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Endogenous Technological Progress and Structural Transformation of Production and Trade

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Abstract. This paper intends to build up a theoretical model that explains the available empirical evidence regarding the relationship that links technological progress with the structural transformation of production and trade. The proposed model is based on the assumption that technological progress takes the form of improved capital inputs, and that the human capital is an essential factor in technology absorption proceses. It suggests that the capital intensity of production increases when technology improves. It suggests also that competitive advantages/disadvantages of a certain country depends upon technology gaps as well as wage gaps that do exist between that country and its trading partners.

Introduction

The developed world has witnessed over the twentieth century a persistence of positive per capita income growth rates, which have been accompanied by continuous technological advancements in all productive respects [1, pp.1-47, 2, 3, pp.5-9]. They were accompanied also by an increase in the share of human capital in the total labor force and with a noticeable decline in the effective cost of capital, which led to a structural transformation of production and trade patterns in favor of capital- and technological-intensive products [4-6].

Moreover, technological advancements have promoted and enlarged,among the others, international flow of products including producer –capital inputs [7].
In addition, wages and standards of living have been sharply improved [3, p. 5, 8].

This study attempts to design a theoretical model, through which we could explain structural transformation of production and patterns of trade that may take place in response to technological improvements.

That will be done by providing an innovative approach where new investments in physical capital when combined with human capital help in fostering the absorption process of new and improved production techniques.

The study utilizes and benefits from recent writings of others in all respective fields especially in the field of endogenous growth theory.

The proposed model considers heterogeneous distributions of technological capacities among countries in determining the base for patterns of competitive advantages / disadvantages by referring to productivity and wage gaps that do exist among such countries.

The available empirical evidence discussed above supports all findings and predictions of the proposed model.

1. Literature Review

Technology is widely considered by many economists as the engine of long-run growth [7, 9]. According to Solow and Swan [10, 11] neoclassical economic growth model, fixing technology levels inhibit per capita income and consumption from growing in the steady state where the economy reaches its long-run capital–labor ratio; which should be consistent with its saving rate. This was attributed to the diminishing returns of accumulative investments (Inada Conditions).

Higher saving rates and better production arrangements as well as lower population growth rates tend to raise levels of per capita variables, but their long-run growth rates remain zero [10, 11].

In contrast to the above predictions, empirical evidence shows that positive rates of per capita growth can persist over decades and centuries. United States of America and Western European countries are among those who achieved positive per capita growth rates over the twentieth century [3, pp.1-8].

Hence, economists recognize that continuous improvement in technology is the key factor, which explains the persistence of long-run per capita growth rates. To reconcile theory with the empirical evidence, the neoclassical growth model is expanded to include a labor-augmenting technology, but without explaining how such a technology improves over time. Hence, technological progress is considered to be exogenously determined.

Recent work in the field of economic growth theory pioneered by Romer and Lucas, and by many other economists attempted to determine sources of technological progress and to explain how it affects production processes. To serve that purpose, different assumptions have been made to endogenize technological progress into the proposed models in order to explain long-run per capita growth. Thus, such models became to be known as "endogenous economic growth models" [9, 12, 13].

Assumptions of endogenous growth models vary from one model to another, depending on hypothesized forms of technological progress on one hand and on the competitive structure of the economy on the other hand.

Lucas [12] growth model emphasizes the accumulation of human capital in generating sustained long-run per capita growth. This would occur because the human capital is assumed to prevent diminishing returns to the broad concept of capital. Per capita growth rate in output tends to increase when human capital becomes relatively more abundant. Steady-state per capita growth rates will be achieved only when human- and physical capital grows proportionally. The role of human capital in enhancing economic growth has been also emphasized by very recent theoretical and empirical studies [8; 14-17].

Romer [9] assumes in his growth model that technological progress takes the form of expanding producer intermediates. According to this model, there is an infinitely number of not yet designed capital intermediates, and that already invented intermediates are conveying technical knowledge that is partially excludable. To invent/innovate new intermediates, firms should utilize the accumulated stock of technical knowledge combined with human capital. Thus, technological progress results mainly from things that people are doing intentionally by devoting some resources for research and development activities in the hope of designing a new capital intermediate that is of a commercial value.

Models of Grossman and Helpman [13], and that of Aghion and Howitt [18] retain the same basic assumptions made by Romer (1990), but they differ in that technological progress occurs when firms improve vertically the quality of available capital intermediates. Continuous movements on the quality ladder of capital intermediates generate long-run per capita growth [13, 18].

Other models in the literature of endogenous economic growth theory make use of Arrow's [19] approach of "learning by doing" or more explicitly "learning by investing". This approach is built up on the argument that investment process in physical capital enable firms to learn simultaneously how to produce more efficiently, and thereby to generate more technical knowledge as a side product. Such knowledge will spill over as a non-rival and non-excludable production factor across the whole economy [19]. Hence, assumptions of perfect competition were retained by such models in describing how technology improves in a decentralized manner over long periods.

Most economic growth models reviewed above treat countries (at least in the original version) as if they were closed economies. So they did not explicitly emphasize the fact that technology diffuses across countries in different forms and channels such as through personal contacts, technical journals, foreign investment, products exchange, etc. [7, 20].

Technological progress in one country depends not only on that country's efforts to innovate and to imitate others, but also on its capacity to exploit the available world-wide pool of technical knowledge [21].

Moreover, that models have described the production of final goods by a one–sector model, which makes the analysis of transitional dynamic changes unable to describe endogenous structural changes accompanying asymmetric rates of technological progress, which are attained by different economic sectors, either within one economy or across different economies.

In an attempt to describe domestic structural changes when technology improves, Ishikawa introduced a model of three sectors: two sectors for final-goods production, and the third for capital-services production. Final-goods production includes two types of products, agricultural and manufacturing.

Agricultural products are produced by the use of land as a specific factor and labor as a mobile factor. Manufacturing products, on the other hand, are produced by the use of capital service as a specific factor, and they use also labor; with each product has its own factor intensities.

As new designs of capital services will be invented and produced, labor productivity and hence wages tend to grow. This would make capital relatively cheaper. Firms in the manufacturing sector will shift their production from labor-intensive products towards higher capital–intensive products. The production of the traditional (agricultural) products will shrink continuously [22].

Similar results have been found by Nelson and Pack [23] regarding the fast-growing Asian economies over the period (1960-1996). They found in particular that these economies were subject to structural changes and sectoral shifts in specialization towards higher usage of capital [23].

Fisher [24] developed a two–sectoral AK model[1] for two trading countries that have identical technologies and preferences, but they differ in their saving behavior. He concludes by his analyses that the thrifty country (the country with a higher saving rate) tends in an overlapping-generation context to accumulate capital, which is used intensively in producing technology–intensive differentiated products; while the other country with the lower saving rate tends to specialize in the production of labor-intensive

[1] This is based upon the works of Jones and Manuelli [28] and Rebelo[29].

goods [24].

Grossman and Helpman [7, 13] developed a model of three sectors: one for traditional goods with weak or no prospects for technological progress, and another sector for high-technological products. The third sector describes research activities. Two factors of production are assumed here, skilled labor -human capital-and unskilled -raw- labor.

The research sector is the most human-capital intensive sector followed by the technological–products sector. In a world of two trading countries, patterns of comparative advantage are to be determined according to relative factor endowments, exactly as in the static Heckscher-Ohlin model. Human-capital rich country specializes in producing high-technology products, while unskilled-labor abundant country specializes in producing traditional goods [7].

Stocky [25], Lucas [26] and Bond and Trask [27] have drawn similar conclusions as to that reached by Grossman and Helpman, although they followed different approaches in building up their theoretical models [25, 26, 27, pp. 211-240].

2. The Basic Model

General description

We assume here that the industrial sector is composed of two industries, M_1 and M_2, where M_2 represents the capital-intensive sector.
We also assume that the production functions of both industries take the following forms:

$$M_1 = L_1^{1-\alpha} Z_1^{\alpha} \tag{1}$$

$$M_2 = L_2^{1-\delta} Z_2^{\delta} \tag{2}$$

M_1 and M_2 represent respectively the output levels of industry 1 and industry 2, while L_1 and L_2 are labor levels employed by those industries. Z is the quality-adjusted capital stock.

Each industry is composed of some number of competitive firms, which exhibit constant returns to scale with respect to L and Z. Since M_2 is assumed to be more capital intensive than M_1, it follows that δ should be greater than α.

Prices of final products as well as prices of capital goods will be assumed constant in real terms and exogenously determined. Smallness of the economy and free competition in world market, including the domestic market, justify such assumptions.

Producers of final products have the incentive and tend to use in each period the latest available up-graded pieces of capital. This would eventually be the case because new designs or improved designs of capital goods will be supplied in world markets at relatively constant prices (in real terms), where at the same time they tend to augment factor productivities as will be shown later below. Thus, final-goods producers will consider old-designed capital inputs as obsolete when adding to or replacing existing capital stock (the creative-destruction effect)[2].

Based upon the above discussion, quality-adjusted investment flows made by final-goods producers will follow a time-sequential of the following form:

$$Z_0 = q_0 I_0$$

$$Z_1 = q_1 I_1 + q_1 I_0 = q_1 (I_1 + I_0)$$

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

$$Z_T = q_T I_T + q_T I_{T-1} + \ldots + q_T I_0 = q_T \sum_{t=0}^{T} It = q_T K_T \quad (3)$$

Where Z remains as defined before.
Subscripts refer to time periods (t), beginning from time period zero to the current time period T.
q is a capital quality index. As time passes, quality improves which means that:

$$q_T > \ldots > q_1 > q_0$$

q_0 is assumed to equal one.
I_t indicates new additions to already existing capital stocks -net investments- that take place during period t.
K_T represents the conventional capital stocks, which has been accumulated up to date.

Technology improves in this model by moving along the quality ladder, that

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[2] This specific argument is based upon the works of Aghion and Howitt [18] and that of Grossman and Helpman [13], where quality-enhancement innovators retain a temporal monopoly power which enables them to charge a price equal to a fixed markup over the fixed marginal cost of capital production. The fixed markup equals to the inverted price elasticity of demand ($1/\alpha$ in M1).

Since the marginal cost of a new innovative and a higher productive capital input is assumed to be equal to that of the next lower-quality substitute, it will be easy for new innovators to drive old competitors out of the market.

usually takes place in technology-frontier economies.

Technology-receiving countries, including the country under study, may absorb and do use only a subset of already improved capital pieces in a rate that is proportional to their investment expenditures on physical capital. In other specification:

$$\left[\frac{\dot{q}}{q}\right] = \phi \; I_t \qquad (4)$$

With $\phi > 0$

$\dot{q}$ denotes quality improvements. ϕ is an absorption efficiency parameter, whose value depends on the capacity of the receiving country in terms of human-capital availability and other country-specific factors, in addition to the presence/absence of market distortions. Abundance of human capital and less presence of market distortions, for instance, result in a higher value of ϕ.

Equation (4) could be reformulated as the following first-order differential equation:

$$\dot{q}_t = \phi \; It \; q_t \qquad (5)$$

Which yields the following mathematical solution:

$$q_t = q_0 \, e^{\phi K_t} = e^{\phi K_t} \qquad (6)$$

This equation suggests that quality, and thus technology, in receiving countries is improving over time in an exponential manner in a rate that depends positively on the density of investments, and on the absorption efficiency parameter.

The higher the absorption capacity of the country and its investments, the larger would be the subset of diffused innovations.

Substituting back our results into the production functions of M_1 and M_2 [3]:

$$M_1 = L_1^{1-\alpha}\left[q_1 K_1\right]^{\alpha} = (q_1)^{\alpha} L_1^{1-\alpha} K_1^{\alpha} \tag{7}$$

$$M_2 = L_2^{1-\delta}\left[q_2 K_2\right]^{\delta} = (q_2)^{\delta} L_2^{1-\delta} K_2^{\delta} \tag{8}$$

$$M_1 = (e^{\phi K_1})^{\alpha} L_1^{1-\alpha} K_1^{\alpha} \tag{7}$$

or

$$M_2 = (e^{\phi K_2})^{\delta} L_2^{1-\delta} K_2^{\delta} \tag{8}$$

It becomes clear from the above equations that production functions exhibit increasing returns to scale with respect to labor and capital because the augmenting factor q is an increasing function in physical and human capital.

It follows that the production functions can not be concave over K and L. The replication argument will not hold because $M_i(\lambda Li, \lambda Ki) > \lambda M_i(L_i, K_i)$, for i =1, 2. λ is a multiplicative factor.

This means that firms would not survive if K and L will be paid their value of marginal products (VMP). Euler's Theorem does not apply in such a case [4].

To maximize profit (π), firms care about the actual cost of hired capital and labor on one hand, and about their effective performance in the production process on the other hand.

Formally; firms of industry 1, for instance, are seeking to:

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[3] The subscript T has been dropped out just to make mathematical expressions seem more simple and clear. Subscripts associated with q denote capital quality levels prevailing in either industry 1 or 2.

[4] To prove that, substitute for the marginal productivities of labor and capital for industry 1. for instance, by referring to equations 7`and 8` to find that:

$$L_1\left[(1-\alpha)\frac{M_1}{L_1}\right]+K_1\left[\alpha\left(\frac{M_1}{K_1}\right)+\alpha\phi M_1\right] > M_1$$

A similar result applies equally to industry 2.

$$\underset{L_1, Z_1}{\text{Maximize}} \quad \pi_1 = P_1\left[L_1^{1-\alpha} Z_1^{\alpha}\right] - W_1 L_1 - C_{Z1} Z_1 \tag{9}$$

The first–order condition implies that[5]:

$$P_1(1-\alpha)\left(\frac{M_1}{L_1}\right) = W_1 \tag{10}$$

$$P_1\alpha\left[\frac{M_1}{Z_1}\right] = C_{Z_1} \tag{11}$$

and

A similar derivation for industry 2 yields:

$$P_2\,(1-\delta)\left[\frac{M_2}{L_2}\right] = W_2 \tag{12}$$

and

$$P_2\,\delta\left[\frac{M_2}{Z_2}\right] = C_{Z_2} \tag{13}$$

Where P, W, and C_Z are denoting respectively the final-product price, the wage rate, and the cost of effective capital.

Profit-maximizing firms tend in equilibrium to equate the VMP of labor and effective capital with their respective costs.

The cost of the effective capital in reality is equal to actual payments received by capital inputs. In other terminology;

The cost of effective capital = The actual payments to capital inputs, or

[5] Since the production function is concave in Z and L, the second-order condition of the maximum problem is likely to be met.

$$C_Z\,Z = P_K\ K \tag{14}$$

Substituting for Z in the above equation:

$$C_Z\,(q.K) = P_K.K, \text{ or } C_Z = \frac{P_k}{q} \tag{15}$$

It becomes obvious now that when technology improves –as q gets larger-, the unit cost of effective capital (C_Z) becomes lower; remembering that P_K is constant.

Substituting for M, Z, q and C_Z in equations 11 and 13, the following result will be reached:

$$P_K = P_1\,\alpha\left[\frac{M1}{K1}\right] = P2\,\delta\left[\frac{M2}{K2}\right] \tag{16}$$

Referring back to equation7`, we find that the VMP of capital in sector 1, for instance, is equal to:

$$VMPK_1 = P_1\,\alpha\left[\frac{M_1}{K_1}\right] + P_1\,\alpha\,\phi\,M_1 \tag{17}$$

It is clear from the above two equations (16 and 17) that the price of capital (P_K) falls short of the VMP_{K1} by an amount equal to the term ($p_1\ \alpha\phi$ M1).
Hence, capital will not receive a payment in equivalence to its value of marginal product. This occurs because accumulation of advanced capital pieces adds a positive externality, which acts as a non-rival input that receives no compensations.

A similar conclusion could be drawn regarding sector 2.
This result combined with the result that labor productivities and wage rates tend to increase as q rises (equations 10 and 12), suggest that firms will in the long-run equilibrium increase the capital intensity of their production processes.

According to equations 10, 12 and 16, the optimal levels of labor and capital that would be demanded by firms in industry 1 and industry 2 will be as the following:

$$L_1 = P_1\ (1-\alpha) \left[\frac{M_1}{W_1}\right] \tag{18}$$

$$L_2 = P_2\ (1-\delta) \left[\frac{M_2}{W_2}\right] \tag{19}$$

$$K_1 = (\frac{\alpha\, P_1}{P_K})\, M_1 \tag{20}$$

$$K_2 = (\frac{\delta P_2}{P_K})\, M_2 \tag{21}$$

Accordingly, the capital-labor ratios of both industries will be as the followings:

$$\frac{K_1}{L_1} = \frac{\alpha}{1-\alpha}\left[\frac{W_1}{P_K}\right] \tag{22}$$

$$\frac{K_2}{L_2} = \frac{\delta}{1-\delta}\left[\frac{W_2}{P_K}\right] \tag{23}$$

The last two equations demonstrate clearly that capital-labor ratios of both sectors are positively related with q through wages. This would strengthen our earlier conclusion regarding the positive impact of technological progress on the capital intensity of production.

If labor is assumed to be a perfectly mobile factor across sectors, then W_1 should equal W_2. It follows then from above that:

$$\frac{K_2/L_2}{K_1/L_1} = \frac{\frac{\delta}{1-\delta}}{\frac{\alpha}{1-\alpha}} \tag{24}$$

The above ratio will be constant when firms face the same input prices -an equilibrium condition. This suggests that the capital intensities of both industries will have the same growth rates in equilibrium.

With reference to equations 7 and 8, growth rates of average labor productivity will be determined according to the following equations:

$$dLn\left(\frac{M_1}{L1}\right) = \alpha\, dLn_{q_1} + \alpha\, dLn\left(\frac{K1}{L1}\right) \tag{25}$$

$$dLn\left(\frac{M_2}{L_2}\right) = \delta\, dLn_{q_2} + \delta\, dLn\left(\frac{K_2}{L2}\right) \tag{26}$$

Utilizing the conclusion drawn by equation 24, and subtracting equation 25 from equation 26 yield the following result:

$$dLn\,(\frac{M_2}{L_2}) - dLn\,(\frac{M_1}{L_1}) = (\delta\, dLn_{q_2} - \alpha\, dLn_{q_1}) + (\delta - \alpha)\, dLn\,(K/L) \tag{27}$$

Since δ is greater than α, and by referring to equation 4 and holding the equilibrium condition imposed by equation 24, we draw our conclusion that for positive growth rates in technology (which lead unambiguously to positive K/L growth rates), labor productivity in industry 2 grows faster than in industry 1. That turns to be the case if industry 2, which is the capital-intensive industry, is carrying out higher investment levels than industry 1 in order to keep the relative capital-labor ratios constant as required by the equilibrium condition[6].

High levels of investments would mean high diffusion rates of modern technologies. This suggests that capital-intensive sectors may experience higher technological growth rates than labor-intensive sectors. That may occur when consumers either at home or abroad, devote high enough shares of their expenditures to capital-intensive products, and also when there exist no resource constraints regarding the availability of the specific factors used by such industries .

This in turn would mean that firms in industry 2 will be willing to offer over time higher wages in order to attract more labor towards their firms[7].
Such a shift in labor towards capital-intensive sectors necessitates a parallel shift in

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[6] It is implicitly assumed here that capital-intensive goods have a market share no less than that of labor-intensive goods.

[7] This turns to be true under the full-employment condition. If unemployed workers do exist, this needs not to be the case. Instead, unemployed people will be absorbed by the growing industry.

capital inputs towards those sectors. Relative capital-labor ratios will remain constant in the comparative sense, but each industry's capital-labor ratio will be higher (equations 22 and 23).

All the above analyses lead us to draw our main conclusion that capital-embodied technological progress gives capital-intensive industries a greater chance to grow relatively faster than labor-intensive industries. If consumers' expenditure shares on capital-intensive products still high enough and growing, and that there exist no resource constraints, domestic production patterns tend over time to shift gradually towards higher capital-intensive products and away from traditional labor-intensive products.

Implications for patterns of international trade

Production functions in equations 1 and 2 imply that unit-cost functions of industry 1 and 2 will take the following forms:

$$C_1 = G_1 W_1^{1-\alpha} CZ_1^{\alpha}; \qquad G_1 = \frac{1}{(1-\alpha)^{1-\alpha}\alpha^{\alpha}} = \text{constant} \tag{28}$$

$$C_2 = G_2 W_2^{1-\delta} Cz_2^{\delta}; \qquad G_2 = \frac{1}{(1-\delta)^{1-\delta}\delta^{\delta}} = \text{constant} \tag{29}$$

Where C is the unit cost of the output produced by the industry which is indicated by the subscript.

Substituting for the value of Cz in the above equations to get:

$$C_1 = \frac{G_1}{(q_1)^{\alpha}} W_1^{1-\alpha} P_K^{\alpha} \tag{30}$$

$$C_2 = \frac{G_2}{(q_2)^{\delta}} W_2^{1-\delta} P_K^{\delta} \tag{31}$$

It is clear from the above equations and for a given price of capital that C_1 and C_2 will decline only over transitional periods where wages do not adjust fully to their long-run levels. Otherwise, C_1 and C_2 will remain constant only when wage rates in both industries grow independently. To see how this may occur, take the natural logarithm of C_1 and C_2 to find:

$$\frac{d\mathrm{Ln}\,C_1}{d\mathrm{Ln}\,q_1} = -\alpha + (1-\alpha)\frac{d\mathrm{Ln}\,W_1}{d\mathrm{Ln}\,q_1} \tag{32}$$

$$\frac{d\mathrm{Ln}\,C_2}{d\mathrm{Ln}\,q_2} = -\delta + (1-\delta)\frac{d\mathrm{Ln}\,W_2}{d\mathrm{Ln}\,q_2} \tag{33}$$

Equation 10 together with equation 22 imply that:

$$W_1 = \left[P_1 (1-\alpha)\right]^{\frac{1}{1-\alpha}} \left(\frac{\alpha}{1-\alpha}\right)^{\frac{\alpha}{1-\alpha}} P_K^{\frac{-\alpha}{1-\alpha}} (q_1)^{\frac{\alpha}{1-\alpha}} \tag{34}$$

so that,

$$\frac{d\mathrm{Ln}\,W_1}{d\mathrm{Ln}\,q_1} = \frac{\alpha}{1-\alpha} \tag{35}$$

Similarly for industry 2, equations 12 and 23 imply:

$$W_2 = \left[P_2 (1-\delta)\right]^{\frac{1}{1-\delta}} \left(\frac{\delta}{1-\delta}\right)^{\frac{\delta}{1-\delta}} P_K^{\frac{-\delta}{1-\delta}} (q_2)^{\frac{\delta}{1-\delta}} \tag{36}$$

So,

$$\frac{d\mathrm{Ln}\,W_2}{d\mathrm{Ln}\,q_2} = \frac{\delta}{1-\delta} \tag{37}$$

hence,

$$\frac{d\mathrm{Ln}\,C_1}{d\mathrm{Ln}\,q_1} = \frac{d\mathrm{Ln}\,C_2}{d\mathrm{Ln}\,q_2} = \tag{38}$$

By comparing equation 35 with equation 37 we find that wages in the capital-intensive industry tend to grow faster than in the labor-intensive industry. This would mean that W_2 should be greater than W_1 if the condition implied by equation 38 is to be fulfilled, but this turns not to be an equilibrium condition.

Wage rates in both industries must be equal in order to ensure that both industries will remain active in equilibrium.

The equilibrium wage rate in the economy should in this case be greater than W_1 but less than W_2.

Referring back to unit-cost functions presented by equations 30 and 31 will lead us to conclude that the unit cost of industry 1 will increase, whereas the unit cost of industry 2 will diminish over time following any technological breakthrough. This result would make products of industry 2 gain a domestic competitive advantage.

At the international level, comparative unit costs are what matter in world markets. The home country, for instance, would gain an international competitive advantage in a given product if that product has no substitute[8], or when it has a quality distinction, and/or if it is supplied at a lower price. The first two possibilities are wiped out under the assumption of perfect competition and for the case of a developing economy. Therefore, I will consider the third possibility in this model.

Denoting variables belonging to foreign competitors with an asterisk, and continuing to assume that capital price is exogenously determined and it has the same value across all countries, comparative unit costs of both industries will appear as follows[9]:

$$\frac{C_1}{C_1^*} = \left(\frac{q_1^*}{q_1}\right)^{\alpha} \left(\frac{W}{W^*}\right)^{1-\alpha} \tag{39}$$

$$\frac{C_2}{C_2^*} = \left(\frac{q_2^*}{q_2}\right)^{\delta} \left(\frac{W}{W^*}\right)^{1-\delta} \tag{40}$$

Among others, it is clear from both equations that technology gaps as well as wage gaps between countries are the determining factors of competitive advantages/ disadvantages in world markets.

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8 From a technical point of view (the production side), or in the eyes of consumers (the consumption side).

9 We assume here that production technologies but not technology levels are identical in all countries.

Since technology levels as well as wage levels are asymmetrically distributed among countries, it is the interaction between both variables that affect patterns of competitive advantages/disadvantages at sectoral or at national levels, and thus they would determine patterns of trade.

3. Summary of Results

The most important results of the theoretical model that has been developed so far could be summarized in the following major points:

I. Technology grows faster where investments in physical capital are higher, or where the capacity to absorb modern technologies is larger. Abundance of human capital or an absence of market distortions -including foreign trade distortions- tends to increase the country's absorption capacity.

II. As technology improves, the unit cost of effective capital becomes lower while wage rates become higher. Therefore, profit-maximizing firms increase their capital intensities.

III. Ceteris paribus, industries with higher technology growth rates are supposed to grow faster, which in turn increases their relative market shares in domestic markets.

IV. Capital-embodied technological progress gives capital-intensive industries a greater chance to grow relatively faster than labor-intensive industries. In the absence of any constraint regarding resources or consumers' demand, domestic production patterns tend over time to shift gradually towards higher capital-intensive or technology-intensive products. This would occur because labor productivity grows faster in capital-intensive industries while equilibrium wages facing all industries grow in proportion to the growth in the general level of labor productivity. Hence, capital- intensive production will exhibit relative cost reductions.

V. The ability to compete in world markets increases when firms in a given sector could achieve higher rates of technological progress than their international competitors.

Achieving comparatively higher growth rates in technology within the domestic economy does not guarantee that such forefront firms or industries will generate a better competitive position in world markets, including the domestic market, unless we assume that technological advancements are evenly distributed among firms and industries at the international level, and that the general technology level of the country is not worsening vis-â-vis world levels.

VI. Generally speaking, technology gaps as well as wage gaps between countries are the determining factors of competitive advantages/ disadvantages in world markets.

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(التقدم التكنولوجي المفسر داخلياً والتحول الهيكلي للإنتاج والتجارة)

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ملخص البحث . تهدف هذه الدراسة إلى بناء نموذج نظري يشرح العلاقة التي تربط التقدم التكنولوجي الحاصل في العديد من البلدان العالمية بالتغيرات الهيكلية المصاحبة سواء في الأنماط الإنتاجية أو التجارية . يقوم النموذج المقترح على افتراض أن التقدم التكنولوجي يتجسد على شكل مدخلات رأسمالية محسنة ، وان رأس المال البشري يعد عنصراً أساسياً في عمليات استيعاب التكنولوجيا الحديثة ، ويخرج هذا النموذج بمجموعة من النتائج من أبرزها أن الكثافة الرأسمالية للإنتاج تزداد مع استمرارية التقدم التكنولوجي ، وأن المزايا التنافسية لبلد ما تتحدد من خلال الفجوات السائدة في المستوى التكنولوجي وفي مستويات الأجور بين ذلك البلد وشركائه التجاريين.