COMPETITIVE PRESSURE: A CHANNEL TO REDUCE THE OUTPUT PER WORKER GAP BETWEEN COUNTRIES.

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Abstract. Using a industry-country based approach, this study investigates the existence of an optimal level of competition to enhance economic growth. With that in mind, we try to show that this optimal level is different from industrialized and under development economies due to the technology frontier distance, the terms of trade and each economy's idiosyncratic characteristics. Therefore the difference in competition level on an industry-country basis is a channel to explain the output per worker gap between countries. The obtained results imply the existence of an inverted-U relationship between competition and growth. Controlling for the terms of trade and the industry-country fixed effect, we have that if the industries of the developing country operated under the same competition levels as that of the industrialized ones there is a potential increase in output of 0.2-1.0% p.y in the economy.

Key-words: Competition, Economic Growth, Industry Studies.

Resumo. Ultilizando uma análise indústria-país, esse estudo investiga a existência de um nível ótimo de competição que favorece o crescimento econômico. Com isso em mente, tentamos mostrar que esse nível ótimo é diferente entre as economias em desenvolvimento e as industrializadas devido a distância de cada uma relação a fronteira tecnológica, os termos de trocas e as características idiossincraticas de cada economia. A partir disso, a diferença nos níveis de competição das indústrias-países é um canal para explicar o gap do produto por trabalhador entre os países. Os resultados obtidos implicam na existência da relação de U invertido entre competição e crescimento. Controlando pelos termos de troca e os efeitos fixos sobre indústria-país, nos obtemos que se as indústrias dos países em desenvolvimento operassem ao mesmo nível de competição das indústrias dos países industrializados o seu produto cresceria 0.2-1.0% a.a.

Palavras-chaves: Competição, Crescimento econômico, Estudos sobre a Industria.

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1. Introduction

Acemoglu et al. (2006) indicates that there exist strategic alternatives to enhance growth involving different institution structures and public policies. For these authors, developing countries should focus their efforts accumulating physical and human capital, imitating and/or adapting technologies developed by developed countries. These proposals would be attainable even in a situation of restricted economic competition. The technological progress - the main engine of growth for developed countries -, however, would be encouraged by a more competitive market structure.

Thus, this study will focus on the relationship between competition and economic growth in the same fashion as Aghion et al. (2005) relates competition and innovation, that is, in an inverted *U* format. The mechanisms which produce this relation, though, are not the same. In one hand, competition discourage innovations by reducing the firm's expected profit. On the other hand, competition also tends to encourage the entry of firms with greater innovative potential[2] while also induces the incumbent to innovate to maintain its leading position. For these reasons, it is possible to obtain benefits from a greater competition level whilst there are possible negative implications caused by its increase (Bento, 2014).

The industrial organization literature just as the Schumpeterian models argues that a a higher level of competition would reduce the innovative firm's profit - rent dissipation effect - in such a way that the competition would have negative impact over the aggregate innovation rate and consequently over the aggregate economic growth. It follows from the theoretical models of price competition and horizontal product differentiation[3] that the increase in competition inhibit the entry of new firms[4] through the reduction of post-entry profit to the innovative firm.

The same result is found in models of product differentiation in monopolistic competition environments as well as in growth models with variety of products Acemoglu (2009). These endogenous growth models indicate that ex post reduction of the monopoly profit discourages ex ante investments in Research & Development (R&D). Therefore this reduce the rate of innovation as well as the long run growth of the economies which in these models is proportional to the aggregate rate of innovation. Going back to the theoretical models of industrial organization, the models of anticipation and innovation tend to disagree with the previous ones suggesting a positive relationship between competition and innovation. According to this literature, if the incumbent and the entrant firms begin an innovation race, it is possible that competition has positive effects on growth (Aghion et al., 2009). It would depend mostly on the net effect of rent dissipation effect and replacement effect.

From the replacement effect the entrant firm would have greater incentive to innovate as it would make possible the transition from zero to a positive profit. Meanwhile, by innovating the incumbent firm replaces its own profit for the monopoly one. On the other hand, the rent dissipation effect implies that the incumbent firm would have bigger losses allowing the entry to happen than the entrant firm would if it was to give up on entry: the incumbent would transition from a monopoly profit to a duopoly situation whilst the entrant would abstain from getting the duopoly price and would maintain zero profit. Thus, the incentive of the incumbent to innovate is proportional to the difference between the monopoly and duopoly profits, whilst the entrant firm's incentive is proportional to the duopoly profit. That means that in an environment of high competition levels, the duopoly profit can be reduced such that the difference between the monopoly and the duopoly profit is greater than the duopoly profit itself (Acemoglu and Akcigit, 2012). For that reason, the incumbent invests more, ensuring that the market situation will not change and implying a positive relationship between competition and innovation.

In summary, competition would encourage growth because it would reduce the pre-innovation profit in a higher magnitude than that of the reduction of its post-innovation profit (Aghion et al., 2005). That is, the competition increases the incremental profit from the innovation which takes place in order to escape post-entry market competition, the so called escaping competition effect. The dominant effect - either the escaping competition or the rent dissipation - will depend on the technological characteristics of each

[2]Aghion and Griffith (2008) states that the rate of innovation is higher on entry firms since they must have at least the same technological level of the incumbent. Thus the search for the technological level of the incumbent generates, on average, a higher rate of innovation among entry firms.

[3]The Hotelling linear model and the circular version of Salop (1977) apud Aghion and Griffith (2008).

[4]We take this as having attenuating effects over the technological progress.

industry in the economy, which in turn depends on the technology gap between the firms operating in each sector.

Given this relationship, Aghion et al. (2005) establishes a theoretical relationship between competition and growth. For this, the authors distinguish the pre and post-innovation profits and argue that an increase in competition has an ambiguous effect on the aggregate innovation rate and that this effect depends on the market structure of each industry. This would justify an inverted U relationship between competition and innovation. There would be a dominant escaping competition effect for low levels of competition and a dominant schumpeterian effect for high levels of competition. Following the model constructed by Aghion et al. (2005), within the same industry there are firms with different technological levels, because even the technological laggards have non-negative profit. Thus, to some extent for each industry we have two states: (i) the sector is leveled - *neck-and-neck* - that is, firms have similar cost structures and technologies and therefore have the same profit; and (ii) the sector is unleveled - Stackelberg competition - where the leading firm has a higher technological level obtaining greater profit than the follower firms.

The balanced aggregate innovation rate and, as a result, the growth rate of the aggregate output, will depend on the fraction of time that each sector remains level or unleveled. This is the so called composition effect. Thus, according to Aghion et al. (2005), if the the fraction of firms in the leveled or unleveled industry in economy is an exogenous parameter, the higher the fraction of *neck-and-neck* industries in the economy, the greater the positive effect competition will have on the aggregate rate of innovation.

Crucially the quest for innovation is the firm's search for higher profits. So in this study we will show that the search for greater profits affect the degree of competition. Moreover, the industrialized and the developing countries' industries grow differently and, to some extent, their growth depend on the different levels of competition among them. This relationship would be different because the industries-countries have different levels of technology as well as because of the fact that the economies have different terms of trade. Thus, it is reasonable to think that the industry structure of each country has an impact on the rate of innovation, on competition and on the difference between the economies' growth rates.

Therefore, the aim of this study is to clarify how the degree of competition and the growth rate of the product are correlated. This correlation would be distinct and dependent on the distance that the industry-country is to the technological frontier and the idiosyncrasies of each industry-country. We show the effect of varying the competition level on the growth of product for the industries in the developing countries. In other words, we compute what would be the gain in terms of growth if each industry in the developing countries had on average the same level of competition as that of the respective industry in the industrialized countries. Thus, the difference in competition industry-country level would be a channel to explain the output per worker gap between countries.

Our results imply that there is an inverted-U relationship between competition and the growth rate of output across industries-countries. The same is also distinctive among industrialized and developing countries. Given that on average the industries in the industrialized countries have higher levels of competition, with appropriate controls variables if the respective industries in developing countries had the same level of competition as of the first the growth rate of their product would rise 0.2-1.0% p.y. Note, therefore, that this study contributes to the literature by presenting an additional channel to explain the difference between the Gross Domestic Product (GDP) per capita of developed and industrialized countries. In summary, we state that the difference in the output per capita in these countries can also be related to the difference in the level of competition in each country and the mechanisms that determines it. Not only it affects the profitability of each firm but it also affects the incentives to rise the technological level, which in turns affect the rate of growth between countries. Finally, while keeping the focus on manufacturing sectors, we predict that the same would happen with other industries.

The rest of the study is divided as: Section 2 presents a theoretical model that relates competition and growth, while Section 3 describes the dataset used and the method of measurement for the key variables. In Section 4 we document and interpret the empirical results. The last section concludes this study.

2. MODEL

The model to be presented relates competition and output growth for the industry-country. In general, it follows the theoretical characterization used by Aghion et al. (2005) but also making use of the Acemoglu and Akcigit (2012) approach.

There are two important differences in the model we present he as opposite to the one normally presented in the literature. First, we don't impose that the intermediary goods used for the domestic production of final goods are necessarily substitutes. Second, there exists a relationship between economies in terms of trade that increase the effects of competition on growth. The integration of these components, along with the interaction between economies should enhance the competitive incentives of firms.

We show that there is an inverted-U relationship between competition and growth. But, this relationship is differently across firms and industries of industrialized and developing countries and that explains part of the difference in GDP per capita between these groups of countries.

2.1. **Environment.** Consider two economies indexed by $i = \{A, B\}$ with finite horizon and continuous timing. Each one of them has a continuum of individuals with standard preferences regarding the consumption of a final good produced domestically, which the utility function is

$$U\big(C^i(t), t\big) = \int_t^\infty \log C^i(s) \exp\big(-\rho(s-t)\big) ds, \tag{1}$$

where $\rho \in (0, \infty)$. Assume that the only relationship between the two economies occur via the trade of intermediate goods and that has no cost of transaction. Each country produces a final good Y_t^i, which is consumed only by domestic individuals. For this production, we use intermediate goods of domestic origin $\tilde{X}_t^i$ and/or intermediate goods of foreign origin $\bar{X}_t^i$, whose production functions are given by

$$Y_t^A = \big[\alpha^A (\tilde{X}_t^A)^{1-\frac{1}{\epsilon}} + (1-\alpha^A)(\bar{X}_t^B)^{1-\frac{1}{\epsilon}}\big]^{\frac{\epsilon}{\epsilon-1}}, \tag{2a}$$

$$Y_t^B = \big[\alpha^B (\tilde{X}_t^B)^{1-\frac{1}{\varepsilon}} + (1-\alpha^B)(\bar{X}_t^A)^{1-\frac{1}{\varepsilon}}\big]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{2b}$$

where $\epsilon \in (0, \infty)$, $\varepsilon \in (0, \infty)$ e $\alpha^i \in [0, 1]$. The intermediate good of domestic and foreign origins are not necessarily complementaries in the production of final goods, in which case $\epsilon \in (0, 1)$ and $\varepsilon \in (0, 1)$ for country A and B respectively.

The aggregate production of intermediate goods in each country is then given by $X_t^i = \bar{X}_t^i + \tilde{X}_t^i$. In other words, the domestic production of intermediate goods divides itself between the share used for the production of domestic final good and the exported share. We will see that the differences in performance of the output per worker across countries are correlated with different levels of domestic and international competition. Not only that but the competition would be correlated with differences in the technological level, the terms of trade and the degree of substitutability in the production of final good in each economy.

In each country two domestic firms compete with each other as well as with two other foreign firms, given the possibility of trade of intermediate goods between countries. Each firm $j = \{1, 2\}$ produces intermediate good using technology q_{jt}^i and labor l_{jt}^i inputs at time t, whose output function is represented by

$$x_{jt}^i = q_{jt}^i l_{jt}^i. \tag{3}$$

Assume each firm's production of intermediate good is perfectly substitute, then $X_t^i = x_{1t}^i + x_{2t}^i$. The marginal (operating) cost of production of the intermediate good is given by

$$MC_{jt}^i = \frac{w_{jt}^i}{q_{jt}^i}, \tag{4}$$

where w_{jt}^i is the wage in time period t. Suppose that this wage is identical between firms and countries, $w_{jt}^i = w_t$. This means that the difference between prices would be exclusively due to the current technological level and the terms of trade.

Assumption 1. *Whenever domestic firms are unleveled, domestically, firm* 1 *has the highest technological level, that is*

$$q^i_{1t} \geq q^i_{2t}. \tag{A1}$$

And so, it assumes the domestic leading position in term of technology.

The technology of each firm is given by

$$q^i_{jt} = \lambda^{n^i_{jt}}, \tag{5}$$

where $\lambda \in (1, \infty)$ is an efficiency term identical between countries and n^i_{jt} denotes the technological level of firm. Define $\tilde{P}^i_t$ as the price of domestically produced intermediate good used in the production of domestic final good, and $\bar{P}^i_t$ as the price of the same good when traded internationally. In addition, with no trade costs, the price of the domestic good must be equivalent to the price of the imported one in terms of domestic currency. This is $\bar{P}^A_t = \rho_t \tilde{P}^B_t$ and $\bar{P}^B_t = \tilde{P}^A_t/\rho_t$, where ρ_t summarizes the terms of trade (exchange rate) between the two economies. The higher ρ_t the higher the price of the exported good from country A and the lowest it is from country B. It that means that the profit from country A's firms increase with the terms of trade whilst the profit of firms in country B decays. This interaction between the markets generates a degree of competition in terms of price between the two economies.

2.2. **Static Equilibrium.** Given the initial setting and equations 2a and 2b, maximizing the final good with respect to the intermediate inputs, we get that the domestic demand for intermediate goods in each country is given respectively by

$$X^A_t = \left(\frac{\tilde{P}^A_t}{\alpha^A}\right)^{-\epsilon} Y^A_t + \left(\frac{\rho_t \tilde{P}^B_t}{1-\alpha^B}\right)^{-\varepsilon} Y^B_t, \tag{6a}$$

$$X^B_t = \left(\frac{\tilde{P}^B_t}{\alpha^B}\right)^{-\varepsilon} Y^B_t + \left(\frac{\tilde{P}^A_t}{\rho_t(1-\alpha^A)}\right)^{-\epsilon} Y^A_t. \tag{6b}$$

Therefore the price of the domestic intermediate good in each country affect their demand for intermediate goods. The challenge now is to determine the domestic prices for the intermediate goods and how they are related to the technological level of each economy.

Assumption 1 and the price competition imply that in each country the price of the domestic intermediate good is given by

$$\tilde{P}^i_t = \frac{w_t}{q^i_{2t}}. \tag{7}$$

From the equations 6a and 6b, we have that this level of prices implies that domestic demand for goods, with domestic or foreign origin, depends mainly on the technological level of the domestic firm that has the lower technological level. Thus, each firm's j from country i profit function is given by

$$\pi^i_{jt} = \tilde{P}^i_t \tilde{x}^i_{jt} + \bar{P}^i_t \bar{x}^i_{jt} - MC^i_{jt} x^i_{jt}.$$

We also have that each intermediate good firm can have its production divided between the internal and external market, that is $x_{jt} = \bar{x}_{jt} + \tilde{x}_{jt}$. So each intermediate good firm's profit is given by

$$\pi^i_{jt} = \tilde{\pi}^i_{jt} + \bar{\pi}^i_{jt}, \tag{8}$$

where $\tilde{\pi}^i_{jt}$ represents the profit made in the internal market and $\bar{\pi}^i_{jt}$ is the profit made in the external one. From this we have that the diferent types of profit for each firm in each country are given, respectively, by

$$\tilde{\pi}^A_{jt} = w_t^{1-\epsilon}(\alpha^A)^\epsilon Y^A_t \left[\lambda^{(\epsilon-1)n^A_{2t}} - \lambda^{\epsilon n^A_{2t} - n^A_{jt}}\right],$$

$$\bar{\pi}^A_{jt} = w_t^{1-\varepsilon}(1-\alpha^B)^\epsilon Y^B_t \left[\rho_t^{1-\varepsilon}\lambda^{(\varepsilon-1)n^B_{2t}} - \rho_t^{-\varepsilon}\lambda^{\varepsilon n^B_{2t} - n^A_{jt}}\right],$$

$$\tilde{\pi}^B_{jt} = w_t^{1-\varepsilon}(\alpha^B)^\varepsilon Y^B_t \left[\lambda^{(\varepsilon-1)n^B_{2t}} - \lambda^{\varepsilon n^B_{2t} - n^B_{jt}}\right],$$

$$\bar{\pi}_{jt}^{B} = w_t^{1-\epsilon}(1-\alpha^A)^{\epsilon} Y_t^A \left[\rho_t^{\epsilon-1} \lambda^{(\epsilon-1)n_{2t}^A} - \rho_t^{\epsilon} \lambda^{\epsilon n_{2t}^A - n_{jt}^B} \right].$$

Note that if $\alpha^A = \alpha^B = 1$ and $\epsilon = \varepsilon = 1$ we fall back in the standard case presented by Aghion et al. (2005) and so $\pi_{jt}^i = Y_t^i[1 - \lambda^{n_{2t}^i - n_{jt}^i}]$.

There are three important point emphasizing as direct results from equation 8 which have distincts implications to the pattern presented by Aghion et al. (2005), Aghion et al. (2009), among others. First, the firm j's profit will not depend only on the technological gap between domestic firms. But also on the gap between firms from the foreign country. The domestic firm low-tech would have zero profit in domestic demand for intermediate good. But it could have positive profit by exporting if it had a technological level sufficiently larger than that of the low-tech firm of the foreign country. This is due to the trade relationship between the two economies.

Secondly, this gap also depend on the complementarity of the intermediate goods in each economy, ϵ e ε. For example, if $\epsilon = \varepsilon = 1$, the profit of the intermediate goods firm of the economy A is

$$\pi_{jt}^A = \alpha^A Y_t^A \left[1 - \lambda^{n_{2t}^A - n_{jt}^A} \right] + (1-\alpha^B) Y_t^B \left[1 - \frac{1}{\rho_t} \lambda^{n_{2t}^B - n_{jt}^A} \right].$$

However, the higher the substitutability of the intermediate goods in the production of final goods, the higher the competition. To the extent that the magnitude of the profit is enhanced by this substitutability, and any technological difference could generate a significant profit gain on selling to the internal and external markets. Therefore, the greater would be the incentive to increase the intermediate good's production and raise the technological level of firms.

Lastly, the third point is that there would be a ratio in the terms of trade that would intensify (or attenuate) the effect of the technology gap between firms and between economies. It would imply that depending on the terms of trade and its impact on the relative prices of each intermediate good in the foreign and domestic market we would have a situation in which the domestic country's firm has incentive to export. Of coarse, since it could have positive profit in the external market and despite having zero profit in the domestic market.

From equation 8, the condition that allows each firm to exports and obtain non-negative profit from exporting is given by $n_{jt}^A - n_{2t}^B \geq \log_\lambda \rho_t$ and $n_{jt}^B - n_{2t}^A \leq \log_\lambda \rho_t$, for firms in country and A and B respectively[5]. The higher ρ_t the higher the price of exported intermediate good from firms in country A. Also the greater the profit of these firms and as a consequence, the greater their incentive to sell to the external market *vis-a-vis* to the firms in country B. But if ρ_t is sufficiently small only the leading company in the domestic market could have a significant gain in exporting. Further note that this would not depend on the degree of substitution between the intermediate good from the domestic or foreign country.

Proposition 1 (Existence of international trade)**.** *There will exist trade of intermediate good between two economies if at least one firm obtains non-negative profit by selling to the external market, thus*

$$n_{jt}^A - n_{2t}^B \geq \log_\lambda \rho_t \geq n_{jt}^B - n_{2t}^A, \tag{P1}$$

would be satisfied to at least one firm in each time period. ■

Even the is the domestic market is under perfect competition, so there is no technological gap between the domestic firms, they could have positive profits by exporting. Moreover, the high degree of domestic competition increases the dynamic incentives to invest in innovation. Because each firm has an incentive to invest in new technologies to perpetuate the leadership or establish one, in relation to at least one firm in the foreign market.

When the domestic market is not perfectly competitive, each firm high-tech always have positive profit by selling to its own domestic market and possibly to the external market. However, the firms obtain distinct profits depending on the existence and size of the technological gap in relation to the domestic and external low-tech firm. This higher profit encourages further investment in R&D to maintain the leadership in both domestic and foreign markets. Thus the replacement effect is intensified. Given the interaction between

[5]Curiosily, note that if $n_{jt}^B > n_{2t}^A$ or $n_{jt}^A < n_{2t}^B$ then it would be necessary that $\rho_t > 1$, otherwise for any condition $\rho_t \in (0, 1]$.

markets, the rent dissipation effect would also be higher than in the situation where the economies are closed because the degree of competition is also higher.

Additionally, let μ_1^i denote the steady-state probability of being an unleveled and μ_0^i that it is leveled. This, together with the fact that $\mu_0^i + \mu_1^i = 1$. We then define the optimal allocation or static equilibrium.

Proposition 2 (Optimum Allocation)**.** *The optimal allocation is a sequence of optimal decisions of each firm j in each country i $\{x_{it}^{*i}\}_{t=0}^{\infty}$ and a sequence of optimal wages $\{w_t^*\}_{t=0}^{\infty}$ for a given sequence of optimal prices $\{\tilde{P}_t^{*i}, \bar{P}_t^{*i}\}_{t=0}^{\infty}$ and an initial distribution $\{\mu_0^i\}$ of firms in each country i and each time period t.* ■

Dynamically, the low-tech firms could have some gain in investing in new technologies to increase the technological gap in relation to the firms with even lower technological level or to become a high-tech and thereby achieve greater profitability both domestically and in externally. Moreover, even for the high-tech firms there is an incentive to create new technologies to further increase the gap against other firms, both domestically and internationally.

Note that the static equilibrium provides a partial response to our problem. Firms in developing countries have on average lower technological level, so they have lower profit, on average, than firms in industrialized countries. This would produce lower profits and incentives to raise the technological level and thus attenuate the long-run growth of product. Since economies interact in trade and firms in industrialized countries tend to be more competitive, these firms generate even bigger profits - additional profits from the export market - coming from the developing countries. This further increases the long-run output growth of firms in industrialized countries and also increases the gap in output per worker between industries-countries.

2.3. **Measure of competition.** Before characterizing the equilibrium dynamic of the model, we will define the measure of competition we used in the model and will also be used in the empirical exercise. Suppose the two domestic firms previously characterized were in a *neck-and-neck* situation, if they enter in collusion each could get a fraction $\tilde{\sigma}_t$ of profit as if there were a domestic leader. So we can set $\tilde{\sigma}_t^i = \tilde{\pi}_{0t}^i / \tilde{\pi}_{1t}^i$, where $\tilde{\sigma}_t^i \in [0, 1]$, as a measure of domestic competition among firms, as developed by Boone (2000). Using the same reasoning for the international market if domestic leaders are in a *neck-and-neck* situation internationally and enter in collusion, they would get a fraction $\bar{\sigma}_t$ of the international profit. So we can set $\bar{\sigma}_t^i = \bar{\pi}_{0t}^i / \bar{\pi}_{1t}^i$, where $\bar{\sigma}_t^i \in [0, 1)$, as a measure of international competition among firms. The less diverse are the profits with and without collusion the higher is the competition which means that competition is increasing in these measures.

We take that it is be possible to have low competition in the domestic market and high competition in the international one. The search for export gains could lead the a race for innovation, and as a result, an increase aggregate activity. Define the aggregate competition as $\sigma_t^i = \pi_{0t}^i / \pi_{1t}^i$ such that the above conditions we can construct it as

$$\sigma_t^i = \tilde{\sigma}_t^i \frac{\tilde{\pi}_{1t}^i}{\pi_{1t}^i} + \bar{\sigma}_t^i \frac{\bar{\pi}_{1t}^i}{\pi_{1t}^i}. \tag{9}$$

In other words, the aggregate competition is the sum of the competition levels weighted by the share of net profit obtained in each origin. Thus, the aggregate competition of each country would depend on the domestic competition as well as the external one weighted by the relative profits obtained in each of the sources. The higher (lower) the profit obtained with the internal market relatively to total income, the higher (lower) is the weight of internal competition on aggregate measure. A similar argument is valid for the profit derived from the external market.

2.4. **Dynamic Path and Equilibrium.** Now we characterize the dynamic equilibrium. Define z_{jt}^i is the innovation rate of the firm such that $z_{jt}^i = F\big(h_{jt}^i\big)$, where h_{jt}^i is the number of researchers devoted to R&D in each firm. To increase its technological degree each firm incurs a cost of R&D given by $w_t G\big(z_{jt}^i\big)$. This firm moving one technological step ahead with a Poisson hazard of z_{jt}^i. Addionaly, suppose $F(\cdot)$ is an increasing and strictly concave function subject to the Inada conditions and $G\big(z_{jt}^i\big) \equiv F^{-1}\big(z_{jt}^i\big) = (z_{jt}^i)^2/2$.

Considering the one-step case if in a period of time Δt a high-tech firm is successful in innovating, then it ratifies its domestic leadership and its level of technology goes from $q_{jt}^i = \lambda^{n_{jt}^i}$ to $q_{jt+\Delta t}^i = \lambda q_{jt}^i$. On the other hand, if the low-tech firm is successful in innovating it becomes a high-tech firm domestically

and its technological level goes from $q^i_{-jt} = \lambda^{n^i_{-jt}}$ to $q^i_{jt+\Delta t} = q^i_{jt}$. Considering the interaction with the external country, depending on the size of the innovation produced, on the terms of trade and on the degree of substitutability in the production of final goods, each domestic firm could increase its profit from the intermediate goods exported through the innovation. This would occur even if the domestic firms are under perfect competition.

Proposition 3 (Dynamic Equilibrium)**.** *The Markov Perfect Equilibrium is given by a optimal sequence* $\{z^{*i}_{jt}, \tilde{P}^{*i}_t, x^{*i}_{jt}, w^{*i}_t, Y^{*i}_t\}^{\infty}_{t=0}$ *such that (i) a sequence of price* $\{\tilde{P}^{*i}_t\}^{\infty}_{t=0}$ *and production* $\{x^{*i}_{jt}\}^{\infty}_{t=0}$ *imply that* $\{z^{*i}_{jt}, \tilde{P}^{*i}_t, x^{*i}_{jt}\}^{\infty}_{t=0}$ *satisfies the equations 6 and 7; (ii)* $\{z^{*i}_{jt}\}^{\infty}_{t=0}$ *maximizes the expected profit of each firm given the aggregate output* $\{Y^{*i}_{jt}\}^{\infty}_{t=0}$*, wages* $\{w^{*i}_t\}^{\infty}_{t=0}$ *and the choice of costs with R&D* $\{z^{*i}_{jt}\}^{\infty}_{t=0}$*; (iii) the aggregate output* $\{Y^{*i}_{jt}\}^{\infty}_{t=0}$ *is given by the equation 2; and (iv) the labor market is in equilibrium in every time period given the sequence of wages* $\{w^{*i}_t\}^{\infty}_{t=0}$*.* ■

We now define V^i_{jt} as the steady-state value of each firm of country and r_t as the opportunity cost of production. Specially, V^i_{0t} would refer to the situation in which there is no technological gap between industries in country, that is $n^i_{1t} = n^i_{2t}$. Thus, each firm's decision to innovate for each country can be summarized by the following Bellman functions

$$r_t V^i_{1t} = \pi^i_{1t} - w_t G(z^i_{1t}) + z^i_{1t}(V^i_{1t+1} - V^i_{1t}) - z^i_{2t}(V^i_{1t} - V^i_{0t}) - z^{-i}_{1t}\xi^i_t(V^i_{1t} - V^{-i}_{1t}) - z^{-i}_{2t}\xi^i_t(V^i_{1t} - V^{-i}_{0t}) \tag{10a}$$

$$r_t V^i_{2t} = \pi^i_{2t} - w_t G(z^i_{2t}) + z^i_{2t}(V^i_{0t+1} - V^i_{2t}) - z^i_{1t}(V^i_{2t} - V^i_{0t}) - z^{-i}_{1t}\xi^i_t(V^i_{2t} - V^{-i}_{1t}) - z^{-i}_{2t}\xi^i_t(V^i_{2t} - V^{-i}_{0t}) \tag{10b}$$

$$r_t V^i_{0t} = \pi^i_{0t} - w_t G(z^i_{0t}) + z^i_{0t}(V^i_{1t} - V^i_{0t}) + z^i_{0t}(V^i_{2t} - V^i_{0t}) - z^{-i}_{1t}\xi^i_t(V^i_{0t} - V^{-i}_{1t}) - z^{-i}_{2t}\xi^i_t(V^i_{0t} - V^{-i}_{0t}) \tag{10c}$$

where $\xi^A_t = \rho_t$ and $\xi^B_t = 1/\rho_t$. For the domestic leader - equation 10a - the first and second term represent the operational profit minus the cost with R&D, the third and fourth are the cost of maintaining its leading position in the domestic and international markets respectively, the last term represents the cost of maintaining its leadership in the face of the follower in the international market. Note that the ratio value functions is readjusted by the terms of trade.

For the domestic follower - equation 10b - the intuition is similar. The operational profit minus the cost with R&D, summing the gains of becoming the domestic leader and the gains of having some sort of leadership in the international market. Note, however, that for the domestic follower the profit from the domestic market is zero. Still, the firm may exhibit some positive profit by selling to the external market if there is a sufficiently high technological gap at least in relation to the foreign country's follower. Otherwise, this profit is also zero.

Equation 10c presents the domestic *neck-and-neck* situation with similar intuition as of the follower one. It emphasizes that the domestic firms may be in a *neck-and-neck* situation domestically, but still in the leadership position facing the foreign companies. Therefore, for them it would be worth increasing spendings with R&D to maintain the leadership (domestic market) or conquer it in the foreign market. This would occur even if the *neck-and-neck* situation was held in the internal market, that is the *replacment effect* in the foreign market could be bigger than the effect than the *rent dissipation effect* in the domestic market.

Assume for simplicity that $w_t = \beta = 1$[6]. Using the fact that each firm chooses its R&D spendings that maximize its current value from the system of equations 10 for each country the first order conditions imply that

$$z^i_{1t} = V^i_{1t+1} - V^i_{1t}, \tag{11a}$$

$$z^i_{2t} = V^i_{0t} - V^i_{2t}, \tag{11b}$$

$$z^i_{0t} = V^i_{1t} - V^i_{0t}. \tag{11c}$$

[6]See Aghion et al. (2005) for more details.

From the system of equations in 10 and 11 we have a system with 12 equations. Using our measure of competition σ we can obtain, recursively,

$$z_{0t}^A = -R_t^B + \sqrt{(R_t^B)^2 + 2(1-\sigma_t^A)\pi_{1t}^A + (z_{1t}^A)^2}, \tag{12a}$$

$$z_{2t}^A = -\big(z_{0t}^A + z_{1t}^A + R_t^B\big) + \sqrt{(R_t^B)^2 + 2\big((1-\sigma_t^A)\pi_{1t}^A + \pi_{0t}^A - \pi_{2t}^A\big) + (z_{0t}^A)^2 + (z_{1t}^A)^2} \tag{12b}$$

$$z_{0t}^B = -R_t^A + \sqrt{(R_t^A)^2 + 2(1-\sigma_t^B)\pi_{1t}^B + (z_{1t}^B)^2}, \tag{12c}$$

$$z_{2t}^B = -(z_{0t}^B + z_{1t}^B + R_t^A) + \sqrt{(R_t^A)^2 + 2\big((1-\sigma_t^B)\pi_{1t}^B + \pi_{0t}^B - \pi_{2t}^B\big) + (z_{0t}^B)^2 + (z_{1t}^B)^2}, \tag{12d}$$

where $R_t^i = r_t + (z_{1t}^i + z_{2t}^i)/\rho_t$ can be understood as the opportunity cost expanded by the foreign firms' spendings with innovation in terms of local currency.

The amount spend in the increase of the technological level z_{jt}^i is decreasing on the degree of competition σ_t, similar to Aghion et al. (2005) and Acemoglu and Akcigit (2012). However, adding the international competition, the amount spend with innovation will dependent on the amount foreign firms spend with it in terms of the national currency. This is another reason why z_{1t}^i tends to be non-null. That is, even if the firm has the domestic leadership but not the international one there would be some gain in increasing the technological level. For this reason the *lazy monopolist effect* tends to be lower in the situation where there is trade interaction between economies due to the higher degree of competition between firms. Moreover, even the domestically low-tech firms have a greater incentive to invest in new technologies to profit in potential foreign markets.

From what we have showed the aggregate rate of innovation in each economy is given by: $I_t^i = \mu_{1t}^i(z_{1t}^i + z_{2t}^i) + 2\mu_{0t}^i z_{0t}^i$, where $\mu_{1t}^i + \mu_{0t}^i = 1$. In steady-state the expected value of the spendings with innovation must be equivalent to the share of leveled and unleveled firms. Which means,

$$\mu_{1t}^i(z_{1t}^i + z_{2t}^i) = 2\mu_{0t}^i z_{0t}^i$$

implying on

$$\mu_{0t}^i = \frac{z_{1t}^i + z_{2t}^i}{2z_{0t}^i + z_{1t}^i + z_{2t}^i} \quad \text{and} \quad \mu_{1t}^i = \frac{2z_{0t}^i}{2z_{0t}^i + z_{1t}^i + z_{2t}^i}$$

and we rewrite the aggregate rate of innovation in each country as:

$$I_t^i = \frac{4(z_{1t}^i + z_{2t}^i)z_{0t}^i}{2z_{0t}^i + z_{1t}^i + z_{2t}^i}. \tag{13}$$

Note that from system 12 and equation 13 the aggregate rate of innovation is a profit function. It is also, implicitly, a function of the degree of competition between firms and countries given the optimal allocation of the production factors (as seen in the above subsection).

2.5. **Unbalanced Growth Path.** From what has been characterized in the previous sections the growth rate of each intermediary goods sector is represented as

$$g_{X_t^i} = \iota_t^i g_{\bar{X}_t^i} + (1-\iota_t^i) g_{\tilde{X}_t^i}, \tag{15'}$$

where $\iota_t^i = \tilde{X}_t^i / X_t^i$ represents a fraction of the intermediary product domestically commercialized. From equations 3 and 13 we have that this rate is also given by

$$g_{X_t^i} = \big(\mu_{1t}^i(z_{1t}^i + z_{2t}^i) + 2\mu_{0t}^i z_{0t}^i\big)\log\lambda \tag{14}$$

Thus, the output growth of each firm and industry depends on each firm's production weighted by the distribution of leveled and unleveled firms in each country. Moreover, this growth would depend on the rate of innovation that, by construction, depend on the degree of competition in each industry-country. From equations 2a and 2b the output growth rate is given by

$$g_{Y_t^A} = \lambda^{-n_{2t}^A}\eta_t^A g_{\tilde{X}_t^A} + [\lambda^{n_{2t}^A}\rho_t]^{-\epsilon/\varepsilon}(1-\eta_t^A)(1-\alpha^A) g_{\bar{X}_t^B} \tag{15a}$$

(15b) $$g_{Y_t^B} = \lambda^{-n_{2t}^B}\eta_t^B g_{\tilde{X}_t^B} + [\lambda^{n_{2t}^B}/\rho_t]^{-\varepsilon/\epsilon}(1-\eta_t^B)(1-\alpha^B)g_{\bar{X}_t^A}$$

where $\eta_t^i = \tilde{X}_t^i/Y_t^i$ represents a fraction of domestic intermediary product used as input to the domestic production of final goods.

Therefore, there are three components on the growth rate of each country's final product which depend on the competitive structure of the industries-countries. The first, the price effect arising from the technological gap; the higher the domestic gap the higher the output growth rate. In this case, the leading firm would have higher profitability and thus greater incentives to invest in R&D to further increase its profits. Therefore, the increase in the domestic level of competition inhibit the aggregate growth because it would reduce the technological gap, the profits and, dynamically, the firms' innovative incentives. That means that the search for *rent dissipation effect* would increase the domestic production of final goods.

Second, the economic output growth rate i is increasing in the sum of the firms' technology growth rate weighted by quantity produced by each of them in the total domestic production of the final good, i.e., $g_{X_t}^i$. The interaction between the economies results in the existence of a spillover effect in terms of economic growth due to the effect of export growth. Note that the above effects are weighted by each good demanded fraction in the domestic production of final good, η_t^i. If $\eta_t^i = 1$, there would be no interaction between economies and the aggregate output would be similar to that developed by standard literature $g_{Y_t^i} = g_{X_t^i}$.

Finally, the terms of trade, ρ_t raise the aggregate output growth rate of country A and decrease the rate of country B. The higher the terms of trade the greater the value received from the exported good by the intermediate producer of country A, which means that he makes higher profits in the event of any technological advantage that provides him with non-negative profits.

In summary the competition effect would be implicitly determined in each one of these terms in that the optimal allocation described in the previous subsection implies the existence of non-negative profits for high-tech firms. Thus, through prices, terms of trade or dynamic incentives to raise the technological level (summarized in this quest for profit) competition affects the growth rate of each economy.

Proposition 4 (Existence of unbalanced growth path)**.** *The Markovian equilibrium guarantees that there is a unique unbalanced growth path equilibrium where the different firms of intermediate goods grow at distinct and constant rates.* ■

Proposition 5 (Growht path)**.** *Given the optimal allocation established by equations 2, 6 and 7, the system of equations established by 13, 15' and 15 trace each country's economy's equilibrium path.* ■

Unlike the Aghion et al. (2005) the domestic economy's growth rate of the final product is increased by an interactive effect with the external market. In short, from equation 14 we estimate $g_{Y_t^i} = f(\sigma_t^i)$, where $f(\cdot)$ would have an inverted *U* shape different for each country due to the *escape competition* and the Schumpeterian effects. For low levels of competition the *escape competition* effect would dominate the relationship, because the expected gains of increase in profits is relatively high. Any increase in competition - domestic or international - would cause a rise in profits. Thus, each firm has an incentive to invest in new technologies to further increase its profits. The increased production of intermediate goods and the increase of technology imply an upward trend in the aggregate output. For high levels of competition, the Schumpeterian effect tends to dominate because the expected increase in profits is increasingly low or zero. The increased competition creates a race for production - to meet domestic and international markets demands - and the generation of new technologies to reduce marginal costs. Thus, profitability decreases in competition for high levels of competition and of certain technologies saturation.

There are other two important points about the model. The first refers to the degree of substitutability between goods in the production of final goods for countries A and B. If $\epsilon > \varepsilon$ the greater will be the positive effect of import variations over country A's aggregate output *vis-a-vis* if $\epsilon < \varepsilon$ of country B. If the production of the final good has greater substitutability (or complementarity) in inputs for country A than B then there is an equalization in the prices of inputs such that for the same level of domestic intermediate production intended to the domestic market, the value of the variation of imports rises. Which in the proposed substitutability case causes the growth of the aggregate product. The same would occur if the production in country A was more complementary than the production in country B. If $\epsilon < \varepsilon$ the

smaller the positive effect of the changes in imports on the aggregate product of country A *vis-a-vis* if $\epsilon > \varepsilon$ of country B. In this case, intuition is similar.

The second point relates to the terms of trade ρ_t. Although it raises the relative price of the exported good of firms in country A and, consequently, their profits *vis-a-vis* of firms in country B, the prices of domestic goods equalize with imported goods and this implies a reduction of growth in country A and an increase in country B. In the described situation, although it coexist with the increase of country A's firm's profit the growth would decay because for the same level of competition and technology there would be a reduction of the value of changes in imports. Moreover, the effect of terms of trade would be enhanced by the degree of substitution described above.

In summary from the framework presented here, competition and growth would be correlated in a inverted-*U* shape mainly due to the interaction of the Schumpetarian and escaping competition effects. In the following session we will seek to corroborate empirically the proposed inverted-*U* relationship between competition and growth, as well as demonstrating that this inverted-*U* differs between industries in developing and industrialized countries.

3. Data and measurement issues

In this section we will describe the data used in our empirical exercise as well as the key variables used in the analysis.

3.1. **Data.**

For the comparison between industry-country we used two databases of United Nations Industrial Development Organization (UNIDO).

The Industrial Statistics Database at the 4-digit level of ISIC Code (Revision 3) contains annual time series data for 1990 to 2010 and for 135 countries. The data is arranged at the 4-digit level of the International Standard Industrial Classification of All Economic Activities (ISIC) Revision 3 pertaining to the manufacturing sector, which comprises 151 manufacturing categories. The database contains information on the number of establishments, employment, wages and salaries, output, value added, gross fixed capital formation, and number of female employees. The initial capital stock is imputed as the average of gross fixed capital formation in each sector and country. The data is stored in current US Dollars.

The other database used is the Industrial Demand-Supply Balance Database at the 4-digit level of ISIC Code (Revision 3) pertains to the manufacturing sector and contains data at the 4-digit level, which comprises 127 manufacturing industries. These database contains information on imports and exports from 94 countries/areas for the period 1990-2010. It is important to mention that period coverage as well as item coverage differ from country to country. The database contains annual time-series data on the imports and exports from industrialized, developing and emerging industrial economies. From these variables we construct the total exports and total imports for each industry-country.

Taking this two databases we have a panel with annual data from 121 sub-sectors of the manufacturing sector from 65 countries between 1990 e 2010. Lastly, the nominal variables are deflated by the total product of the manufacturing sector of each country in 2000 year. For some tests we also use aggregate data summarized by Feenstra and Timmer (2013) and Botero et al. (2004). We will be explicit about this additional data as we make use of them throughout the study. It is important to emphasize that we will be working with a small panel that contains missing data. For that reason, specially in the linear regression cases, we will make use of methods to mitigate this problem such as the forward orthogonal deviations suggested by Arellano and Bover (1995).

3.2. **Measurement issues.**

3.2.1. *Growth value added.* We define the rate of output growth of firms in the intermediate sectors in the standard fashion, as the intertemporal difference of the logarithm of value added for each industry-country in time, $g_t^i = \ln X_t^i - \ln X_{t-1}^i$.

3.2.2. *Exchange rate.* We use two measures of exchange rate. The first is constructed from the output value in terms of national currency and of U.S. dollars. So we have a measure of terms of trade ranging from industry-country and also over time. In the second we use the exchange rate provided by the Feenstra and Timmer (2013) that relates domestic currency and U.S. dollars, but that rages only in the country and time.

Our base models are focused on the use of the first measure (terms of trade), whilst the second will be used to check for measurement error, because the variability of the same industry in different countries could be due to changes in prices or other unobservable costs and not necessarily in the terms of trade.

3.2.3. *Measures of competition.* We use two index of competition. The first, from equation 9, establishes a level of competition that depends on production for the domestic and the external markets. For each sector and year we calculate the maximum across all countries and measured how far each industry-country is from the maximum, in terms of profit, in the domestic and external markets. To avoid cases where a industry-country has an excessively higher profit than the average, we have alternative measurements calculated based on the 90 and 75 percentile. We also calculate using the U.S. industries as the benchmark[7]. The second measure is the Competitive Industrial Performance (CIP) index developed by UNIDO. Fundamentally this index combines four measures of competition that vary between countries-sectors.

It is noteworthy that in our empirical exercise we expect the results to be better for the full sample when we use the basic measurement. For the subsample of developing countries, however, we expect the results to be be better when we use the 90th and 75th percentile as the benchmark to the competition measure. This is because the profitability of firms in developing countries is low relatively to the profitability in the developed countries, which would distort our measure of competition. This would also happen when for some industries there are industries-countries with excessively high profitability, usually associated with abundance of a commodity/natural resource. When using the 90 or 75 percentile we do not exclude an excessive number of industries from developing countries and we do not distort competition between them, which makes these alternative measures fit for use. So we reduce the impact of atypical situations and also generate greater variability of competition between industries-countries .

In figure 1 we showed a correlation between the average growth rate of the output's value added of each industry-country and the average of each competition index. Firstly, the competition in the industries of industrialized countries is on average higher than the ones in developing countries. Moreover, for the same level of competition the output growth rate varies mainly in industries of the developing countries[8]. When we use the basic measure of competition, σ^i_{jt}, we have a negative relationship between competition and growth, which suggests that the schumpeterian effect is strong in this correlation. But the inverted-U appears in the subsample of industries in developing countries only changing the baseline.

4. Empirical investigation

4.1. **Econometrics methods and issues.** The existence of the inverted-U and the difference in optimal levels of competition and growth will be tested in this section. Our goal is to show that the industry-countries have different levels of competition and this have implications on their output growth rates.

The equation to be estimated relates the growth rate of value added g^i_{jt} and the competition index σ^i_{jt} such that $g^i_{jt} = f(\sigma^i_{jt}, x^i_{jt}, u^i_{jt})$. Where x_{jt} is a vector of control variables such as time and industry-country dummies, and u^i_{jt} is the error component that has standard properties. In addition, x_{jt} includes observable variables that affect the output growth rate of industries-countries but are not explicit in the model such as the logarithm of initial GDP, investment and human capital. Additionally, we will test the effect of property rights - which would increase the incentive to raise the technological level thus rising competition -, labor regulation - which enhance profits by making labor less costly -, and the effect of civil rights - which contribute to control the different institutional structures in addition to serving as proxy for property rights.

Controlling for variables that affect the output growth rate of industry-country and are not related to competition, we show that there is an *inverted-U* relationship between competition and growth and that it is different in developing versus developed countries. We have some challenges on the econometric point of view such as heterogeneity and nonlinearity of parameters, cross-section dependence, endogeneity and unobserved and constant-in-time effects for each industry-country (Arellano and Bover, 1995; Bond et al., 2010; Ciccone and Papaioannou, 2010).

[7]Ciccone and Papaioannou (2010) states that normalizing the explanatory variable with respect to an industry-country attenuates the bias resulting from the variation within each country.

[8]Probably due to some comparative advantage in a specific sector. For example, the oil industry in Venezuela.

We first estimate the following equation

$$g_{ist} = \alpha\sigma_{ist} + \beta\sigma_{ist}^2 + \gamma E_{it} + \delta x_{ist} + u_{ist}, \tag{16}$$

where $s = \{1, \ldots, S\}$ index industries and $i = \{1, \ldots, N\}$ index countries. The variable E_{it} is the exchange rate and x_{st}^i is a vector of control variables that also include industry, country and time dummies. This vector can include (depending on the specification) the logarithm of the 1990 GDP to control for the wealth and the economic development of each country. Note that we could index the variables by j firms instead of s industries for the N countries as presented in the model. Our observation unit will be on the industry-country level because we are interested in the implication of competition on this level of aggregation. From the econometric point of view this choice generates a smaller variability in the interest variables but we will try to attenuate this problem with the methods suggested by Ciccone and Papaioannou (2010).

We will also introduce a few control variables: (i) an index of human capital per person based on years of schooling and returns to education (Feenstra and Timmer, 2013) to control for the effect of human capital; (ii) a measure of flexibility in the labor market (Botero et al., 2004) that would affect the reallocation of labor and consequently the efficiencies and profits across industries-countries; (iii) and an index of civil rights to control for the effects of each economy's institution on the relationship between competition and growth (Botero et al., 2004).

First, we estimate OLS regressions using each of the proposed competition index for the full sample and then for each subsample of countries (industrialized vs. developing). We also know that industry-country output growth and competition are endogenous. We will use the lag of each control variable previously described as instruments as well as the exchange rate. We use this instruments to estimate a dynamic panel method as suggested by Arellano and Bover (1995) and Blundell and Bond (1998). Furthermore, the Arellano-Bond GMM estimator enable the treatment of two other issues: (i) industry-country fixed effects correlated with the dependent variables, and (ii) the fact that we are working with a small panel. The fact that we use annual data of industries-countries may cause the result to reflect time-series cyclical behavior and not that of the long-run which we would like. Therefore, the use of dynamic panel enable the filtering of high frequency fluctuations.

We expect the OLS and GMM estimates of σ_{ist} to have positive sign and the ones for σ_{ist}^2 to have a negative sign, which characterizes the inverted-*U* shape. From figure 1, we also expect that for developing countries this inverted-*U* has a lower peak and higher positive skewness than the industrialized ones. From the model, the exchange rate should present a positive sign because the higher the exchange rate the lower the price of the domestic good in the international market making this good more competitive in terms of price. This would generate a greater profit expectation and, finally, a higher output growth rate of the resulting industries-countries.

4.2. **Basic results.** Table 2 reports the estimates from the panel regression of equation 16 taking into account the whole sample of countries between 1990 and 2010 not worrying if the country is developing or industrialized and without controlling for this fact (this will be addressed in the next subsection). We emphasize that the equations were also estimated in real terms and we obtained the same pattern of results. In columns (1) we use as explanatory variables only our variables of interest - *exchange* corresponds to the terms of trade, *competition index* e *competition index2* are the competition index and the square of the competition index, respectively. For all specifications the competition index is defined in two fashions: σ and *CPI*, as described in the previous section.

The coefficient estimates associated to the variables *competition index* and *competition index2* are statistically different from zero with positive and negative signs respectively. This correspond to the inverted-*U* format described by the model. The effect of variable *exchange* also meet our expectations. The rise in the terms of trade (or exchange rate) would have a positive effect on the output growth rate of each sector-country to the extent that the domestic products would be relatively cheaper abroad and so, for the same level of competition there would be an increase in the output growth rate of the sector.

In columns (2) we include as control the difference of the logarithm of GDP. This variable control the economy's dynamic behavior such as growth of the service and agriculture sectors (Ciccone and Papaioannou, 2010). Columns (3) controls the effect of changes in the efficiency of the employed worker

because of differences in human capital. In columns (4) we include the logarithm of GDP in 1990. Following the literature, we have that this variable controls the initial differences in the production structure and economic development of countries. The inclusion of the latter variable affects only marginally the magnitude of the coefficients of interest for both specifications of the competition index. Columns (5) contain all controls described previously. These controls are significant, both individually and jointly and present the expected sign.

The results indicate that the inverted-U relationship between growth and competition exists and persists the inclusion of several different control variables as well as changes in the estimation method - Panel A and Panel B. Of the control variables, the log of the initial GDP, variable which capture the country's economic development have a strong effect on this relationship. Furthermore, the relationship holds for different specifications of the competition index. All estimates were also tested using the aggregate exchange rate and the results also hold the same pattern.

It is noteworthy that these results (for the OLS case) have no causal relationship to the extent that competition is clearly endogenous. The theoretical model itself establishes it. Therefore, we use the lag of the explanatory variables in the dynamic panel method. In this method, the obtained autocorrelation is high in all specifications, especially for the first lags, as stated by the Arellano-Bond test for zero autocorrelation in first-differenced errors. We also can not reject the Sargan test of over-identifying restrictions. Thus, the instruments used are strongly correlated with the endogenous variable and, moreover, can not be statistically rejected, which means that the results from the dynamic GMM panel are also valid.

4.3. **Developing versus Industrialized Economies.** In order to establish the different impacts of competition on growth in developing and industrialized countries, we stratified the sample into two groups according to the countries' economic development using UNIDO's classification. We will investigate if indeed the relationship is maintained in the different groups of countries and also what would be the gain in terms of growth for the industries in the developing countries if the degree of competition was elevated to the same level of the respective industries in industrialized countries.

Our hypothesis is that the Schumpeterian effect should occur more rapidly in the industrialized economies that tend to invest more in developing new technologies than in developing economies whose technological progress tends to occur via imitation and incorporation of new technologies. This is because the industries that are more distant from technological frontier tend to benefit more from spillover effects of the technology available in the global technological frontier.

Columns (1) and (5) of table 3 replicate the specification (5) in table 2 using the competition indexes σ and *CPI* respectively, but segregating between developing and industrialized countries. In both subsamples the results are qualitatively similar, except for the dynamic GMM panel specification of *CPI* in developing countries, where the coefficient of interest does not maintain the expected sign. These results corroborate what was observed on figure 1 and show that, on average, there is an inverted-U relationship for many measures of competition and it is distinct among industries-countries.

Following Ciccone and Papaioannou (2010), in column (2) we report the estimates for the case in which the U.S. manufacturing sector is excluded from the regressions and it is used as benchmarks for each respective industry. The results are significant and as expected for panels A and B, in the case of developing countries. For the subsample for industrialized countries, however, the number of observations for this measure of competition drops substantially due to this exclusion of the U.S. industries.

Finally, in columns (4) and (5) we tested two additional specifications for the competition index. We changed the benchmark of the industry failing to consider it the United States manufacturing sector - *usa* columns (3) - or the maximum of each industry - σ columns (1) - substituting it by the 90th and 75th percentiles of the output distribution of each industry. Note that now the reference country is changing between industries. In the case of the static panel, we realized that the results remain significant and with the expected sign. That means that using various measures of competition and control variables there would exist a relationship between competition and growth and this relationship would differ between the industries of developing and industrialized countries.

In table 4 we performed a similar exercise as in table 3 adding as a control the employment laws index and the civil rights index. We expect the industry-country growth to be increasing in both variables to the extent that the more flexible the labor market the better tends to be the allocation of labor and the better should

be the performance of the industry-country output. Moreover, the quality of institutions - summarized by the civil rights index - should reveal the impact of the existence of property rights which should increase the dynamic incentives to innovation, and legal soundness in favor of a more competitive market structure implying that the *rent dissipation effect* was more blunt. However, this pattern was not significant and consistent in the estimates. Thus, it is not possible to state conclusively the effect of these variables on the relationship between competition and growth.

Again the autocorrelation is high in all specifications and subsamples, specially for the first lags, even in the exercise that we include the employment laws index and the civil rights index as control. We also can not reject the Sargan test of over-identifying restrictions. Thus, we have that the instruments used for the subsample are also correlated with the endogenous variable and can not be statistically rejected. Again, the results used in the dynamic panel remain valid. Furthermore, all of these estimates were also tested using the aggregate exchange rate and the results showed the same pattern.

In summary, there is an inverted-U relationship between competition and growth and it is different between developing an industrialized countries. We now verify what would be the gains of economic growth to the manufacturing sector of the developing countries would have if they had the equivalent level of competition of the manufacturing sector of the industrialized countries as well as similar economic conditions (see figure 2). Figure 2 has been parameterized in accordance with the values estimated in the dynamic panel. Thus, for each given level of competition any difference between the growth rates reflects how much economic growth would that country gain compared to the other group of countries.

Primarily, as already mentioned the inverted-U appears in all specifications and estimation methods of σ. Furthermore, the simulations imply that the increase in σ in the industry-countries of developing economies would not reduce the difference of your output gap in relation to industrialized economies. However, for this measure of competition we can not affirm that the optimal level of σ in developing countries is higher. This is so because in the situation where competition results in the greatest growth of value added the difference between the growth rates would still be -0.6% against the industries in developing countries.

However, when we use relative measures we see significant changes. At the same level of competition the output growth rate would be higher in the developing countries industries. Thus, when we exclude some excessively disparate industries (in terms of value added), the increased competition would reduce the output gap between industries in the developing and industrialized countries. However, the magnitude of this reduction would have the shape of the inverted-U. Once we control for economic development, human capital and economic growth as a whole, the figure 2 tells us that for low levels of competition its elevation would have a greater effect on developing economies than on industrialized ones. Nonetheless, as the competition increases the gains become more restricted, even though there is still some improvement in relation to the industrialized countries.

In quantitative terms, the difference between the growth rates across industries-countries when the competition index takes the value 0.5 is equivalent of 0.224%, 0.585% and 1.035%, to σ usa, σ p(90) e σ p(90), respectively, in favor of developing countries industries. That means that when we exclude some outliers industries and we control for economic development, human capital and momentary growth rate of each country, the increased competition among industries-countries tend to enhance the industry-country output growth for developing economies in a higher magnitude than the industrialized economies. Moreover, our results indicate that the optimal level of growth is greater for developing countries. In table 1, we show the gains in terms of economic growth per year to the manufacturing sector of the developing countries would have if they had the equivalent level observed of competition of the manufacturing sector of the industrialized countries as well as similar economic conditions. Thus, according this table, the manufacturing sector of the developing countries accumulate an increase of about 4-6% between 1990-2011, if they had the equivalent level observed of competition of the manufacturing sector of the industrialized countries.

5. Conclusion

This study attempted to show how competition and output growth are related. Departing from the theoretical framework developed here, this correlation would be different and dependent on the distance that each industry-country is to the technological frontier and on the terms of trade.

Our results imply that there is an inverted-U relationship between competition and the growth rate of the output across industry-countries using a competition index based on relative profits of industry-countries. We also find that this relationship is distinct among developing and industrialized economies. Since on average the industries in the developed countries tend to present higher levels of competition even when we control by the terms of trade and the characteristics of each industry-country, if each industry in the developing countries had the same level of competition of the respective industry in the developed ones, we estimate that their product growth would rise substantially.

We present here a channel to explain the difference between output per capita across countries. Industrialized countries tend to have more competitive markets, so there is greater dynamic incentives to raise their production. Both by developing new and better technologies that reduce costs and raise profits and also by searching new consumer markets given the possibility of gains in international trade. However, in developing countries the low technological level, as well as the productive inefficiencies and idiosyncratic malfunctioning of the production system would result in less competitive industry-countries and under determined output growth rates Acemoglu et al. (2006). Lastly, it would contribute to the maintenance of the gap in the per capita GDP between economies.

Finally, it's worth to mention that from the point of view of corroboration of the constructed theoretical framework, we are estimating a linear relationship when the parameters of the theoretical model itself indicate a non-liner relationship, making this the main focus regarding the next steps on this work. We plan to estimate a non-linear relation that relates the different measures of competition used here, and thus ascertain how the results behave.

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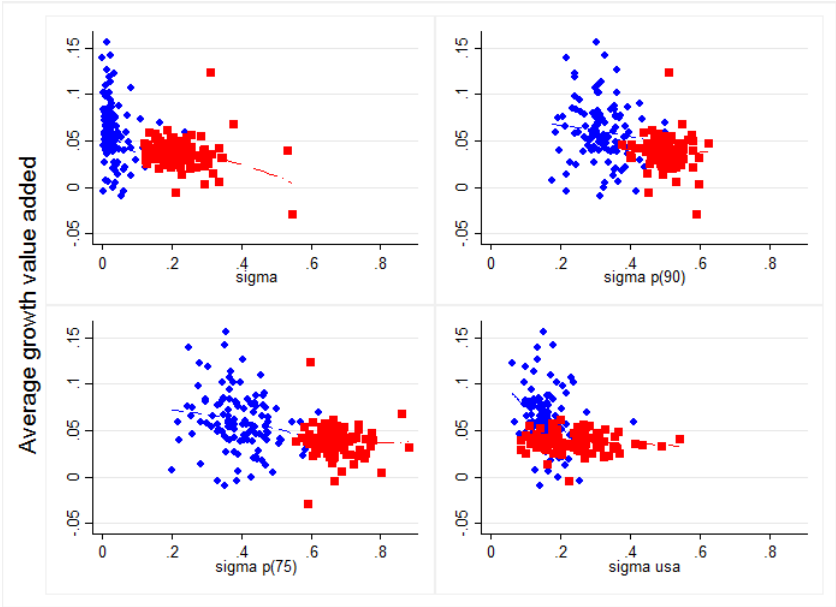
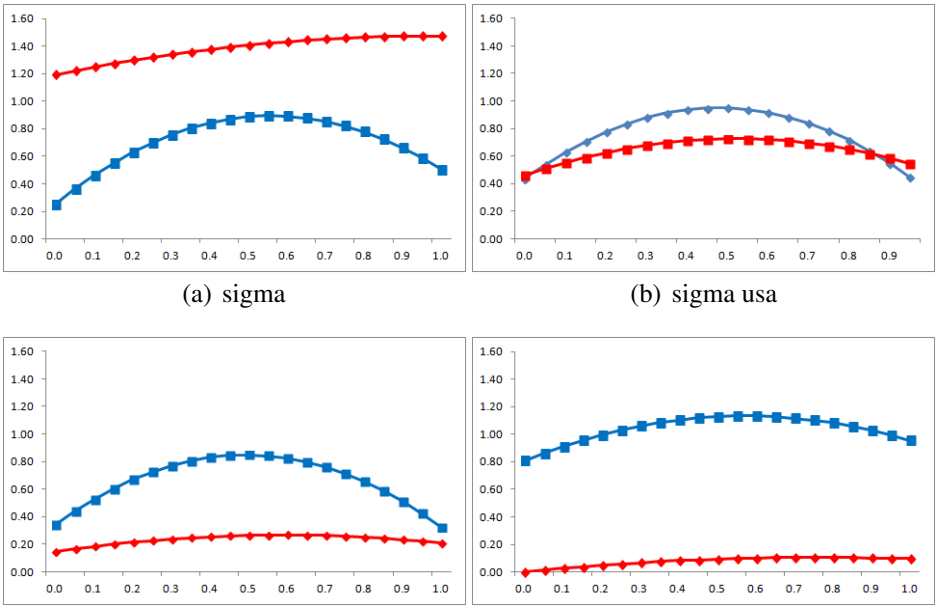
FIGURE 1. Growth x Competition



■ Developing & emerging industrial economy ■ Industrialized economy.

FIGURE 2. Simulation



(a) sigma (b) sigma usa

(c) sigma p(90) (d) sigma p(75)

■ Developing & emerging industrial economy ■ Industrialized economy.

Note: Simulations from the parameters of the Dynamic panel.

TABLE 1. Simulation II

Competition index	Developing & emerging industrial economy	Industrialized economy	Gains in growth rate
σ	.0278	.1244	.1905
$\sigma\ p(90)$	.0865	.3300	.2890
$\sigma\ p(75)$	.1936	.5471	.1418
$\sigma\ usa$	.0371	.1438	.1856

Note: Second and third columns show the average between 1990 and 2011 from each competition index and its group of countries. Gains in growth rate represents how much in terms of economic growth to the manufacturing sector of the developing countries would have if they had the equivalent level observed of competition of the manufacturing sector of the industrialized countries as well as similar economic conditions.

TABLE 2. Basic results

	σ					CPI				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
Panel A: OLS Panel with fixed effect (industry-coutnry) and time effect										
competition_index	0.225***	0.221***	0.227***	0.178***	0.177***	1.601***	1.651***	1.737***	1.138***	1.073***
	(0.0364)	(0.0363)	(0.0346)	(0.0361)	(0.0352)	(0.136)	(0.136)	(0.132)	(0.144)	(0.141)
competition_index2	-0.191***	-0.188***	-0.192***	-0.154***	-0.154***	-3.099***	-3.251***	-3.331***	-1.958***	-1.834***
	(0.0360)	(0.0360)	(0.0342)	(0.0357)	(0.0348)	(0.351)	(0.351)	(0.338)	(0.368)	(0.357)
exchange	0.333***	0.339***	0.302***	0.171***	0.207***	0.147***	0.154***	0.131**	0.0752	0.142***
	(0.0519)	(0.0519)	(0.0521)	(0.0528)	(0.0533)	(0.0512)	(0.0512)	(0.0513)	(0.0532)	(0.0536)
controls:	none	dlGDP	hc	lGDP90	all	none	dlGDP	hc	lGDP90	all
year dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Number of id	39,156	39,123	37,267	30,775	29,607	41,458	41,425	39,348	32,314	30,928
Number of groups	3,293	3,290	3,133	2,412	2,330	3,294	3,291	3,134	2,413	2,331
chi2	2495	2576	2495	1802	2038	2632	2763	2683	1910	2186
R2	0.0602	0.0621	0.0631	0.0556	0.0648	0.0600	0.0628	0.0641	0.0561	0.0664
Panel B: GMM Dynamic Panel										
competition_index	0.568***	0.567***	0.676***	1.037***	0.992***	1.441***	1.658***	2.797***	1.047***	1.409***
	(0.0245)	(0.0243)	(0.0280)	(0.0397)	(0.0395)	(0.0481)	(0.0495)	(0.0688)	(0.0416)	(0.0486)
competition_index2	-0.444***	-0.442***	-0.516***	-0.808***	-0.730***	-4.418***	-5.033***	-7.019***	-2.007***	-2.668***
	(0.0261)	(0.0259)	(0.0281)	(0.0358)	(0.0347)	(0.149)	(0.153)	(0.177)	(0.0986)	(0.102)
exchange	1.158***	1.133***	1.329***	1.006***	1.342***	0.489***	0.438***	0.171***	0.536***	0.460***
	(0.0516)	(0.0513)	(0.0563)	(0.0482)	(0.0575)	(0.0247)	(0.0255)	(0.0248)	(0.0248)	(0.0240)
controls:	none	dlGDP	hc	lGDP90	all	none	dlGDP	hc	lGDP90	all
year dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Number of id	31,124	31,091	29,486	24,662	23,583	32,804	32,771	31,037	25,824	24,617
Number of groups	3198	3195	3038	2405	2323	3200	3197	3040	2407	2325
chi2	18721	18710	21162	30281	38121	13916	14481	17624	23989	29339
Number of instruments	619	620	620	619	621	619	620	620	619	621
Arellano-Bond test order 1	-5.239	-5.198	-4.408	-3.920	-3.556	-5.162	-5.123	-4.335	-4.231	-3.786
Arellano-Bond test order 2	-1.875	-1.866	-1.723	-1.711	-1.462	-1.939	-1.878	-1.970	-1.822	-1.799
Sargan test	1328	1325	1323	1103	1123	1820	1812	1785	1484	1444

Note: Standard errors in parentheses. $***p < 0.01$, $**p < 0.05$, $*p < 0.1$. $dlGDP$ is a Growth rate of GDP, hc is an index of human capital and $lGDP90$ is a GDP in 1990.

TABLE 3. Basic results for countries

	Developing & emerging industrial economy					Industrialized economy				
	σ	σ usa	σ 90th	σ 75th	CPI	σ	σ usa	σ 90th	σ 75th	CPI
Panel A: OLS Panel with fixed effect (industry-coutnry) and time effect										
competition_index	0.913***	0.547***	0.449***	0.232**	2.379***	0.142***	0.136***	0.0967***	0.0526**	1.186***
	(0.178)	(0.157)	(0.117)	(0.0993)	(0.668)	(0.0248)	(0.0304)	(0.0208)	(0.0211)	(0.115)
competition_index2	-1.387***	-0.637***	-0.487***	-0.220**	-6.002***	-0.109***	-0.136***	-0.0831***	-0.0303*	-1.759***
	(0.238)	(0.161)	(0.119)	(0.0930)	(2.294)	(0.0238)	(0.0287)	(0.0184)	(0.0175)	(0.260)
exchange	0.0977	0.0849	0.135	0.114	-0.0707	0.429***	0.791***	0.420***	0.410***	0.324***
	(0.113)	(0.109)	(0.112)	(0.112)	(0.118)	(0.0622)	(0.103)	(0.0616)	(0.0615)	(0.0620)
controls:	all	all	all	all	all	all	all	all	all	all
year dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Number of id	7,400	5,616	7,691	7,691	7,691	22,207	15,185	23,235	23,235	23,237
Number of groups	670	623	671	671	671	1,660	1,431	1,660	1,660	1,660
chi2	310.3	268.6	292.4	280.2	296.6	3968	2978	4045	4035	4198
R2	0.0411	0.0467	0.0373	0.0358	0.0379	0.153	0.165	0.149	0.149	0.154
Panel B: GMM Dynamic Panel										
competition_index	2.283***	2.146***	2.047***	1.131***	0.501***	0.576***	1.018***	0.407***	0.271***	1.673***
	(0.00173)	(0.139)	(0.0256)	(0.0366)	(0.0155)	(0.0259)	(0.0840)	(0.0290)	(0.0279)	(0.0376)
competition_index2	-2.033***	-2.247***	-2.065***	-0.985***	2.845***	-0.295***	-0.977***	-0.344***	-0.177***	-2.685***
	(0.00174)	(0.139)	(0.0258)	(0.0344)	(0.0456)	(0.0226)	(0.0798)	(0.0256)	(0.0223)	(0.0691)
exchange	0.657***	0.870***	0.687***	0.694***	0.0353***	1.276***	0.569***	1.132***	1.010***	0.538***
	(0.00150)	(0.0643)	(0.0200)	(0.0239)	(0.00288)	(0.0545)	(0.100)	(0.0532)	(0.0494)	(0.0250)
controls:	all	all	all	all	all	all	all	all	all	all
year dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Number of id	5628	4583	5799	5799	5799	17955	13726	18818	18818	18818
Number of groups	668	622	670	670	670	1655	1425	1655	1655	1655
chi2	1.690e+11	7418	1.426e+06	1.124e+06	3.170e+09	25045	5894	13745	13268	27103
Number of instruments	615	280	616	616	616	621	280	621	621	621
Arellano-Bond test order 1	-2.426	-7.508	-2.571	-2.535	-2.667	-10.66	-14.40	-11.50	-11.52	-11.21
Arellano-Bond test order 2	-1.539	0.0325	-1.831	-1.629	-1.940	-0.387	-0.331	-0.690	-0.541	-0.515
Sargan test	580.7	349.6	610.6	607.9	640.7	1001	554.9	991.1	954.3	1233

Note: Standard errors in parentheses. $***p < 0.01$, $**p < 0.05$, $*p < 0.1$. The controls are: a Growth rate of GDP, an index of human capital and a GDP in 1990.

TABLE 4. Basic results for countries II

	Developing & emerging industrial economy					Industrialized economy				
	σ	σ usa	σ 90th	σ 75th	CPI	σ	σ usa	σ 90th	σ 75th	CPI
Panel A: OLS Panel with fixed effect (industry-coutnry) and time effect										
competition_index	0.894***	0.557***	0.451***	0.241**	2.286***	0.141***	0.140***	0.0991***	0.0537***	1.165***
	(0.185)	(0.164)	(0.122)	(0.104)	(0.713)	(0.0243)	(0.0293)	(0.0205)	(0.0208)	(0.113)
competition_index2	-1.371***	-0.647***	-0.486***	-0.226**	-5.796**	-0.109***	-0.137***	-0.0847***	-0.0307*	-1.728***
	(0.246)	(0.168)	(0.123)	(0.0968)	(2.432)	(0.0233)	(0.0277)	(0.0181)	(0.0172)	(0.256)
exchange	0.0749	0.0757	0.108	0.0870	-0.0877	0.405***	0.747***	0.398***	0.387***	0.301***
	(0.117)	(0.113)	(0.115)	(0.115)	(0.121)	(0.0620)	(0.105)	(0.0614)	(0.0614)	(0.0619)
employment laws index	-0.432	0.415	-0.698	-0.845	-0.709	0.178***	-0.00349	0.149***	0.152***	0.0811***
	(1.105)	(1.271)	(1.068)	(1.068)	(1.066)	(0.0326)	(0.255)	(0.0312)	(0.0311)	(0.0312)
civil rights index	-2.361	2.662	-4.350	-5.606	-4.673	-0.292	0.0837	0.00541	-0.0519	-0.366*
	(7.359)	(8.580)	(7.085)	(7.086)	(7.078)	(0.204)	(0.358)	(0.198)	(0.197)	(0.198)
controls:	all	all	all	all	all	all	all	all	all	all
year dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Number of id	6,922	5,233	7,210	7,210	7,210	21,703	14,713	22,697	22,697	22,699
Number of groups	625	580	626	626	626	1,616	1,389	1,616	1,616	1,616
chi2	302.2	258.8	286.0	275.1	287.2	4905	3176	4926	4914	5082
R2	0.0427	0.0483	0.0389	0.0375	0.0391	0.161	0.179	0.157	0.156	0.162
Panel B: GMM Dynamic Panel										
competition_index	2.173***	2.247***	2.030***	1.150***	0.418***	0.601***	0.905***	0.425***	0.307***	1.664***
	(0.00160)	(0.147)	(0.0177)	(0.0245)	(0.00653)	(0.0260)	(0.0849)	(0.0286)	(0.0283)	(0.0393)
competition_index2	-1.956***	-2.367***	-2.044***	-0.992***	3.102***	-0.303***	-0.873***	-0.357***	-0.204***	-2.711***
	(0.00157)	(0.146)	(0.0177)	(0.0229)	(0.0183)	(0.0225)	(0.0804)	(0.0250)	(0.0223)	(0.0734)
exchange	0.644***	1.173***	0.642***	0.622***	0.0310***	1.294***	0.756***	1.186***	1.143***	0.544***
	(0.00163)	(0.0863)	(0.0149)	(0.0178)	(0.00176)	(0.0555)	(0.110)	(0.0553)	(0.0536)	(0.0252)
employment laws index	0.510***	3.039***	-0.0152	-0.475***	0.154***	0.0502**	0.0745	0.0632***	0.157***	-0.00226
	(0.0143)	(0.192)	(0.0220)	(0.0323)	(0.00139)	(0.0199)	(0.0457)	(0.0196)	(0.0201)	(0.00563)
civil rights index	0.964***	1.409***	0.129***	-0.602***	0.0868***	-0.0201	0.172**	0.101***	0.0398	0.0948***
	(0.0152)	(0.171)	(0.0228)	(0.0289)	(0.00234)	(0.0298)	(0.0817)	(0.0299)	(0.0316)	(0.0115)
controls:	all	all	all	all	all	all	all	all	all	all
year dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Number of id	5242	4286	5410	5410	5410	17536	13310	18377	18377	18377
Number of groups	623	579	625	625	625	1611	1383	1611	1611	1611
chi2	1.660e+11	8624	3.821e+06	2.795e+06	6.260e+09	25352	5927	14506	13735	28832
Number of instruments	615	280	616	616	616	621	280	621	621	621
Arellano-Bond test order 1	-2.424	-7.393	-2.552	-2.526	-2.659	-10.13	-13.82	-10.95	-10.95	-10.62
Arellano-Bond test order 2	-1.577	0.188	-1.807	-1.587	-1.898	-0.472	0.287	-0.520	-0.391	-0.522
Sargan test	547.1	337.7	586.5	576.7	601.9	1016	558.0	974.4	942.6	1245

Note: Standard errors in parentheses. $***p < 0.01$, $**p < 0.05$, $*p < 0.1$. Note: Standard errors in parentheses. $***p < 0.01$, $**p < 0.05$, $*p < 0.1$. The controls are: a Growth rate of GDP, an index of human capital and a GDP in 1990. Employment laws index measures the protection of labor and employment laws as the average of: Alternative employment contracts; Cost of increasing hours worked; Cost of firing workers; and Dismissal procedures. Civil rights index measures the degree of protection of vulnerable groups againts employment discrimination as the average of the preceding five variables.