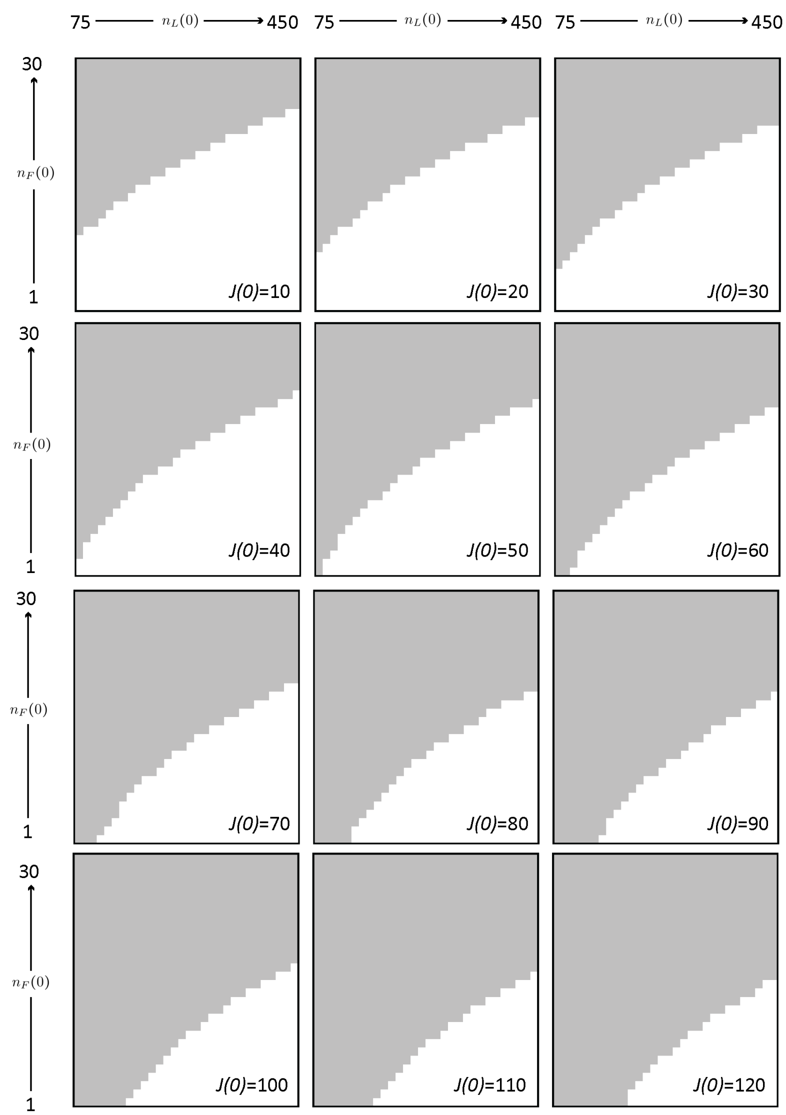
$$\dot{n}_F(t) = \alpha\pi_j(t) \tag{29}$$

$$\dot{n}_L(t) = \alpha \pi_i(t) \tag{30}$$

$$\dot{J}(t) = \beta n_F(t) \tag{31}$$

With these simulations we wish to understand the sensitivity of the model to the initial conditions $n_L(0)$,$n_F(0)$ and $J(0)$, to see whether they are in line with the results obtained analytically in section 5.1.

Figure 4. *Simulations for different initial values $n_F(0)$, $n_L(0)$ and $J(0)$.*



A total of 10800 simulations are run where $n_L(0)$ is varied between 75 and 450 at discrete intervals of 12.5, $n_F(0)$ is varied between 1 and 30 at intervals of 1, while $J(0)$ is changed twelve times between 10 and 120. It is worth to take note that $n_L(0)$ is not allowed to change entirely freely in the model, since, at $t = 0$, it must be that firms from L saturate the market (equation 5). In order to experiment with variation of $n_L(0)$, the total number of consumers in the world market (E) is varied. With respect to the choice of the other parameters, we use the same selection as in section 3

Simulations may run for several periods during which a number of firms from L and F coexist, but, ultimately, the simulation reaches one of the two only possible outcomes of the model: catching up occurs and firms from F have 100% of the market or catching up does not occur and no firms from F have survived. In figure 4 a dark pixel is assigned in the first case (catch up), while a white pixel in the second one (no catch-up).

The simulations give a clear indication that catch-up is more likely to occur for larger values of $n_F(0)$ and $J(0)$. They also suggest that a large market (hence large $n_L(0)$) may prevent catch-up. These conclusions are perfectly in line with the analytical ones of section 5.1.

6 Extensions

In this working paper we presented a model that captures the role of the interactions between demand and supply factors on industrial catch-up. The model was kept as simple as possible to describe the essence of the dynamics of catch-up, when demand plays an important role. We are, however, working on a number of extensions that are meant to allow for increasing complexity. These extensions will be included in future versions of this paper and are briefly described hereafter.

In a first extension of the model we make technology also a dynamic variable. It is assumed that the production process is characterized by economies of experience (learning by doing): the costs of production are a decreasing function of the time a firm is in the market. In this way we can model the challenges of the latecomer to acquire a cost-efficient production technology and deepen out understanding on how the supply side and the demand side of the story of catch-up interrelate with one another. In this extended model we can also analyze and discuss how the catch-up in different sectors is affected by supply and demand factors, by looking at how fast consumers adopt new products relatively to how quickly producers can climb the learning curve.

In a second extension, the model is made more complex by fully endogenizing the changes over time of demand and technology. In this model, the evolution of two key variables (1) number of aware consumers and (2) costs of production depends on investment choices of firms in the catch-up country. If a firm decides to invest its profits in marketing, it will benefit form a larger demand base in the following period. If it chooses to invest in technology, the average production cost will decrease. This analysis brings to the fore a discussion on local spillovers. It is an explicit assumption of the model we propose (in all its variations) that technology within each country is freely available to all imitators: a potential entrepreneur in the catch-up country cannot imitate the technology of the leader, but it can use the same technology of other firms in her country. Similarly, also demand is subject to local spillovers. If a number of consumers have discovered that the products of the catch-up country meet their taste, a new entrepreneur does not have to start from scratch to create a base of consumers (think for instance of a new wine producer in Chile). Local spillovers in both demand and supply have important consequences for a model that wants to analyze investment decision.

In a third extension, we explore the role of internal demand. The market of the sector is split into three different segments. One is constituted by demand of consumers in the developed country, another one by demand in the catch-up country, while a third one by that in the rest of the world. While local demand is biased towards local produce, international markets are neutral in this respect and an important part of competition is played in these markets. The catch-up country, in this instance, can benefit from the protection of local consumers, a protection that can assure a longer survival in the market. This in turn can provide sufficient time to improve firms efficiency (through learning by doing) or increase their demand (by broadening the consumers base) in the world markets.

The addition of local demand is a trigger for the closing layer of complexity. In this section we make an attempt to endogenize demand to see if it can add something meaningful to the model. This final step requires two key additions to the model. First, what is consumed locally depends on wages and profits made by workers and firms respectively. It is implied that the larger the wage, the larger the local demand, but also the larger the cost of local production. Second, it would been strikingly at odds with our intent of studying sectoral catch-up if we let the wages being entirely determined by the catch-up sector. To make the model credible, it is necessary to include the remainder of the economy. This could be done, for instance, by simply including a perfectly competitive non-tradable sector.

7 Conclusions

In line with the observations of authors such as Mathews (2005), Adner (2002), Malerba (2006) Lee and Jeehoon (2011), this paper focuses on the role played by changing demand in sectoral catch-up. It is argued that the firms from the latecomer country, even if they learned an efficient production technology, may face insufficient demand. This is because reaching a sizable consumer base does not happen overnight. The new products introduced in the market by a latecomer country need to be discovered by consumers, who are initially unaware of the quality of these varieties. Only a small portion of pioneering consumers are willing to try the new varieties from the latecomer country initially. If it is the case that these new products meet consumers' needs, then - with time

- more and more consumers become willing to include these products in their consumption basket. However, the time it takes to increase the consumer base may be highly detrimental for the latecomer country and contribute to failure of the catch-up process.

The model proposed in this paper is aimed at shading light on these dynamics of catch-up. We show that the the dynamics of diffusion of awareness to consumers in the world markers make catch-up a process, whose success is determined by a strong interplay by supply and demand factors. Both large cost advantage and large consumer base are required to catch-up. The analytical results suggest that - to some extent - one advantage can compensate for the other. However this largely depends on the sector: when the products of a sector are imperfect substitutes, the monopolistic power of firms mitigates the benefits of cost efficiency.

Another interesting conclusion of the model is on dynamics. We show that for an adequately large consumer base, as well as a sufficient cost advantage, catch-up happens independently of dynamics. The insight is that as long as imitating firms entry and exit according to the profits made - and as long as the consumers' awareness grows over timer - there is a set of conditions for which catch-up is unavoidable. Contrariwise, if these conditions do not apply, the occurrence of catch-up depends on how the dynamics unfold. More precisely, it depends on how fast firms fail when they operate with losses and on how fast the consumer base expands over time.

The findings of this paper have immediate policy repercussions. The model shows that catch-up cannot occur if the latecomer is not more efficient than the incumbent. This implies that policies aimed at learning a valid and efficient production process are necessary. However, to facilitate catch-up, an excessive focus on the supply side of the catch-up dynamics may be misguided. An effective policy package should also include measures that help latecomer firms to build a collective reputation. Institutions that foster coordination among firms and promote branding and marketing efforts are examples of policy measures that can facilitate catch-up. For instance, in the history of the wine industry such institutions played a prominent role in catch-up, with initiative such as Brand Australia, Australian Wine and Brandy Corporation, South African Wine and Brandy Corporation and Vinos de Chile (Morrison and Rabellotti, 2013).

A mixed policy package that tackles both the supply side and the demand side of the catch-up process could also use our model's results to be better tailored to the targeted sector. This paper, in fact, also highlights that the demand side is all the more important for sectors in which firms have high degree of monopolistic power as well as relatively accessible and slowly changing technology of production.

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Appendix - Proof of Propositions

Proposition 1. *In the long run, the market is dominated either by the firms from country L, or by the firms of country F. Intermediate solutions are not possible.*

Proof. Whenever there are firms from F in the market, $J(t)$ is growing. It follows that to have stable coexistence in the long run J must equal E (the upper limit of J) and profits must be zero for both types of firms. In this case, firms from L make zero profits if

$$n_F(t) = \frac{E}{\sigma wb} r^{1-\sigma} - r^{1-\sigma} n_L(t) \tag{32}$$

Firms from F, instead, make zero profit if

$$n_F(t) = \frac{E}{\sigma wb} - r^{1-\sigma} n_L(t) \tag{33}$$

Since the two linear functions are parallel, the two only possible solutions are: $n_F(t) = 0$ and $n_L(t) = E/\sigma wb$ or $n_L(t) = 0$ and $n_F(t) = E/\sigma wb$. These solutions are possible because firms that are not in the market make zero profit. ■

Proposition 2. *If at any time in the model, the share of aware consumers becomes greater than $r^{1-\sigma}$, the firms from the catch-up country F will eventually dominate the entire market. This is both a necessary and sufficient condition and it is i.o.d.*

Proof. The proof is in three parts. First we prove that if the attractor e is above the $n_L(t)$-axis, it remains above. This is easily done (and was also shown in the text). The attractor has the following coordinates.

$$n_L(t)^e = -\frac{J(t)}{wb\sigma}\frac{1}{1-r^{1-\sigma}} + \frac{E}{wb\sigma}\frac{1}{1-r^{1-\sigma}} \tag{34}$$

$$n_F(t)^e = \frac{J(t)}{wb\sigma}\frac{1}{1-r^{1-\sigma}} - \frac{E}{wb\sigma}\frac{r^{1-\sigma}}{1-r^{1-\sigma}} \tag{35}$$

Since by the model assumptions we have that

$$\frac{\partial J(t)}{\partial t} \geq 0 \tag{36}$$

then we have that

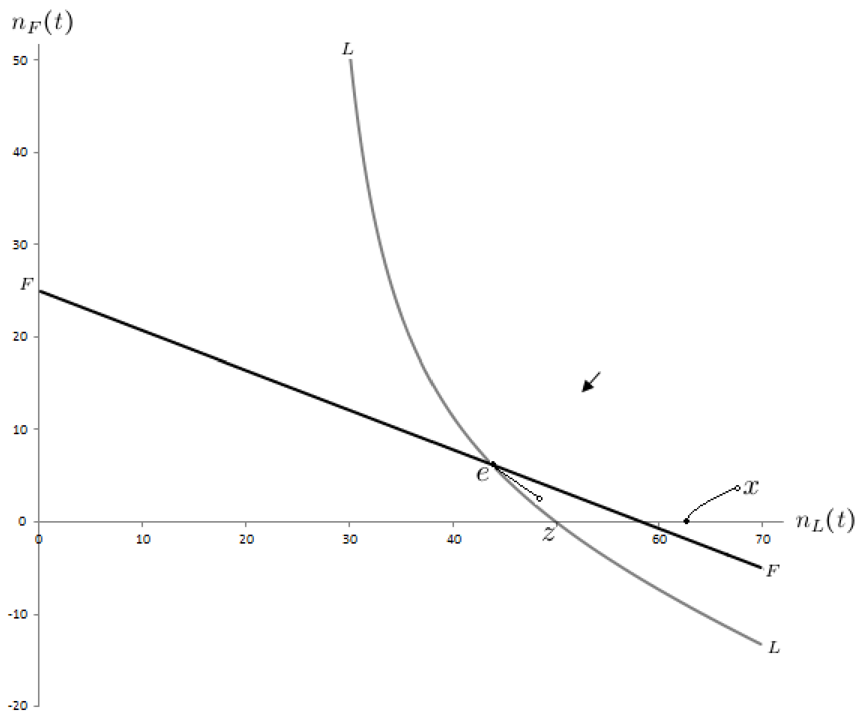
$$\frac{\partial n_L(t)^e}{\partial t} \leq 0 \tag{37}$$

$$\frac{\partial n_F(t)^e}{\partial t} \geq 0 \tag{38}$$

The graphical intuition is that the 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 the attractor e is above the $n_L(t)$-axis, then the point x will eventually be caught by it. This may seem intuitive, but we need to rule out one possibility, which we illustrate in figure 5. In this graph we show a potential evolution over time of the points x and e. The empty dot represents the position of the point at the beginning. The solid dot the position at the end. The line that links them the path they take.

Figure 5. *The evolution of x and e in time*



It can be seen that, in this case, the attractor e is above the $n_L(t)$-axis at the beginning of the period. Yet, x intersects $n_L(t)$-axis (hence $n_F(t)$ goes to zero) before it gets caught by the attractor e.
We prove here that this cannot happen in the model. In fact, $n_L(t)$ cannot ever 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

$$n_F(t) < \frac{n_L(t)Er^{1-\sigma} - n_L(t)^2 wbr^{1-\sigma}\sigma}{J(t) - E + n_L(t)wb\sigma} \tag{39}$$

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

$$n_F(t) < 0 \tag{40}$$

Given that $n_F(t) \geq 0$ this condition is never verified, $n_L(t)$ never exceeds $E/wb\sigma$.

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

$$\frac{J(t)}{wb\sigma} - n_L(t)r^{1-\sigma} \geq 0 \tag{41}$$

which we can write as

$$\frac{1}{r^{1-\sigma}}\frac{J}{wb\sigma} \geq n_L(t) \tag{42}$$

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

$$\frac{E}{wb\sigma} \geq n_L(t) \tag{43}$$

It follows that - since we have shown that $n_L(t)$ cannot be greater than $E/wb\sigma$ - the FF line is always above the $n_L(t)$-axis. In sum, for feasible values of $n_L(t)$, if e is above the $n_L(t)$-axis, also the FF line is positive, and $n_F(t)$ cannot get to zero without encountering the FF line.

We clarify this point. With all the conditions above holding, either the point x is below FF and $n_F(t)$ grows until is caught by the attractor e, or the point x is above FF, in which case FF is between x and the $n_L(t)$-axis. Unavoidably x will decrease until it touches FF and then move towards the attractor.

The third and last step of the proof is the easiest. We have shown that if e is above the $n_L(t)$-axis, x is moving towards it. To finish the proof we only need to show the final position of e.

We know that now there are firms from F in the market, as x is above the $n_L(t)$-axis. Hence $J(t)$ is growing 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

$$n_L(t)^e = 0, n_F(t)^e = E/wb\sigma \tag{44}$$

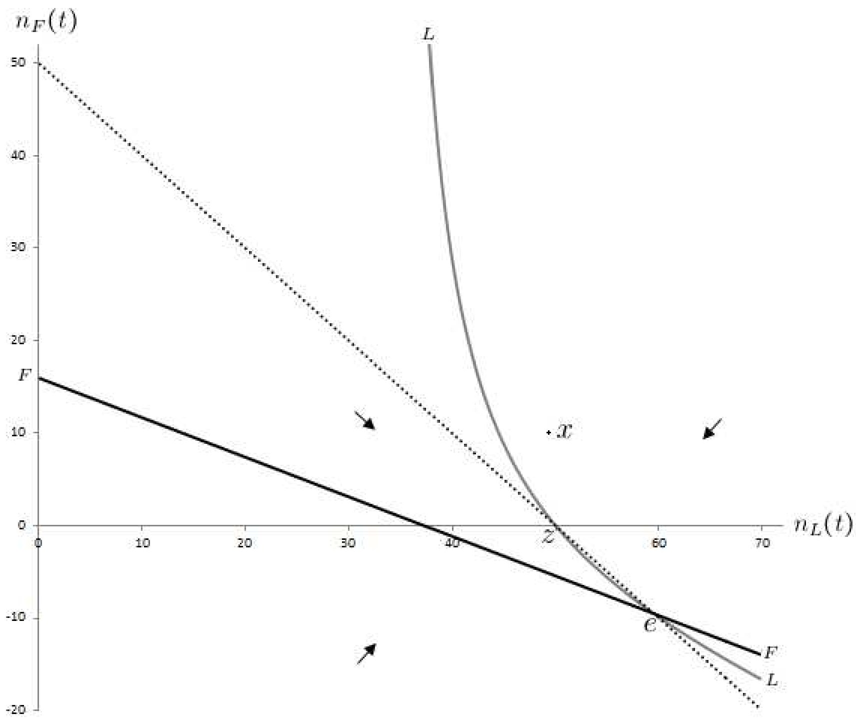
When all consumers are eventually informed, the market is entirely dominated by firms in the catch-up country.

■

Proposition 3. *If at time zero, the share of aware consumers is smaller than $r^{1-\sigma}$, catch-up is still possible, but dynamic dependent. It depends on the speed of entry and exit of firms (α), on the speed of diffusion of information (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 $r^{1-\sigma}$, it means that the point e is below the $n_L(t)$-axis, as illustrated in figure 6

Figure 6. *Zero profit loci if* $J(0)/E < r^{1-\sigma}$



The proof is in three parts. We first show that if catch-up does not occur, the point x crosses the $n_L(t)$-axis at the point z. Then we show that if catch-up occurs, The point e crosses the $n_L(t)$-axis at the point z. Finally we identify the catch-up condition in proposition 3 by imposing that e overlaps with z before x does.

First. Firms from both countries are operating at losses and the point x moves South-West. In fact, the point x in $t = 0$ has coordinates $(E/wb\sigma, n_F(0))$, which - with $n_F(0) > 0$ by assumption - always lies above both the LL and FF curve. This can also be seen algebraically substituting $n_L(t) = E/wb\sigma$ in the functions of LL and FF (see the expressions in 16 and 17).

The graph in figure 6 also reveals that it is impossible for the point x to cross the $n_L(t)$-axis without intersecting first the LL line. More rigorously. We have just shown the x at $t = 0$ is above the LL line as well as the FF line. In the previous proof we have shown that the number of firms from L cannot be larger than $E/wb\sigma$ (it cannot be to the right of point z). Then it can be verified, using the expression in 16 that the LL curve always intersect the $n_L(t)$-axis always in the same point, where $n_L(t) = E/wb\sigma$ (z is always the same). As the point x moves South-West (fewer firms from both F and L) - given that FF is below LL for $n_L(t) > 0$, $n_F(t) > 0$ and $n_L(t)^e < 0$ - the first intersection that point x experiences is with the LL line.

Once x is on the LL line (and the point e is still below the $n_L(t)$-axis), the number of firms from F keeps decreasing. The number of firms from L - instead receives opposing push from the two sides of the LL line. It implies that the point x will start moving down, towards the $n_L(t)$-axis, following the LL line. This process necessary continues until either x also crosses the $n_L(t)$-axis or x crosses the FF line. If x crosses first the $n_L(t)$-axis, it does so necessarily at point z.

Second. If point e manages to cross the $n_L(t)$-axis, it also does it at point z. In fact we can derive the exact equation that express the path of the point e, as $J(t)$ over time. We first find the slope of the path

$$\frac{\partial n_F(t)^e}{\partial J(t)} / \frac{\partial n_L(t)^e}{\partial J(t)} = -1 \tag{45}$$

We the solve for the intercept to obtain the equation of the path of e

$$n_F(t)^e = \frac{E}{wb\sigma} - n_L(t)^e \tag{46}$$

The path of e is shown in figure 6 with a dotted line. For $n_F(t)^e = 0$, we have that $n_L(t)^e = E/wb\sigma$, which shows that the point e crosses the $n_L(t)$-axis at point z.

Third. Given proposition 2, we know that if e crosses the $n_L(t)$-axis catch-up will occur. Given the first two parts of this proof, we know that the crossing will happen at the point z, which implies that we do not have to worry about the horizontal dimension of the dynamics, but only about the vertical one. That is we want to know if the $n_F(t)^e$ component of e gets to the $n_L(t)$-axis before the $n_F(t)$ component of x.

With respect to x, the number of firms in F then decline as follows

$$n_F(t) = n_F(0) - \alpha t \tag{47}$$

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

$$n_F(t)^e = \frac{J(0) + \beta t - Er^{1-\sigma}}{wb\sigma(1 - r^{1-\sigma})} \tag{48}$$

The attractor e reaches zero at time t'

$$t' = \frac{Er^{1-\sigma} - J(0)}{\beta} \tag{49}$$

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

$$t'' = \frac{n_F(0)}{\alpha} \tag{50}$$

The dynamic catch-up condition is then obtained imposing that $t' < t''$.

$$\frac{Er^{1-\sigma} - J(0)}{\beta} < \frac{n_F(0)}{\alpha} \tag{51}$$

Substituting E we get

$$\frac{n_L(0) w b \sigma r^{1-\sigma} - J(0)}{\beta} < \frac{n_F(0)}{\alpha} \tag{52}$$

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

■