INNOVATION AND ECONOMIC DEVELOPMENT:
Toward a system dynamics perspective

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ABSTRACT

This paper revises the theoretical approaches regarding the dynamics of innovation intending to understand whether or not they can explain the process of quick growth and stagnation of countries. It is contended that system thinking approaches might complement some of classic ones, which we analyze under a system dynamics framework, facilitating exploration and simulation, in order to asses how the dynamics innovation might accelerate the process of growth and development of societies.

It is though that the current approaches to the innovation discussion do not clearly explain what has happened to the countries with a quick growth and they do not propose frameworks that allow us to study the effects of possible driving forces that might reflect those same dynamics in countries in development stages. We argue that a systems approach supported by systems dynamics models allow us to better study and evaluate the dynamics of innovation, by considering what effects might have feedback and delays over growth.

KEY WORDS: Innovation, Development, Development Economic, New Theory of Growth, Technological Change, Evolutionist Theory, System Dynamics

1. Introduction

From the initial discussions about the wealth of nations and their development, innovation and technology have been central arguments. In a general way the accepted general conclusion could be summarized by two of the more recognized experts on the topic in their book: “The technological advance is a powerful instrument for the human progress” (Nelson & Winter 1977). But we are standing amid the paradoxes presented by North: "How can we explain the persistence of the poverty amid abundance? If we know the sources of the abundance why the poor countries are not limited to adopt the politicians that contribute to it? We should create incentives so that people invest in a technology but efficient, have a better preparation and organize markets more efficient. These incentives are embodied in the institutions.” DOUGLAS C. North, 2000, mentioned in page 1 (World Bank 2002) .

It seems that we have neither resolved the matter of "... the sources of the abundance...." as North suggests that the technological advance in itself it is not the key, nor the means embodied in institutions.

In fact, large numbers of countries seem to be seeking development by following a trend of institutional character which indicates the formalization and support of their national systems of innovation and their science and technology systems. The path reported is instituting state agencies and prioritizing science and the technology. This is the policy presented in speeches but without a doubt there are key elements, bounded within innovation, that have not been elucidated.

A contribution to this respect can be found in the work of Richard Nelson and Howard Pack for the World Bank: The Asian Miracle and the modern Growth Theory as proposed: "The Asian miracle is explained by the undertakings in innovation and the underlying learning processes. These are the significant factors for the quick growth of the Asian tigers. p1." (Nelson & Pack 1998).

In this paper it is pretended to deepen this discussion, making a revision of the theoretical approaches on the innovation dynamics and examining whether they are able or not to explain the process of quick growth as well as the stagnation or incipient development of countries. It is intended a systems approach which leans on systems dynamics which allow us to simulate, discuss, explain and learn the effects of the innovation dynamics in the processes of growth and development of societies.

2. Technology, innovation and development.

Since the early 90s there has been increasing interest in the economic study of the innovation process, largely as consequence of the result of diverse studies which demonstrate that competitiveness of companies, economic growth and quality of life are closely related with the capacity of introducing successfully technological innovations. (Landau Ralph 1991) (Bank Mundial2002; ECLAC 2002; Freeman 1998; Gomez 2002a)

The discussion with respect to innovation and technical change has had two defined influences. On the one hand, the neoclassical trend initiated by Solow (1956, 1994) that explains technological change as the residual obtained in the econometric regressions of production factors and product growth. And, on the other hand, the current that has its origins in Schumpeter (1983), that explains the effect of innovation over development. For the first one, change is exogenous and, for second one, the origins of the process are considered at a micro-economic level, with the articulation of the "innovative manager."

Resent contributions, at the beginning of the nineties, started by considering the power of the technology over economic growth and its effects on the competitiveness of companies; these are known as models of endogenous growth (Romer, 1990).

In this discussion it is important the work by Nelson and Pack (1998) for the World Bank: The Miracle and the modern Seized Growth Theory. They discuss the concept of the new theory of the growth. In the document, the Asian miracle is explained in terms of innovation and the learning. They outline the theories about the Asian miracle that can be divided in two groups. On the one hand, we have the "accumulative" theories (inscribed in the neoclassical tradition and the macroeconomic approaches of the current of Solow) that emphasize the rules of the capital investments and their effects in the function of production of these countries. If countries make investments and they get the resources, development will emerge. And, on the other hand, we got the "assimilative" theories (clearly of the Schumpeterian line) that emphasize the undertakings in innovation and learning. These theories understand that investments in both physical and human capital are essential but insufficient if there is not a process of assimilation.

A useful approach which integrates the different perspectives is the systems theory of growth that explains quick growth in terms of the rules of innovation, their undertakings and the capacity of assimilation (from the assimilation proposal). There is an attempt in this direction by Gómez (2002a, 2002b, 2002c).

Although, suggested by the different authors mentioned above, a more detailed discussion is required to understand the preponderancy of innovation over development, trying to elucidate some important factors that might drive growth and development as well as the relevant interrelations and feedbacks that might exist among them.

3. The theoretical approaches to the innovation dynamics: Demand pull & Technology Push

An element that has not been incorporated in this discussion is the one about the origin and the inciter of the innovative process. Initially the theoretical proposals intended to explain that innovation and technological change were given by the existence of appropriate technological conditions - under these settings, “there would be a push” in technological change and innovation. Some authors even argue that the Schumpeterian proposals, in essence of “push” character, provide the conditions for the emergence of management undertakings.

A second current sustains that innovation exists as soon as the market demands it and that this is a driving force for the emergence, dynamics and consolidation of technology change and innovation. Equally they

argue that the development of markets were fundamental for impelling the automobile, electronic and software industries. Freeman (1998) argues that one of the main and long lasting controversies of the economic analysis of innovation is the debate between technology push and technology pull of demand (demand pull).

How can these approaches explain the processes of quick growth or stagnation of the countries? Initially the countries do not have an appropriate technological base. The proposal of the "technology push" suggests investing in the scientific and technological base of the countries. The approach of "demand pull", however, suggests actions from the potential demands for products and the existent capacities. Why not integrating both approaches in a systemic framework? This is what this paper intends to do in the following sections.

4. The Empiric Evidence in the Processes of Quick Growth and of Stagnation.

Innovation has a relative meaning (OECD 1993; OECD 1997). For a country or a society, something is said to be new when it does not possess it, or it does not make it. Here we understand innovation as the introduction of something new in the economy of a country - for example, new products or services that were not produced before in that society. And productivity, in its wider sense, is understood as the capacity of generation value by the individuals of a nation and is expressed in terms of GDP (Gross Domestic Product) per person.

In a series of works, the effect of innovation over growth has been examined for a number of countries (Gomez2002b; Gomez2002c): Germany, Singapore, Japan, Ireland, Spain, United States, Russia, Korea, Taiwan, Hong Kong, Hungary, Bulgaria, Vietnam, Chile, Mexico, Brazil and Colombia; with the intention to understand the role of productivity and the innovation in economic development.

It was found that the countries that had processes of fast growth in some period of their history had achieved significant improvements in innovation terms – technical advances which include technological progress, and the introduction of new products. These countries also attained continuous improvements in productivity, a notable increase and diversification of their exports as well as significant increase in discharge rates of economic growth. Those discharges rates that are reflected in the improvement of incomes per capita have meant higher consumption rates. And in a systematic way, this whole process led to an important social transformation.

It was observed that the assimilation of innovation is a fundamental determinant in productivity growth in the long-term. Its effect depends not

only on its incidence over productivity by the introduction of new technologies but also in the capacity of management to incorporate the advances in knowledge, to absorb technical progress and adapt it to the productive processes, the administration of the human resources and corporate strategy.[1.]

Japan and the so called Asian tigers, have had successful development processes, with very significant results in terms of growth, diversification of exports, and social benefits. The largest economic growth registered by Japan took place after the Second World War and lasted until the late 70s, when the economy expanded 55 times. Singapore on the other hand, experienced discharges rates of growth some time later in the 1960s, which in 1991 reached 8.25% average yearly; during the same period, the growth in GDP per capita was faster than in Singapore (6.25%) and than any other Asian countries, with exception of South Korea. Singapore and Japan are economies at the edge of innovation on the technological frontier. Nevertheless, Japan presents during the recent years a period of stagnation, in comparison with Singapore, United States and several countries of Europe, in what has to do with the technology of the information.

As Japan and Singapore, the Irish economy is approaching the status of a "miracle", and we may soon call this country the "Celtic tiger." Although Ireland undertook a late industrialization processes in comparison with the European average, Japan and Singapore, turned in one decade from an economy based in natural resources (agriculture) to an economy intensive in technology and knowledge, with a strong exportation base. Between 1987 and the year 2000, the Irish economy grew at an average rate of 7% yearly, and between 1995 and 2001 it grew at a rate exceeding 10% and it reached growth rates up to 11.5% (See Figure 1). For the four countries of Latin America, the decade of the nineties was one of deep reformations and no significant growth took place.

The differences in the development, shown so far, can be appreciated in the Figure 1. In terms of the GDP per capita, a wide breach exists among the Latin American countries, and the two Asian ones. But this was not always the case. In the year 1970, as can be appreciated in Figure 1, the difference in GDP between the Latin American countries and the Asian ones were fairly small – US$ 372 to US$ 1.953 (values corresponding to Colombia and Japan) – but in 1998 this difference became much larger – US$ 2.523 to US$ 29.956.

[1] Informe Anual 2001. Banco de España.

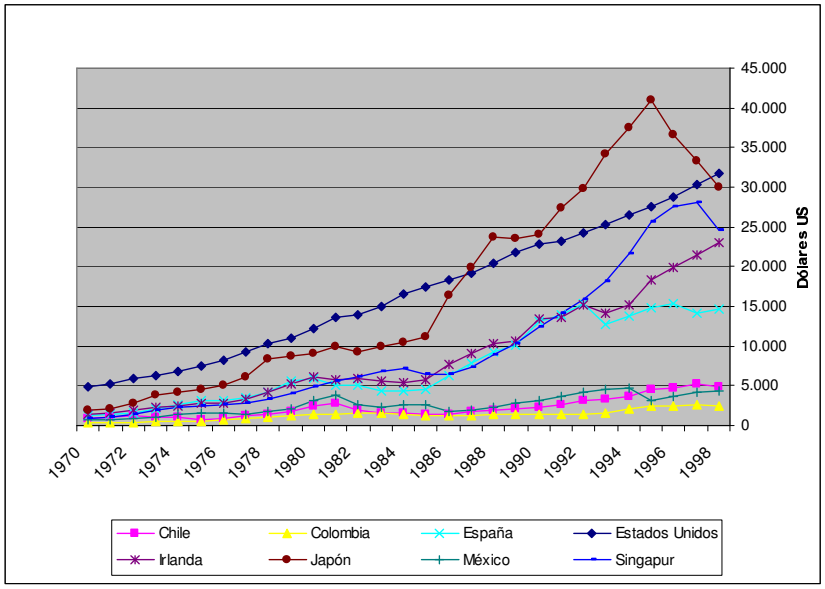


Figure 1
Compared evolution of the GDP per cápita
Source: The authors with information of Monthly Bulletin of On-line Statistics. United Nations

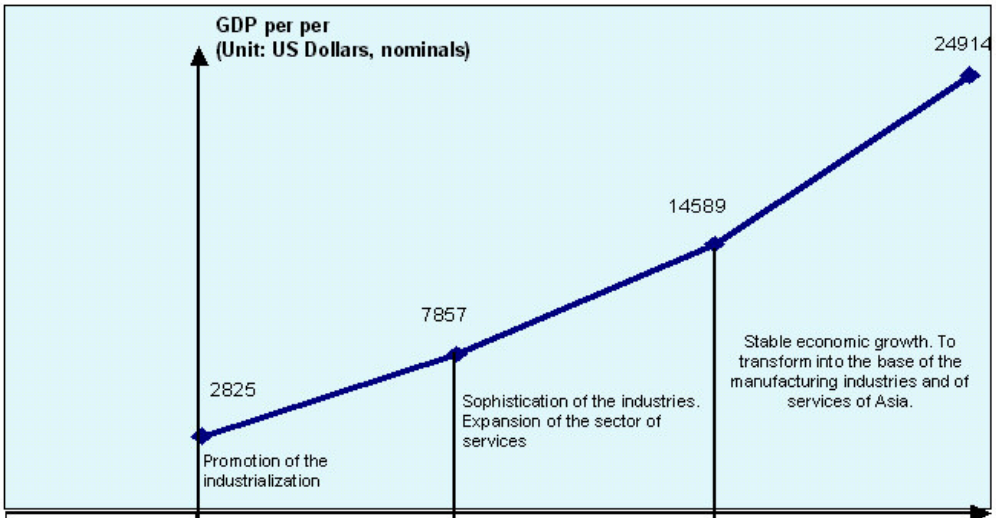
The orientation to exports of all the countries as a strategy for growth, needed deep transformations in the productive apparatus, for which there were necessary strategies towards increases the productivity, and improvements in innovation. All those strategies were supported in industrial policies that gave an answer to the necessities and challenges of each phase of the development.

Productivity and innovation are factors that have been present in the process of the quick growth experienced in successful economies (Japan, Singapore and Ireland). From the first phases of their industrialization processes, that is to say, from those moments in which the industrialization was guided toward intensive activities in manpower, the governments from Japan and Singapore were conscious of the importance of the improvements in productivity, and directed policies to promote it, as it is observed in Figures 2 and 3.

In this direction, these governments invested more in education with the purpose of improving access and quality, and they also promoted the technological modernization of the economy. An element to highlight in this sense is that the efforts of technological modernization were linked to the existent domestic resources: for example in Japan and Singapore, as in the first development phase the abundant factor in the economy was manpower, the strategy consisted in gaining access to new technological knowledge for the improvement of competitiveness. Nevertheless, part of

the new technology was also guided to the development of new sectors, in which you could exploit the technological breach.

The innovation pattern of “technology push” is insufficient to explain the processes of quick growth, as it has not shown very useful in the Latin American countries. In this part of the world, after decades of insisting in policies of science and technological, based on investments in education and in science and technology aiming to crate a scientific and technological base, this does not seem to have had a significant effect on growth and social development.



	1970	1980	1990
Industries that prompt the economy toward the future.	▪ Light industries (textiles, etc.) ▪ Human resources Intensive industries	▪ Intensive processes in industries of high technology ▪ Financial industries	▪ Electronic industries ▪ Technologies of the information industry
Capital relation – incremental Product = Rate of investment/ Rate of increment	4.3 (1970-1979)	4.8 (1980-1989, ex. 1985,1986)	4.5 (1990-1997)
Economic and industrial policies	▪ To adopt an industries promotion politics oriented to the exports. ▪ To promote the introduction of foreign capitals	▪ To promote the change from intensive industries in work oriented to the technology ▪ To establish the goal of which the manufacturing sector reaches a participation in the GDP of 25% or more	▪ To aim transform into the central financier and commercial of Asia

Figure 2
Process of Transformation of the Economy of Singapore
Source: Singapore Productivity Center, Adapted for the authors

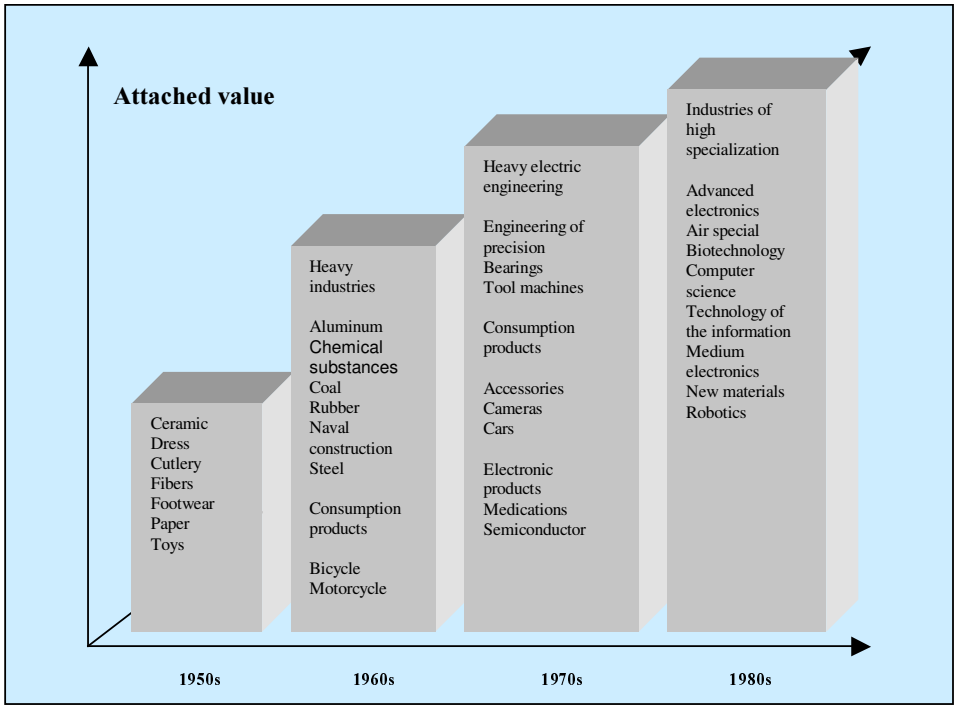


Figure 3
Process of Transformation of the Economy of Japan
Source: *El Caballo de Troya Japonés*. Barrie James. Adapted by the authors

For Japan and Singapore the processes seem better explained by a systems integration of "demand pull" with processes of "technology push" nested into their strategy. The action was directed to the potential demand for new products that incorporate more value and they invested in the necessary technology to introduce the necessary innovations in society. The strategy was directed to capture markets that were attractive and actions were defined depending on the phases of maturity of these markets. Development was built upon the products that involved more value additions and complexity.

5 - The Dynamics of Innovation and Development.

Innovation is understood as the entrance of new products or services that were not produced previously in a society. As an example let us examine what happened when the television industry appeared. On one hand, as demand for a new item was generated - the television - new services emerged - entertainment and audiovisual information. On the other hand, new companies were constituted for the provision of those new goods and services. The economy was transformed in some measure and new jobs were created and new flows of money were generated. The innovation process produced an expanding dynamics in the economy.

We understand technological change as the introduction of a new production line that allows improvements in productivity. For example, the introduction of machines for numeric control to the metal-mechanical industry allowed to manufacturing more complex and more exact pieces in less time. This reduced the number of people required at the work place. In this sense, technological change can produce a contraction in the economy.

The dynamics that induce the innovation and technological change are represented in the causal diagram presented in Figure 4. Innovation will expand the external and intern sales, providing more resources for investment, allowing capacity expansion to support demand growth. Additional employment is generated reinforcing demand and investment. Technological change increases productivity which will allow generating more goods with the same resources, reinforcing innovation, contributing to increases in the population's income.

A model was built and applied to the Colombian economy. Simulation show the effects of that long-term increases in productivity and innovation have over economic growth, see Figure 6. This model has more than eight thousands equations. Its parameters are more than one thousand six hundred economics variables taken from national statistics department. The model was calibrated for the period 1995-2000.

Basic simulations are shown in Figures 5 and 6. It is observed that in presence of an endogenous process of innovation, technology change allows the system to enter in an expansive dynamics, reducing unemployment, increasing output and exports, which bears an increment of income per capita.

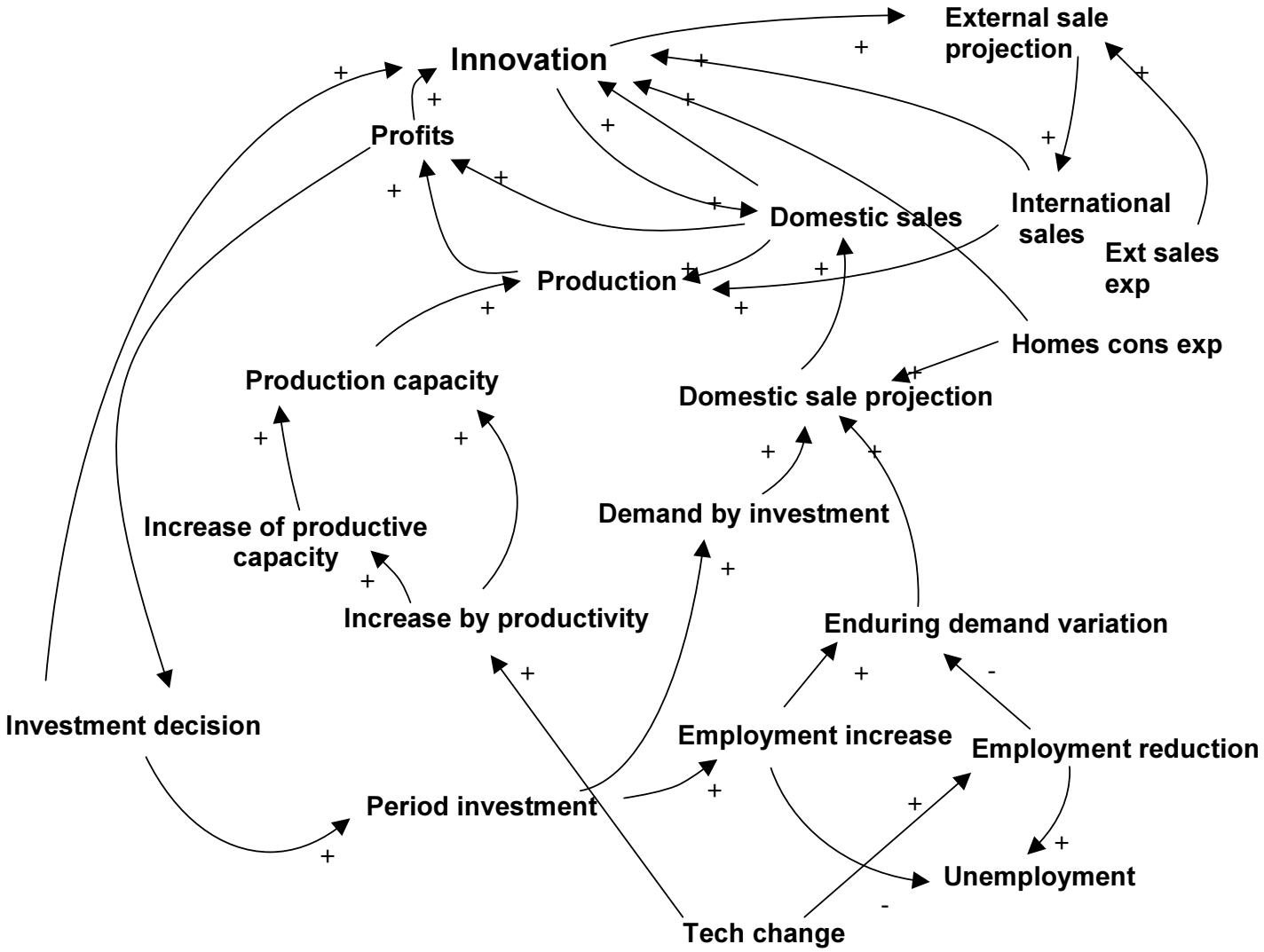


Figure 4
Induced dynamics for the Innovation and the Technological Change

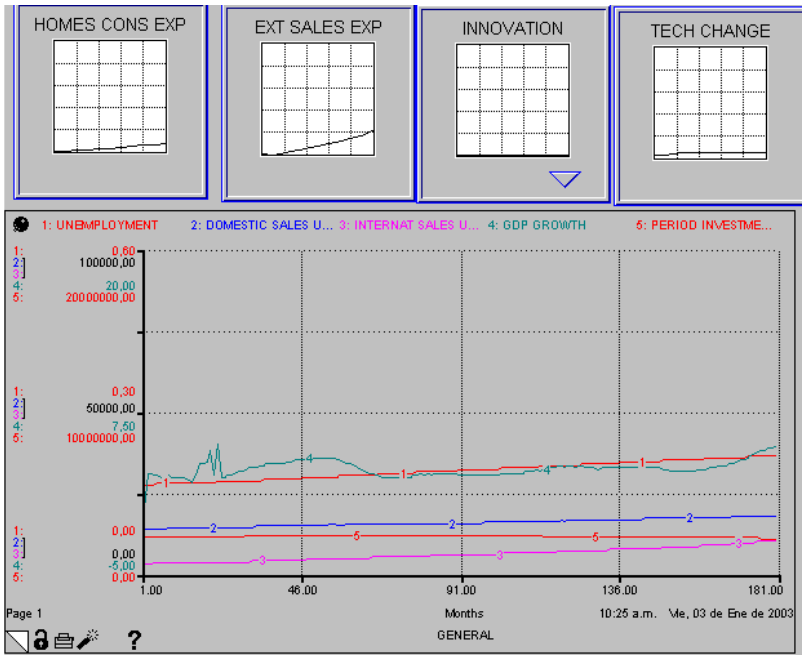


Figure 5

Behavior of the economy of Colombia without introduction of innovations and with a level of incipient technological change

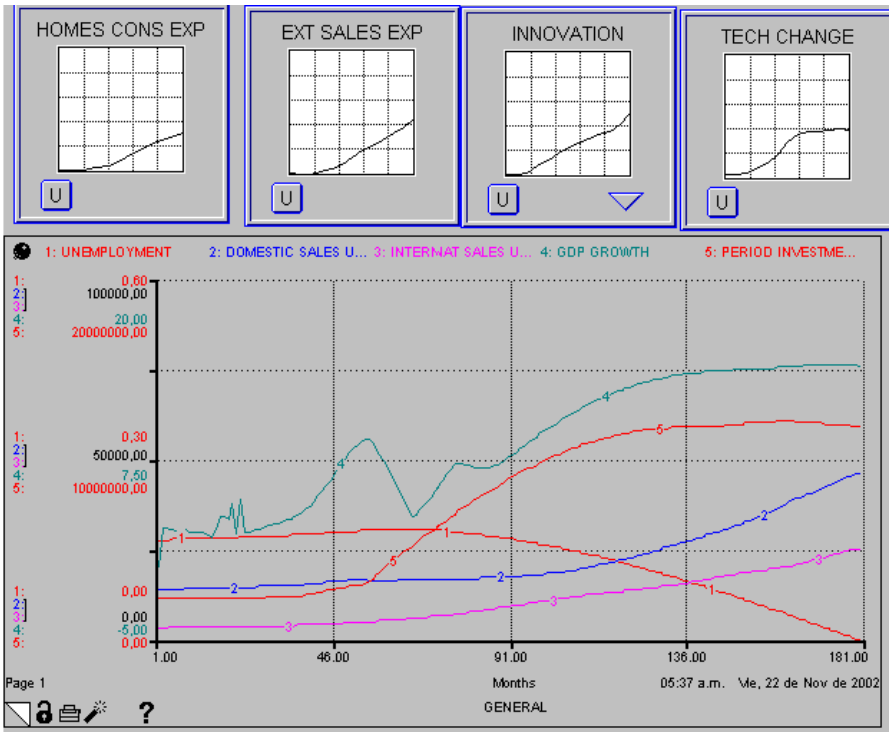


Figure 6

Behavior of the economy of Colombia with introduction of innovations and with a level of half technological change.

Simulations show that innovation induces a dynamic process of economic growth and expansion. Technology changes for improving productivity are necessary to make possible the process of growth.

These simulations suggest that with a virtuous dynamics can generate quick and sustainable growth and can explain the processes of growth which have been achieved by some countries.

6. Conclusions.

The approaches to the innovation dynamics suggested by the “demand pull” and the “technology push” do not explain in an integral way the processes of quick growth which has been achieved by some countries. There is not evidence that each of these approaches alone would induce similar dynamics, to the ones experienced in Singapore and Japan, in countries that are seeking development. It has been observed in simulations, based on induced technology processes within virtuous dynamics, that quick and sustainable growth is possible.

The systemic approach, supported by system dynamics allows us to study and to evaluate the dynamics of innovation in such way that we can explain and simulate system behaviors and feedbacks in them.

In the model that was developed other considerations are given away which are fundamental. The main idea is that a central concern of the economy should be an effective integration of individuals to the generation of well-being in society; associated to the search and construction of the social outlines directed to link the individuals to the processes of generation of goods and services.

The authors believe that the theoretical discussion that has been started and that is ingrained in the model might support the proposal of a “new theory of the growth” if further research is conducted in the direction presented in this paper.

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Back to the Top