TECHNOLOGY ADOPTION, INDUSTRIAL STRUCTURE, AND GROWTH IN EMERGING ECONOMIES

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Abstract:
This paper explores the link which is often neglected in the literature between the industrial structure and the aggregate economic growth in emerging economies (EE) that are implementing an openness trade policy. Based on the Schumpeterian technological paradigm concept, we show the relevance of the technology adoption hypothesis rather than the innovation hypothesis in an EE's context. We develop an endogenous deterministic growth model for small open economies in which domestic agents adopt technology incorporated in equipment import. Through the model, we prove that equipment import, technological externalities, and the fall in relative prices are the sources of openness growth effects. In this paper we determine endogeneously the minimal efficiency threshold of entry and exit dynamics in the domestic industrial structure within an endogenous growth framework. We show that the consumption goods diversity improves the growth rate of consumption and welfare by its negative action on the surviving firms monopoly power. We argue that for intermediate goods, the agents heterogeneity is negatively correlated with stationary state growth rate. From an economic policy point of view, it would be recommended to intervene by improving the performance of the domestic firms before implementing the trade openness policy, and after its implementation by controlling the markets to avoid the monopolistic structure that is negatively correlated with economic growth at the aggregate level.

Key words: *Technology Adoption; Heterogeneous Agents; Monopolistic competition; Efficiency Threshold; Entry-Exit Dynamics*

I. Introduction

The link between trade openness and economic growth has been reviewed in the literature based upon two types of research work. The first studies the link between trade openness and the growth rate of per capita GDP as illustrated in the endogenous growth models which allow to establish the transmission channels of trade policy dynamic effects as argued in Baldwin (1998), Romer and Batiz (1991), and Martin and Barro (1995). These channels result in the spread of various forms of technology and in types of externalities, international capital flows, prices adjustment, and adequate macroeconomic policies.[1] But these models retain the restrictive assumption of homogeneous agents behaviors in a perfect market final goods context. Consequently, a symmetric equilibrium may be achieved. The results obtained from these models in there majority indicate the positive effect of trade opppenness on GDP and its growth. But the extent of this effect and its relevance remain mainly dependent on homogeneous agents assumption and thus on symmetric equilibrium. However, the behavior of agents is indeed not identical for at least two reasons. First, the industrial and technological strategies carried out separately by the agents are to give place to product differentiation (Chamberlin, 1933).[2] Second, the non-uniform costs undergone by firms lead to specialization (Stigler, 1949). In this context, each agent positions herself as a monopoly of her own innovation. A monopolistic structure is established and a symmetric equilibrium is then evacuated from the analysis.

The second type of studies, initiated more recently by Bernard et al. (2000), Melitz (2002), and Yeaple (2002), emphasize the microeconomic bond between the exporting firms and their productivity. Within this analysis framework, J. Bradford et al. (2003) explore the productivity evolution in industry resulting from the firms reallocation in response to changes in the trade costs (*i.e,* tariffs and costs of transport). Others treated the structure of the market endogenously, namely, Katja (2006) for space endogenous location, and Mazzeo (2002), for endogenous quality choice. However, they did not treat economic growth. Finally, Holmøy (2003) is interested in an evaluation of the standard Dixit-Stigliz model when the asymmetry is taken into account. However this second type researchers were not interested in economic growth at the aggregate level.[3]

We will retain the assumption of heterogeneity to analyze the market structure, and to describe the entry and exit agents dynamics. This dynamics is determined by the efficiency, profitability and competitiveness of the various agents operating in such a heterogeneous structure (Montagna, 1995).

The trade openness makes it possible for the EEs to take advantage of the volume of imported equipment goods as well as the technology which they incorporate. The structure of their industry will then be modified and efficiency conditions will be imposed on the economic agents. In fact, diversified products and competition in terms of efficiency between the agents will characterize their industrial structures.

It would be then interesting to adapt this approach of heterogeneous agents to the problems of endogenous growth in an open EE which chooses trade liberalization. In this paper we study the effects of diversified equipment goods import on industry structure in EE imitating foreign technology and on their economic growth. For the industry entry-exit dynamics and heterogeneity effects on growth, we use a framework for an economy witch has two sectors. The intermediate good sector has imported goods together with foregone output to produce the large number of durable goods that are available for use in final goods production at any time. We adopt the hypothesis of all intermediate goods being imported. This hypothesis may be questionable when we consider all the developing countries. But for the Middle East countries in specific, the weight of domestic equipments is negligible compared to that of imported equipment. This assumption is not unrealistic when technological innovation is taken in the sense of Schumpeter as presented in the previous section[4]. Our analysis separates the case of consumption goods diversity and imitated goods diversity so that a simple model is established for each.

Essentially, our idea is to investigate the following issues: Is there a relationship between the degree of agents heterogeneity and their individual efficiency? What are the consequences on the efficiency threshold necessary for the access to industry, and what are the effects on the economic growth rate in a stationary state?

This paper is organized as follows: In the second section, we show that the assumption of technology adoption is more realistic compared to its innovation in some LDC's. The third section is devoted to the study of a stationary state equilibrium in the case of the consumer goods variety. We should note that in our formulation heterogeneity of agents is not considered in intermediate production sector. The fourth section introduces heterogeneity into the sector of imitation of the technology incorporated in the imported intermediate goods. Sensitivity analysis by numerical simulations will be carried out at the end of each section. The last section concludes the paper findings and suggests recommendations of economic policy for the EEs.

II. Imitation *Versus* Innovation of Technology in EEs

The imitation assumption of foreign technology is more suitable than that of technological innovation in developing countries. This is due to two main reasons. The first is related to the technology concept and the second may be explained by the huge innovation costs.

First, technology paradigm according to Schumpeter means a succession of stages. Each one is defined by processes leading to the innovation. These stages start by rising a new question related to the limits charged to the present technology. The answer to this question results in a technological patent generating revenue. Next, this patent is implemented by a new tool giving its producer a monopoly rent. Once this new tool is standardized by the externalities which it generates, competition on its market is no longer monopolistic. To avoid losing its monopolistic position and thus its rent, the innovator starts another technological paradigm. The technological innovation results in the means leading to lower cost or at least the same level of output. In reality, they are modern organisational forms, sophisticated tools, and differentiated products. Grossman and Helpmann (1991) show that the differentiation of inputs (which results in technological progress) prevents the decrease of their marginal productivity.

It is in this context of technological paradigms that Schumpeter as well as the pioneer authors of the endogenous growth (Romer, 1986 and 1987) justify the innovation mainly by the revenue which it allows. Aghion and Howitt (1992) introduce the concept of the creative destruction through anticipations that the innovator formulates in connection with the future standardization of technology.

It is with a view to keep its monopolistic power and thus its revenue that the innovator launches on the market his new technology before it is standardized. In addition, one should note that this production of technology depends basically on material and social conditions of knowledge production. Furthermore, the compliance with intellectual copyrights suggests that human capital accumulation requires the distinction between the "lab equipment model" and the "knowledge driven model". The first supposes the combination between the physical capital and preliminary knowledge (initial human capital endowments), while the second supposes the combination between the various types of available knowledge (Barro, 1996, and Romer and Batiz, 1991).

In this way, the technology production according to Schumpeter becomes a very difficult task to achieve in EEs because of the absence of a knowledge production sector as well as social conditions for the implementation of the technological paradigms. The foreign technology transfer in EEs should not therefore be intended as a simple transfer of its output only (technological product, sophisticated equipment, etc.). According to Schumpter, that should be equivalent to a transfer of the *whole process* allowing technology production and as was the case of a very reduced number of countries in the world, that benefited from this type of transfer (for example Japan).

The second reason in favour of the technology imitation in EEs is the huge cost which it generates (Easterly, King, Levine and Rebelo, 1994) and the divergence in growth rates that it would be likely to generate, as shown in Barro and Batiz (1995) with reference to the catch-up argument. Through a model of technology diffusion based on imitation, Barro and Batiz (1995) show that the relatively low cost of imitation implies that the followers grow relatively quickly and tend to catch up the leaders.

We should add that trade liberalization in the developing countries targets the externalities generated by the technology incorporated in imported equipment. In what follows we keep the assumption of technology imitation rather than its innovation for somme LDC's specific context. In this paper we deveop two models. The first considers the variety of goods and agents heterogenity only in the final goods sector. The second takes into account the heterogenity of agents only in imitated-intermediate goods sector.

III. Final good varieties, agents heterogeneity, and economic growth

We begin with the case where heterogeneity of agents in imitation sector is not considered. Suppose that each agent produces only one final good. The production technology is described according to the following CES function:

$$Y_t = BL_t^{\alpha}\left[\int_0^A x_t^{\gamma}(j)dj\right]^{\frac{1-\alpha}{\gamma}} \qquad (1)$$

where, Y_t is the final good, B is a productivity parameter, $x_t(j)$ denotes the input (*j*) imported at time *t*, such as $j \in [0,\ A]$, and L_t, is the volume of homogenous labor assumed constant. A is an indicator of horizontal differentiation of the inputs *x(j)*, $\gamma \prec 1$ and $0 \leq \alpha < 1$.

Imported capital varieties are given by $\int_0^A x(j)dj$. In this economy, income Y_t is allocated between final consumption, investment in the adoption of technology denoted by $\frac{dA}{dt} = \dot{A}$, and the import of intermediate goods $\int_0^A x(j)dj$. As mentioned above, we refer to technology as the differentiation of product which is defined similarly as in Grossman and Helpmann (1991). This can be explained by horizontal diversity of the imported equipment goods $x_t(j)$.

A constant share μ of output is devoted to the financing of technology adoption:

$$\frac{dA}{dt} = \dot{A} = \mu BL_t^{\alpha}\left[\int_0^A x_t^{\gamma}(j)dj\right]^{\frac{1-\alpha}{\gamma}} \qquad (2)$$

The producer maximizes profit π and the resulting necessary condition of equilibrium is given by:

$$\frac{\partial \pi}{\partial x} = \frac{1-\alpha}{\gamma} P_f(j) B L_t^{\alpha} \left[\int_0^A x_t^{\gamma}(j) dj \right]^{-1+\frac{1-\alpha}{\gamma}} \gamma x_t^{\gamma-1} - P_I(j) = 0 \qquad (3)$$

where $P_f(j)$ and $P_I(j)$ are the prices of the final and the impoted goods, respectively. From the symmetry assumption, $i.e., x(j) = x, \text{and } P_I(j) = P_I, \forall j \in (0, A)$, the producer equilibrium condition gives the following demand function:

$$P_I = (1-\alpha) P_f B L^{\alpha} A^{-1+\frac{1-\alpha}{\gamma}} x^{(1-\alpha)-1} \qquad (4)$$

where time subscripts are omitted whenever no ambiguity results.

It follows that,

$$x = \frac{P_I^{-\frac{1}{\alpha}}}{\left[(1-\alpha) P_f B L^{\alpha} A^{-1+\frac{1-\alpha}{\gamma}} \right]^{-\frac{1}{\alpha}}} \qquad (4-a)$$

From (4) we may get the equation of output Y for a fixed employment to the unit:[5]

$$Y = (1-\alpha) B^{1-\alpha} A^{\sigma} \left({}^{P}/_{P_f} \right)^{-\frac{\frac{1}{\alpha}}{\alpha}} \qquad (5)$$

$\sigma = \frac{(1-\alpha)(1-\gamma)}{\alpha\gamma}$ is the elasticity of output to the varieties of imported goods. It is inversely related to the share of imported equipment goods in income[6].

In this model heterogeneity is due to non-uniformity of costs which are specific to each type of product. We therefore consider a monopolistic structure of the consumer goods market where competition is based on costs.

The representative consumer maximizes the following intertemporal utility function U_t on an infinite time horizon,

$$U_t = \int_0^{\infty} e^{-\rho t} \frac{C_t^{1-\theta} - 1}{1-\theta} dt \qquad (6)$$

where C_t is a composite consumer good defined by:

$$C_t \equiv \left(\sum_i^M [C_t^{\varepsilon}(i)] \right)^{\frac{1}{\varepsilon}} \qquad (6-a)$$

The intertemporal utility function (6) becomes then as follows:

$$U_t = \int_0^{\infty} e^{-\rho t} \frac{\left(\sum_i^M [C_t^{\varepsilon}(i)] \right)^{\frac{1-\theta}{\varepsilon}} - 1}{1-\theta} dt \qquad (7)$$

M is the number of varieties of consumption goods, C_i denotes the consumption of good i, ρ is the discount rate, θ is the risk aversion parameter, and $\in$ is an intra-temporal substitution parameter. Since labor supply is constant it will not be introduced in the utility function because inter-temporal arbitrage between leisure and consumption is beyond the scope of this paper, and also because aggregate and per capita growth rates of consumption are identical.

The general price index P may be expressed by:

$$P \equiv \left[\frac{1}{M}\sum_{i}^{M} P_i^{1-\frac{1}{1-\varepsilon}}\right]^{1-\frac{1}{1-\varepsilon}} \qquad (7-1)$$

We suppose that accumulation is financed by households savings. To estabilish the equilibrium conditions in a stationary state we maximize (6) subject to the following accumulation constraint:

$$\dot{a} = wL + ra - PC \qquad (8)$$

Equation (8) describes the dynamic budgetary constraint of houshold. The economic agent owns financial assets a, and labor L. Assets yield a rate of return r while labor is paid the wage rate w. Then the total income received by houshold is the sum of asset and labor income, $ra + wL$.

Each houshold uses the income that she does not consume to accumulate more assets, $\dot{a} = {da}/{dt}$. Equation (8) shows that investment $\dot{a}$, and saving (the difference between labor and asset revenues $wL + ra$, and consumption exenditure, PC) are equal. Debt is not considered in the model.

The solution to this optimization program is carried out in two stages. We begin with the determination of the static optimal demand functions and how they are related, and then we compute the growth rate of control variables in a stationary state.

A. Stationary state equilibrium

In order to show just the effect of diversity consumption goods on welfear we assume perfect competition. The stationary state is defined where the control and state variables in the system (7)-(8) change at the same constant rate (the proof is in Appendix A-1). The static demands (demand functions) are determined as follows:

$$C_i = \frac{E}{M}\left[\frac{P_i}{P}\right]^{1-\varepsilon} P_i^{-1} \qquad (9)$$

Equation (9) shows that the demand for each variety i depends negatively on the number of varieties M and positively on the consumption expenditure E. In addition, due to substitution between the goods the demand for each variety depends positively on the relative price of the composite good (P_i/P). To determine the stationary state equilibrium in the second step we initially remove the heterogeneity assumption of agents and we only keep the assumption of diversity of consumer goods. Heterogeneity will be introduced later in the paper.

In order to isolate the effect of diversity of products on the growth rate we assume that the marginal costs are identical for all firms ($v_i = v$ for any $i \in [1, M]$). Later we relax this assumption and we introduce the asymmetry of equilibrium ($v_i \neq v_j \quad \forall\, i \neq j$) for the purpose of analytical comparisons.

In the symmetric equilibrium case the prices of various consumer goods C_i become equal and the goods enter the function of utility symmetrically, and the consumption quantities of each variety are identical:

$$P_i = P^*$$

$$C_i^* = C^* = \frac{C_t}{M}, \forall i \in [1, M]$$

.

The growth rate of homogeneous C_i in a stationary state may be written as follows:

$$\frac{\dot{C}_i}{C_i} = \frac{1}{\theta}\left[r - \rho + \left(\frac{1-\theta-\in}{\in}\right)\frac{\dot{M}}{M} \right] \qquad (10)$$

We substitute the interest rate $r = \partial \mathrm{Y} / \partial \mathrm{A}$ in (10) and we obtain the growth rate expression for a fixed labor level to unity, $L_t \equiv \bar{L} = 1,$ in a stationary state given by:

$$\gamma = \frac{1}{\theta}\left[\sigma B^{\frac{1}{\alpha}} (1-\alpha) A^{\sigma-1} \left({}^{P}\!/_{P_f} \right)^{-\frac{1-\alpha}{\alpha}} + \frac{(1-\theta-\epsilon)}{\epsilon} \gamma_M - \rho \right] \quad (11)$$

where $\gamma_M = \frac{\dot{M}}{M}$ is the growth rate of differentiated consumer goods[7].

Equation (11) shows that when $(\theta + \in)$ is less (more) than one the change of consumer goods differentiation $\dot{M}/M$ has a positive (negative) effect on the growth rate of consumption. The sign of this effect depends on the preference parameters. We study this sign with simulation experiments in the next section.

According to Equation (11) when the consumer goods are perfect substitutes $\in = 1$, diversity is no longer relevant. Its evolution γ_M will not affect the growth rate of the stationary state. When these goods are perfectly complementary ($\in = 0$) the effect of their diversity on the growth rate is maximum for a given elasticity of intertemporal substitution θ. In fact, following Grossman and Helpman (1991) diversity of goods in the consumption basket avoids the fall of marginal utility and improves the consumer surplus. In this case when the number of varieties increases, the growth rate of per capita consumption and consequently the growth rate of per capita income both increase.

Equation (11) is important because it shows also that if domestic agents make an effort to differentiate their final goods and an effort to adopt imported technology their growth rate and welfare will improve. This happens due to the role of the adopted foreign technology in growth. Therefore, trade openness leads to a decrease in relative prices of imported goods and thus contributes positively to growth and better resource allocation through a growing volume of equipment goods, as argued in De Long and Summers (1991) and Tai and Klenow (2002). In fact, not only trade liberalization decreases price distortions, it may also trigger higher growth rate stemed from the lower relative prices of equipment goods and the spread of technology expressed here by the diversity of imported equipements. These positive dynamic effects of trade openness policy are shown in the following equation, including a reduction of the rate of customs duty τ which is referred to as a proxy of trade openness policy:

$$\gamma = \frac{1}{\theta}\left[\sigma B^{\frac{1}{\alpha}}(1-\alpha)A^{\sigma-1}(1+\tau)^{-\frac{1-\alpha}{\alpha}}\left(P/P_f\right)^{-\frac{1-\alpha}{\alpha}} + \frac{(1-\theta-\varepsilon)}{\varepsilon}\gamma_M - \rho\right] \quad (12)$$

Set $\sigma=1$, we obtain :

$$\gamma = \frac{1}{\theta}\left[B^{\frac{1}{\alpha}}(1-\alpha)(1+\tau)^{-\frac{1-\alpha}{\alpha}}\left(P/P_f\right)^{-\frac{1-\alpha}{\alpha}} + \frac{(1-\theta-\varepsilon)}{\varepsilon}\gamma_M - \rho\right] \quad (12-a)$$

Equation (12-a) shows that *trade openness* policy results in a decrease of τ and impies a higher growth rate (*i.e.* $\frac{\partial \gamma}{\partial \tau} \prec 0$). This type of result is established within the framework of a consumption goods market where producers are *homogeneous*. We are turn to the case of heterogeneous producers.

B. Agents heterogeneity, entry-exit dynamics, and industrial efficiency threshold in industry

Heterogeneity allows us to analyze the industry structure, to describe the suppliers behavior, and to establish the conditions of exit and entry in industry. Each firm *i* has a variable specific cost per unit produced v_i and a constant cost K_c which is identical to all firms for a given industrial activity. The constant cost is the expenditure in physical and human or financial capital which is necessary to enter the industry. The quantity and the quality of K_c account for the specificity of the industrial activity that each agent targets. The irreversible cost K_c is then the first necessary condition for the firm to be considered as "potential candidate" to access the industry. We show in what follows that the industry cost structure plays a key role for the demand of each variety of consumer goods by its action on the prices and the number of varieties.

Let TC define the total cost,

$$TC = K_c + v_i Y_i \qquad (13)$$

where Y_i is the specific output produced by agent *i* such as $i \in$ [1, *M*]. The fixed cost K_c involves the need for *specialization* in *a particular product* (Stigler, 1949). Thus it can partially explain the heterogeneous structure of the production in industry once the final output is produced. This heterogeneous structure gives necessarily place to a framework of imperfect competition analysis. For a cost function given by (13), let $Y_i = C_i$ for any given M , then the mark-up price of the monopoly denoted by P_i is given by:

$$P_i = \frac{v_i}{\in} \qquad (14)$$

Since the marginal cost v_i is specific to each firm, it follows that for a given market structure there is an asymmetric equilibrium that results in as many prices, quantities and profits, as products.[8]

Within a monopolistic structure and the given the characteristics of costs, only the most efficient firms will survive in the industry and there will be no long term profit. Agents will to decide to enter the market according to the expected profit which in turn is non predictable and follows a stochastic process generated by the variable costs. These costs vary in the interval $[1-\delta, 1+\delta]$. The limit values of this interval are indicative of the firm's technological heterogeneity degree. In other words, the degree of heterogeneity of the firms increases with higher values of δ. When $\delta=0$ we go back to the case where all firms are homogeneous.

Faced with given values of cost opportunity *r*, a firm that has already incurred the fixed-cost equipement in imitation will choose a level of output to maximize its revenue mins cost at every date,

The profit for firm *i* , for a given price P_i is given by:

$$\pi_t = P_t Y_t - v_t Y_t - K_c \qquad (15)$$

We focus the analysis on the partial equilibrium where the opportunity cost *r* is given for each firm.[9] As usually, equilibrium production in equation (15) is obtained by taking into account labor and capital cost. For now, this is all we need to study the effect of consumer goods diversity on growth.

Substitute the expression of P_i from equation (14) in equation (15), and use equation (9) to obtain:

$$\pi_t = \eta \left({}^{E}\Big/_{(M)P^{\frac{1}{1-\epsilon}} v_i^{-\frac{1}{1-\epsilon}}} - K_c \quad (16) \right)$$

where $\eta = (1-\epsilon)\left(\frac{1}{\epsilon}\right)^{-\frac{\epsilon}{1-\epsilon}}$ and $\epsilon < 1$

It is clear that the profit of firm *i* decreases with the number of varieties M and with the variable costs, and it increases with the general prices index *P*. Hence, the higher the price index, the more tempted the firm will be to enter the market because it anticipates a high profit. In addition, if there are more agents that specialize in the production of only one good then the conditions of comparative competitiveness will be more difficult. In fact these conditions are directly related to the variable costs, and it is interesting to find the value of v_i that matches the minimum threshold of technological efficiency from which the firm decides to enter the industry. This threshold is determined by a null profit that corresponds then to a threshold of variable cost $v*$, such as:

For $\pi_i = 0$, we have the variable threshold of cost:

$$v^* = \left[M.K / \left(\eta . P^{\in/(1-\in)}\right)\right]^{(1-\in)/\in} \qquad (17)$$

For a given number of varieties, firms whose marginal cost is lower than $v*$ will have a positive profit and those firms which have $v_i = v*$ will have a zero profit.[10] Lastly, firms with variable cost exceeding $v*$ will leave the industry because they are not efficient.

For a given price, there is a number of potential candidates who expect a null profit. We can write equation (9) in terms of growth rates to describe the dynamics of firms entry to and exit from the industry:

$$\frac{\dot{C}_i}{C_i} = \frac{\in}{(1-\in)}\frac{\dot{P}}{P} - \frac{1}{(1-\in)}\frac{\dot{P}_i}{P_i} - \frac{\dot{M}}{M} \qquad (18)$$

Both P_i and Ci decrease with the subtitution between goods when M increases. Also, notice that for a given Ci which corresponds to the increase in the number of varieties, the general price index P drops along with the price P_i of each variety. To complete the description of global market action on individual price, we can rearrange terms in equation (18) to obtain an expression of growth rate of variety *i* price as follows:

$$\frac{\dot{P}_i}{P_i} = -(1-\epsilon)\left[\frac{\dot{C}_i}{C_i} + \frac{\dot{M}}{M}\right] + \frac{\dot{P}}{P} \qquad (18-a)$$

Intuitively, equation (18-a) means that following a decrease of good's price which is caused by a surge in the number of varieties, the profit of firm *i* falls until the firm exits the industry. In addition this exit impacts M negatively and this is likely to generate an increase in Ci and P_i rather than an increase in the profit of the remaining firms. As a consequence, there will be new entries to the industry. We can then describe the stationary state by an expected null profit of the last firm where this entry-exit dynamic stops.

It should be noted however that before their entry, all firms have the same uncertainty about their technical efficiency. But once access cost to industry *K* and marginal cost (v_i) are undergone, any uncertainty will disappear. Lastly and following Jovanovic (1982), it is supposed that each agent who is a potential an entry candidate does not consider their influence on the market structure and on the minimum threshold of efficiency. Therefore the agent maximizes expected profit π^a as follows:

$$\pi^a = \int_{1-\delta}^{1+\delta} \pi f(v)dv \qquad (19)$$

Then,

$$\pi^a = \int_{1-\delta}^{1+\delta} \left[\frac{\eta E}{M} P^{\left(\frac{1}{1-\epsilon}\right)-1} v^{-\frac{1}{1-\epsilon}} - K_c\right] f(v)dv \qquad (19-a)$$

Where *f(v)* $\equiv 1/(2\delta)$ is the probability density of a random variable v and δ is the standard deviation of *v*. This term indicates the disparity of firms in terms of technological efficiency.

Now it it shown that new entries will have a negative impact on the price since the demand for each variety decreases and so does the firm's income. This is likely to raise the minimum efficiency threshold and forces non-efficient firms to leave the industry. The stationary state is then characterized by: $\begin{cases} \pi^a = 0 \\ \pi = 0 \end{cases}$ (20)

Combining Equations (17-18), the solution to this system is given by:

$$\begin{cases} \dot{M} = 1/(2\delta)\dfrac{\eta E}{K} P^{\frac{\in}{1-\in}}\left[(1+\delta)^{\frac{1-2\in}{1-\in}} - (1-\delta)^{\frac{1-2\in}{1-\in}}\right] \\ \dot{v} = \left[1/(2\delta)\dfrac{1-\in}{1-2\in}\left[(1+\delta)^{\frac{1-2\in}{1-\in}} - (1-\delta)^{\frac{1-2\in}{1-\in}}\right]\right]^{\frac{\in-1}{\in}} \end{cases} \qquad (20-a)$$

The solution gives the number of firms M^* and the level of efficiency v^* and therefore we obtain what is known as the stable structure of industry.

Finally, by combining the two equations of this system with equation (17) we get the expression of the general price index:

$$P = P v^{-1} \eta^{\frac{\in -1}{\in}} [M K]^{\frac{2(\in -1)}{\in}} \qquad (21)$$

C. Simulation Experiments

The simulation experiments that we have conducted relate the effect of firm δ heterogeneity to the threshold of efficiency v^* for various values of degrees of intra-temporal substitution $\in$. The results are obtained in the Figure-1[11]:

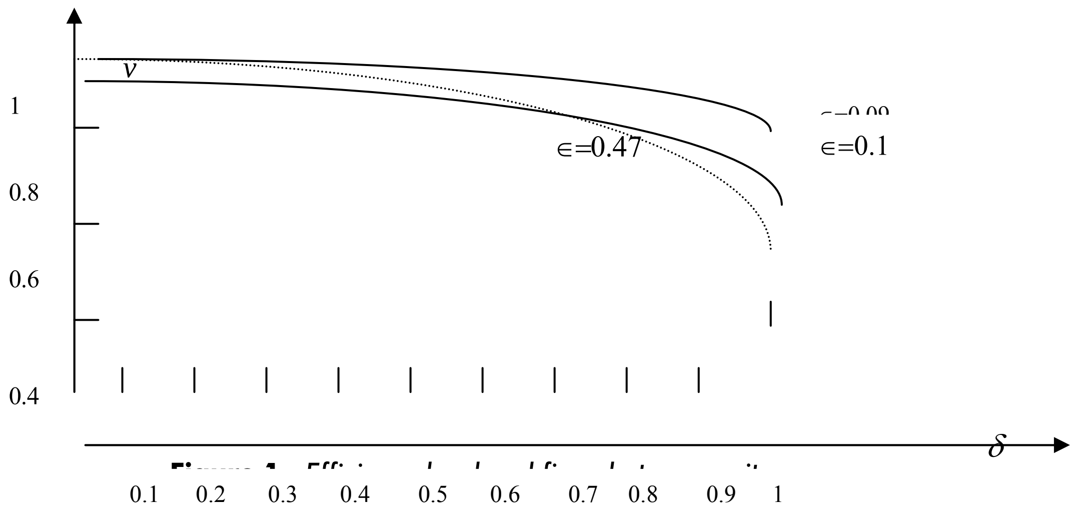

Figure-1- shows a negative correlation between the minimal degree of efficiency v^* in the industry and the degree of firm's heterogeneity. This negative relationship is due to competition costs for firms in the same industry. In fact, competition is tougher when the difference in efficiency between firms δ is higher. Thus, only the more efficient firms may survive in an industry that is more heterogeneous. Moreover, in a heterogeneous industry the conditions of access become so difficult because the price of variety is lower and the marginal cost v is weaker. As a consequence, this situation results in a lower profit.

We also simulate the degree of intra-temporal substitution between goods. The results show that efficiency level is low to the extent that varieties are substitutable. In fact, monopoly price and profit decrease as the varieties are substitutable (this can be seen from equation (14) when $\in$ is high). Cost competition becomes harder and the conditions of marginal firm's survival become increasingly difficult. This is illustrated in the efficiency curve where the dotted lines are lower than the solid lines for the highest values of $\in$. We can draw from this observation an interesting results that shows two negative effects on the efficiency of surviving firms. The effect of heterogeneity and the effect of goods substitution.

Agents heterogeneity and substitution between final goods decrease the monopolistic power of firms that are carrying out competition by costs, since in this case the margin on the price (and thus on the revenue) may decrease. This could result in a positive effect on consumption and on welfare. Heterogeneity of agents who specialize in final consumer goods production will result in an asymmetric equilibrium and thus will provide a spectrum of prices, quantities and profits. It becomes now possible to establish the minimal threshold of technological efficiency for the access to production activity. The diversity of consumer goods improves the growth rate of consumption not only by its negative action on the monopoly power of the firms and thus on the prices, but also by its positive effect on welfare. As a policy implication, it is shown that trade openness that allows more diversified final goods will have a positive impact on consumption an welfare.

IV. Heterogeneity of agents and economic growth

We now present a second model that addresses the issue of industry structure with agents heterogenity in the imitation sector. We introduce agents heterogeneity only in the sector of technology imitation of imported equipment, while agents in the sector of final goods are still homogeneous. What are then the effects of imitators heterogeneity on economic growth? Are there technological conditions to access this type of activity? If so, how are they established? What are the economic policy implications of trade liberalization?
Following Spence (1976), Dixit and Stiglitz (1977), and Ethier (1982), the technology of production in imitation sector is given by:

$$Z_t = L_t^{\alpha} \int_0^{A} x_t^{1-\alpha}(i)\,di \qquad (22)$$

Z_t is the imitated good produced, L_t is (constant) labor used in the sector, $x_t(i)$ is the intermediate good used in the imitation sector, and A denotes the number of *imported* $x_t(i)$ varieties at time *t*.

Following Romer (1990), we assume that the final good market is perfectly competitive, whereas the market of internediate goods is not. Agents differ by a specific marginal cost. We keep the same cost expression as in Romer (1987), namely:

$$\zeta_i = \frac{1}{2} V_i x_i^2 + K \qquad (23)$$

V_i denotes the coefficient of marginal cost $C_m = V_i x_i$

K is the fixed cost which is a prerequisite to access the imitation sector.

To determine the economic growth rate in a stationary state, we determine the prices, the profits, and the quantities at equilibrium in order to lay out the conditions of access to industry. Next, we determine the growth rate of per capita income in order to obtain the links between heterogeneity and growth.

In the imitation sector each agent maximizes profit π_{Zt} as follows:

$$\pi_{Z_t} = L_t^{\alpha} \left[\int_0^{A} x_t^{1-\alpha}(i)\,di \right] - wL_t - \int_0^{A} P_i x_i\,di \qquad (24)$$

The inverse demand function of the variety $x_t(i)$ resulting from profit maximization *in perfect competition is given by:*

$$P_{x_i} = (1-\alpha) L_t^{\alpha} x_t(i)^{-\alpha} \qquad (24-a)$$

$$x_t(i) = P_{x_i}^{-\frac{1}{\alpha}} (1-\alpha)^{\frac{1}{\alpha}} L_t \qquad (25)$$

In the imitation sector of *imperfect competition* each agent maximizes its profit π_{x_i}:

$$\max_{x_i} \pi_{x_i} = P_{x_i} x_i - r\left(\frac{1}{2} V_i x_i^2 + K\right) \quad (26)$$

where r is the opportunity cost of capital which is introduced in a general equilibrium framework and which is determined endogenously.

We make use of the above equations to obtain the profit function as:

$$\pi_i = (1-\alpha)\ x_t^{1-\alpha}(i)\ L^{\alpha}\ - r\ (\frac{1}{2} V_i\ \ x_i^2 + K) \quad (27)$$

It follows that

$$\frac{\partial \pi_i}{\partial x_i} = (1-\alpha)^2 x_i^{-1-\alpha} L^{\alpha} - rV_i = 0 \quad (28)$$

From equations (25) and (28) we can determine each variety's monopoly price for a fixed value of labor as follows:

$$P_i = \left[(1-\alpha)^{\frac{1-\alpha}{\alpha}} rV_i\right]^{\frac{\alpha}{1+\alpha}} \quad (29)$$

The monopoly price for each variety is an increasing function of the corresponding variable cost and interest rate. As shown in Appendix A-2, we can write firm *i*' s profit as follows:

$$\pi_i = h\ \ (r.V_i)^{\frac{\alpha-1}{1+\alpha}}. - r.K \quad (30)$$

where $h \equiv \frac{(1-2\alpha)}{2}(1-\alpha)^{2(2-\alpha)/(1+\alpha)}\ L^{2\alpha/(1+\alpha)}$

Equations (28-30) satisfy the general structure of the industry established in the first section. This structure is characterized by a spectrum of prices, quantities, and profits. Equation (30) shows the relationship between the profit of firm *i* and its technological efficiency *Vi*. It is then a matter of comparing the firms with repect to technological efficiency whose threshold of entry to industry is to be determined thereafter.

The dynamics of the imitated intermediate goods market in which agents are heterogeneous is similar to the market of final goods developed in the the preceeding section. We follow the same approach to determine the economic growth rate in a stationary state.

Each agent *i* wishing to enter the market should have an expected profit $\pi_i^a \geq 0$:

$$\pi_i^{\ a} = \int_{1-\delta}^{1+\delta} \pi_i f(V_i) dV_i \geq 0 \quad (31)$$

From (30) and (31), the profit equation becomes:

$$\pi_i^{\ a} = \int_{1-\delta}^{1+\delta} \left(h\ \ (rV_i)^{\frac{\alpha-1}{1+\alpha}} - rK\right)(1/2\delta)dV \geq 0 \quad (32)$$

It is now possible to determine the interest rate *r** of the long term equilbrium where entry and exit of agents in the industry stops when the expected profit $\pi_i^{\ a}$ becomes null. The solution to (32) and the condition $\pi_i^{\ a} = 0$ give the interest rate as follows:

$$r^* = (2\delta K)^{-(1+\alpha)/2}\ \Psi^{(1+\alpha)/2} \quad (33)$$

where $\Psi \equiv h\frac{(1+\alpha)}{2\alpha}\left[(1+\delta)^{(2+\alpha)/(1+\alpha)} - (1-\delta)^{(2+\alpha)/(1+\alpha)}\right]^{(1+\alpha)/2} L^{-2\alpha/(1+\alpha)}$

It should be noted that r^* is determined by the specific market structure and the technological conditions of efficiency to enter the industry. It is determined, as shown in equation (33), by the degree of heterogeneity of the firms and of the fixed cost.

As for the minimal threshold of efficiency V^*, it corresponds to a zero profit obtained by the marginal firm.

Given r^* , the expected profit of the marginal firm is:

$$\pi^a = \int_{1-\delta}^{1+\delta} \left(h \left(r^* V_i \right)^{\frac{\alpha-1}{1+\alpha}} - r^* K \right) (1/2\delta) dV = 0 \qquad (34)$$

Thus r^* determines the threshold of efficiency V^*. Firms for which V_i exceeds V^* (V_i between V^* and $1+\delta$) will leave the market since they become noncompetitive. Only firms with V_i in the interval $[1-\delta, V^*]$ will stay. The profit of surviving firms may be determined as follows:

$$\pi^{a^*} = \int_{1-\delta}^{V^*} \left(h \left(rV_i \right)^{(\alpha-1)/(1+\alpha)} - rK \right) 1/(2\delta) dV_i = 0 \qquad (35)$$

$$\pi^{*a} = h \frac{r^{*-2(1+\alpha)}}{2\alpha} [\left(V^{*2\alpha/(1+\alpha)} - (1-\delta)^{2\alpha/(1+\alpha)} \right) - \left(V^* - 1 + \delta \right) K] = 0 \qquad (36)$$

This result shows that the relationship between threshold of efficiency V^* and heterogeneity of the firms is ambiguous. The simulation results for $\alpha = 0.3$ and a constant capital stock indicate that the effect of agents heterogeneity on efficiency threshold is negative as shown in Figure 2:

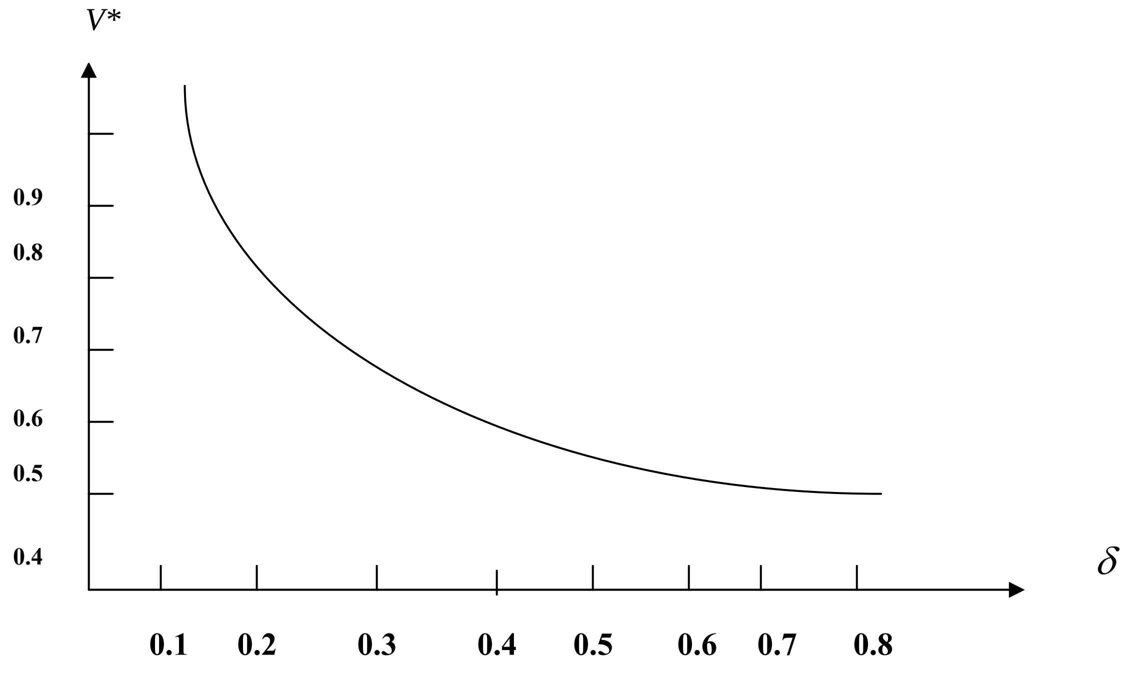

Figure 2. Efficiency threshold and agents heterogeneity

It is now clear that we obtain the same type of heterogeneity effect on the efficiency threshold as in the case studied in the first section. The higher is the variation of efficiency between the firms, the more difficult are the survival conditions, and the more intense becomes the competition through costs.

So what are the consequences on growth rate?

From the expression of growth rate at the stationary state shown in Appendix A1 and for homogeneous consumer goods (*M=0*) we have:

$$g = \frac{1}{\theta}\left[r^* - \rho\right] \qquad (37)$$

Substituting equation (33) in equation (37), we obtain:

$$g^* = \frac{1}{\theta}\left[(2\delta K)^{-(1+\alpha)/2}\,\Psi^{(1+\alpha)/2} - \rho\right] \qquad (38)$$

It can be seen that per capita income growth rate has changed by agents heterogeneity in the imitation sector compared to the homogeneity case. In fact, even compared to the case of consumer goods heterogeneity the stationary state per capita growth rate is negatively correlated with the degree of agents heterogeneity in the imitation sector. This negative correlation is shown in our simulation results as depicted in Figure 3 below:

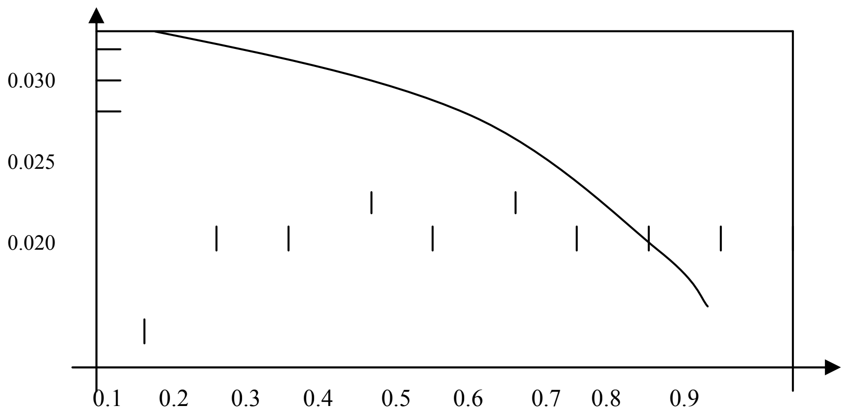

Figure 3. Stationary state growth rate and agents heterogeneity

Therefore, as the stationary state growth rate becomes weaker the disparity in terms of technological efficiency of the imitating firms becomes higher. We can lay out two features that characterize the imitation technology sector. First, the minimum threshold of irreversible capital which is necessary to access the imitation activity reduces the number of candidate firms and creates competition through costs. Second, this competition occurs in a monopolistic context. The resulting aggregate equilibrium is non optimal because of imperfect competition corresponding to prices higher than in perfect competition. It is the agents' heterogeneity and thus the imperfect structure which is at the origin of a non-optimality. With higher degree of heterogeneity we have lower economic parformance as a whole and a resulting lower growth rate. Finally, from equations (33) and (36) and also from figure 2, our results show that for a given degree of heterogeneity the threshold *V** would be the equivalent barrier to entry since marginal costs are increasing and thus would have a negative impact on profit progressively with the accumulation of capital as interest rate decreases.

V. Conclusion

In this paper we shed some light on the important link between industrial structure and aggregate economic growth for emerging economies seeking to implement openness in their trade policy.

Our results show the relevance of the technology adoption hypothesis as opposed to the traditional hypothsesis of innovation. Following Romer (1990), we develop an endogenous growth model for small open economies where domestic agents adopt technology incorporated in imported equipment. In the model, equipment import coupled with technological externalities and with the fall in relative prices explain the growth effects of openness.

Entry and exit dynamics in industry depend on expectations that heterogeneous agents form about future profit and also on their technological competitiveness. The market structure characterized by a spectrum of prices and pofits is given *endogenously*. In such a structure, competition takes place through costs. In the long run, surviving firms would make some non-zero profits. Minimum efficiency threshold of entry and exit dynamics in the domestic industrial structure are then endogeneously determined. The diversity of consumption goods improves the growth rate of consumption and welfare by its negative action on the monopoly power of the surviving firms. The results seem to be consistent with those established in the basic models of endogenous growth with differentiated products.

In the case of intermediate goods, agent's heterogeneity is negatively correlated with stationary state growth rate. In fact, monopolistic competition leads to a non-optimal growth equilibrium at the aggregate level although it will result in a reduced number of agents.

For the decision maker, we argue in this paper that openness trade policy shows mixed results. Specifically, there are two opposite effects on economic growth. A positive effect described by the fall in relative prices of the equipment which leads to an increase in imports and allows more technology to be adopted. A negative effect described by exit of domestic firms from industry as their efficiency decreases compared to foreign firms, making the market structure more monopolistic.

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Appendix

A-1: Solution to optimization program (7)-(8) and determination of equation (9)

a) *First solution stage: determination of static demand*

$$\begin{cases} \max U & = \left(\sum Ci^{\in}\right)^{\frac{1}{\in}} \\ S/C & E = \sum PiCi = PC \end{cases} \qquad \text{(A-1.1)}$$

E is the total revenue allocated to consumption.

The number of varieties *M* is supposed sufficiently high such that the variety *i* producer neglects the effect of P_i on household total expenditure by variety of goods.

Let *L* the Lagrange function:

$L=\left(\sum_i^M C_i^{\in}\right)^{\frac{1}{\in}}+\lambda\left(E-\sum P_i.C_i\right)$. The necessary condition is:

$$\frac{\partial L}{\partial C_i}=\left(\sum C_i^{\in}\right)^{\frac{1}{\in}-1}C_i^{\in-1}-\lambda.P_i=0$$

Let $X=\left(\sum C_i^{\in}\right)^{\frac{1}{\in}}$, then $X^{1-\in}C_i^{\in-1}=\lambda.P$, and $X^{\frac{-1}{1-e}}=C_i P_i^{\frac{1}{1-e}}$ is constant.

Observe that $P_i^{\frac{1}{1-\in}}.C_i.\sum_i^M P_i^{1-\frac{1}{1-\in}}=E$ and $\sum_i^M P_i.C_i=E$. Mmultiplying and dividing by $P_i^{\frac{1}{1-\in}}$, we obtain the following expression of variety *i* static demand, equation (9) in the text: $\sum_i^M P^{\frac{1}{1-\in}} P_i^{1-\frac{1}{1-\in}}.C_i=E$. Then,

$$C_i = \frac{E}{M}.\left(\frac{P_i}{P}\right)^{1-\in}.P_i^{-1}.$$

b) *Second resolution stage (symmetric equilibrium case)*

In this case the prices of the various consumer goods are equal. *Ci* enters the utility function in a symmetric and the consumed quantities of each variety are identical. In other words *Pi* $\equiv$ *P**, and,

$$C_i^* = C^* = \frac{C_t}{M} \forall i \in [1, M]$$

.

The Hamiltonian is given by:

$$H = e^{-\rho t}.\left[\frac{\left(\sum^M C_i^{\in}\right)^{\frac{1-\theta}{\in}} - 1}{1-\theta}\right] + \lambda\left[wL + ra - \sum P_i C_i\right] \qquad \text{(A-1.3)}$$

The necessary conditions are as follows:

- ✓ $\frac{\partial H}{\partial C_i} = 0 \qquad \Rightarrow e^{-\rho t}\left[M.C_i^{\in}\right]^{\frac{1-\theta}{\in}-1}.C_i^{\in-1} = \lambda.P_i$
- ✓ $\frac{d\lambda}{dt} = \dot{\lambda} = \rho\lambda - r\lambda$, thus $\frac{\dot{\lambda}}{\lambda} = \rho - r$

The growth rate of homogeneous C_i, in a stationary state is thus:

$$\frac{\dot{C}_i}{C_i} = \frac{1}{\theta}\left[r - \rho + \left(\frac{1-\theta-\in}{\in}\right)\frac{\dot{M}}{M}\right] \qquad \text{(A-1.4)}$$

The equation (A-1-4) is not other than the equation (10) of the text. We replace the yield $r = \partial Y/\partial A$ by its value from equation (8) in equations (5)-(12) and we obtain the stationary state growth rate expression,

$\gamma_{C_i} \equiv \dot{C}_i/C_i$,

$$\gamma_{C_i} = \frac{1}{\theta}\left[\sigma B^{1/\alpha} L^{\alpha} (1-\alpha) A^{\sigma-1}\left(p^*/P\right)^{-(1-\alpha)/\alpha} + \frac{(1-\theta-\in)}{\in}\gamma_M - \rho\right] \qquad \text{(A-15)}$$

Where,

$\gamma_M = \frac{\dot{M}}{M}$ is the growth rate number of the of differentiated consumer goods. Equation (A-15) is numbered (11) in the text.

A-2- Determination of the profit expression in equation (29)

The profit, price, and demand expressions are respectively as follows:

$\pi_i = P_i x_i - r\left(\frac{1}{2}V_i x_i^2 + K_c\right)$, $P_i = (1-\alpha)x_i^{-\alpha}L^{\alpha}$, and $x_i = (1-\alpha)^{\frac{1}{\alpha}}\left[(1-\alpha)^{\frac{1-\alpha}{\alpha}} rVL\right]^{-\frac{1}{1+\alpha}}$

We replace the input demand and the price of each variety by their values in the profit equation to obtain the expression (29) in the text:

$$\pi_i = -\frac{(1-2\alpha)}{2}(1-\alpha)^{2(2-\alpha)/(1+\alpha)} L^{2\alpha/(1+\alpha)} \left(r.V_i\right)^{\frac{\alpha-1}{1+\alpha}} - r.K \qquad \text{(29)}$$

With $h \equiv \frac{(1-2\alpha)}{2}(1-\alpha)^{2(2-\alpha)/(1+\alpha)} L^{2\alpha/(1+\alpha)}$

A-3- Matlab program

The simulations results obtained in section 3 of this paper are performed with the following Matlab program:

```
%diary aly.out
clear
%epsilon1=0.01 ;
%epsilon2=0.03 ;
%epsilon3=0.05 ;
epsilon1=0.09 ;
epsilon2=0.35 ;
epsilon3=0.49 ;
sigma=1 ;
amaj=1 ;
kmaj=2 ;
etat1=(1-epsilon1)*((1/epsilon1) ^ (-1/(1-epsilon1))) ;
etat2=(1-epsilon2)*((1/epsilon2) ^ (-1/(1-epsilon2))) ;
etat3=(1-epsilon3)*((1/epsilon3) ^ (-1/(1-epsilon3))) ;
delta=0.01 :0.01 :0.99 ;
%
a1=1./(2.*delta) ;
a21=(1-epsilon1)/ 1-2*epsilon1) ;
a22=(1-epsilon2)/ 1-2*epsilon2) ;
a23=(1-epsilon3)/ 1-2*epsilon3) ;

a31=(1+delta). ^ (1/a21) ;
a32=(1+delta). ^ (1/a22) ;
a33=(1+delta). ^ (1/a23) ;
a41=(1+delta). ^ (1/a21) ;
a42=(1+delta). ^ (1/a22) ;
a43=(1+delta). ^ (1/a23) ;
a51=a31-a41 ;
a52=a32-a42 ;
a53=a33-a43 ;
a61=(epsilon1-1)/ epsilon1) ;
a62=(epsilon2-1)/ epsilon2) ;
a63=(epsilon3-1)/ epsilon3) ;
vmaj1=(a21.*(a1.*a51)). ^ a61 ;
vmaj2=(a22.*(a1.*a52)). ^ a62 ;
vmaj3=(a23.*(a1.*a53)). ^ a63 ;
%
%
a11=(etat1*amaj/kmaj) ;
a12=(etat2*amaj/kmaj) ;
a13=(etat3*amaj/kmaj) ;
a21=pmaj1. ^ ((1/1-epsilon1))-sigma ;
a22=pmaj2. ^ ((1/1-epsilon2))-sigma ;
a23=pmaj3. ^ ((1/1-epsilon3))-sigma ;
a31=(1/1-epsilon1)/(1-2*epsilon1) ;
a32=(1/1-epsilon2)/(1-2*epsilon2) ;
a33=(1/1-epsilon3)/(1-2*epsilon3) ;
a4=1./2.*delta) ;
a51=(1+delta). ^ (1/a31) ;
a52=(1+delta). ^ (1/a32) ;
a53=(1+delta). ^ (1/a33) ;
a61=(1-delta). ^ (1/a31) ;
a62=(1-delta). ^ (1/a32) ;
a63=(1-delta). ^ (1/a33) ;
a71=a51-a61 ;
a72=a52-a62 ;
a73=a53-a63 ;
mmaj1=(a4.*(a11*a21*a31)).*a71 ;
mmaj2=(a4.*(a12*a22*a32)).*a72 ;
mmaj3=(a4.*(a13*a21*a33)).*a73;
%%%
subplot(2,1,2) ;
```

```
plot(delta,vmaj1'-',delta, vmaj2,'.',dalta,vmaj3,'-') ;
title(FIG.1.Efficiency level')
xlabel ('delta') ;
ylabel('V') ;
legend('- :epsilon=0.09','.. ::epsilon=0.3','-- :epsilon=0.47')
subplot(2,1,2) ;
plot(delta,mmaj1'-',delta, mmaj2,'.',dalta,mmaj3,'-') ;
title(FIG.2.firms number')
xlabel ('delta') ;
ylabel('M') ;
legend('- :epsilon=0.09','.. ::epsilon=0.3','-- :epsilon=0.47')
diary off %
```

---

[1] See Baldwin (2003) and J.Temple J (1999) for syntheses of the empirical literature.

[2] From this point of view, some authors explain that heterogeneity comes from the asymmetry of information and uncertainty about technological efficiency as argued in Lippman and Rumelt (1982), Lippman et al. (1991), and Hopenhayn (1992).

[3] Note in addition that the question of industrial structure in connection with trade brought about a great deal on interest in recent empirical literature. The reader may be referred to Guadalupe and Wulf (2008), and Gorodnichenko, et al. (2008) for more detail.

[4] It would be possible to take into account also a domestic production of equipment as in Benigno and Theonissen (2008) that seems more realistic for countries in witch a weight of domestically produced intermediate goods is not negligible compared to that of imported intermediate. These authors develop an interesting macroeconomic model which analyzes the relationship between the real exchange rate and the ratio of home to foreign consumption under supply side shocks, taking into account both the domestically produced and imported equipments.

[5] Labor demand is such for a given real wage ω, prices P_f and P_I, we have $\omega = \alpha(1-\alpha)^{\frac{1-\alpha}{\alpha}} B^{\frac{1}{\alpha}} A^{\sigma} P_I^{\frac{1-\alpha}{\alpha}}$.

[6] In fact, σ is decreasing with □□.

[7] See proof in Appendix (A-1)

[8] It is assumed that each firm will not affect significantly the price index.

[9] In the next section we introduce a general equilibrium analysis to study the outcome of opportunity cost endogeneity of capital as in Romer (1987) and (1990)

[10] In industrial organization, firms whose marginal cost is equal to $v*$, are referred to as *marginal firms.*

[11] It should be noted that the sign of the effect of the heterogeneity of firms on the threshold of efficiency is ambiguous: $\frac{\partial v}{\partial \delta} = [\frac{1}{2\delta}(1-\epsilon)/(1-2\epsilon)]^{(\epsilon-1)/\epsilon} \frac{(\epsilon-1)}{\epsilon}[(1+\delta)^{(1-2\epsilon)/(1-\epsilon)} - (1-\delta)^{(1-2\epsilon)/(1-\epsilon)}]^{-1/\epsilon}$.
All the simulation experiments are carried out in Matlab.