Modelling the role of national system of innovation in economical differentiation

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Abstract.
Nowadays it is well accepted that science and technology has a fundamental role in the economic development (GNP per capita) of any country. Aiming to study this role, we introduce a model that creates an artificial world economy that is a network of countries. Each country has its own national system of innovation (represented by a technological parameter). The interactions among the countries are given by functions that connect their prices, demands and incomes. Starting from random values, the artificial world economy self-organize itself and create hierarchies of countries.

INTRODUCTION

In the last decades, it is increasing the debate on the role of national systems of innovation (NSI) in the developing of the countries [1]. NSI is an institutional arrangement, involving firms and their R&D departments, universities, research institutes, financial systems supporting innovation, education institutions, law, etc. These institutions interact with each other, and mutual feedbacks among them are key. Thus, the NSI represents an institutional arrangement that articulates the economic wealth with the underlying technological competence.

Recently, by using statistics of patents (USPTO) and scientific papers (ISI) [2], we have studied the interplay between science and technology and its influence on the country level of development. We have identified strong correlations among these three variables and a threshold level in the scientific production, beyond which the use of scientific output by the technological sector increases. Figure 1 shows a log-log plot of Articles per million inhabitants versus Patents per million inhabitants for 150 countries. There one can see clearly two different regimes (for better discussion, we suggest the reading of Ref [2].)

In the evaluation of the data for different periods, we proposed the existence of three regimes concerning the interplay between scientific production, technology and development. The very simple model suggests that as the ŞregimesŤ change, the number and the channels of interactions between scientific infrastructure, technological production and economic growth concomitantly also change. As the country evolves, more connections

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are Ştumed onŤ and more interactions operate. In the first regime, present in less developed countries, scientific activities do not feed technological production. In contrary, the third regime is the case where all connections and interactions are working (they have been Şturned onŤ during previous phases). So, as a country upgrades its economic position, its economic growth is more and more ŞcausedŤ by its scientific and technological resources. The mutual feedbacks between them contribute to explain why the modern economic growth is fueled by strong scientific and technological capabilities.

In this work, we present a model that aims to reproduce those correlations and the hierarchy of countries of our empirical studies. Our model is inspired in earlier approaches introduced by Dosi it et al. [3]. Physicists are usually much more interested in studying the general behavior of financial markets and lots of papers have been published on this subject (some discussions are presented in the Proceedings of this 8th Granada Seminar). However, not only on market dynamics are the physicists interested. In the last years, different approaches using statistical physics tools dealing with the role of NSI in the development of the countries and the interactions between countries have been introduced [4], most of them using the fundamental concepts of Nelson and Wintert's Evolutionary Theory [5].

In our model, we create an artificial world economy that is a network of countries. Each country has its own national system of innovation, which plays a decisive role on the country level of development. The interactions among the countries are given by functions that connect their prices, demands and incomes.

Starting from random values, the artificial world economy self-organize itself and create hierarchies of countries. We show that the longer the system takes to reach steady state, more different the final configuration is from the initial one.

MODEL AND DISCUSSIONS

In our model, each country i is represented by its real population L_i and richness Y_i (the Gross National Product - GNP), being the wage or per capita income $W_i = Y_i/L_i$.

In the beginning of the simulation, we have an unbalanced network, that means, each point (a country) in the configuration space has its own set of features but one needs to obtain the interactions which will produce that specific configuration. The interactions between countries are given by the competitiveness of a country compared with all in the world. Competitiveness will define the weight (or strength) of the country in the market share and the role of its NSI compared with all countries. In this way, the more technology a country incorporates in the production of its goods the more competitive it is and the greater portion of the global richness it can pursue. From the above assumptions, the competitiveness of a country is given by:

$$C_i = \frac{1}{P_i} \tag{1}$$

and

$$P_i = \frac{Y_i}{(L_i T_i + V_i)} \tag{2}$$

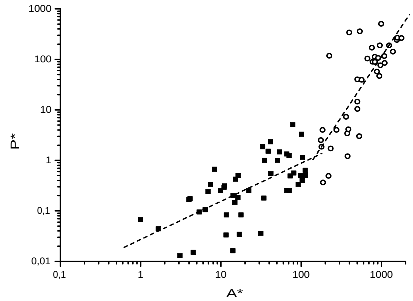

FIGURE 1. The log log plot of articles per million of inhabitants vs. patents per million of inhabitants for the year 1998. Here the two subsets are identified by different symbols. Two power functions have been used to fit the two subsets. From Ref [2]

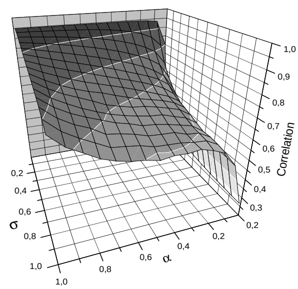

FIGURE 2. Correlation coefficient between initial date and final result as a function of the two parameters: α and σ. For discussion see text.

where P_i are the average prices of all goods and V_i is the country stock of unsold goods. At steady state, there is no inventory: $V_g = \sum V_i = 0$, which is a first measure of equilibrium in this artificial world economic system. The pricing follows an simple adaptive rule: everything else constant, unsold stocks and decreasing income reduce prices and increase competitiveness, and decreases in inventory and raising income do the opposite.

The variable T_i is a measure of technological development of a country and how this development impact on the prices of goods produced by that country. Technology adjusts following a rule, which is a simple version of a replicator dynamic routinely used in evolutionary game theory and other dynamic models:

$$T_i^{(k+1)} = T_i^{(k)} \left\{ 1 + \alpha \times \left(\frac{C_i}{C_g} - 1 \right) \right\} \tag{3}$$

The coefficient α is a proxy to the national system of innovation, which corresponds to the country participation in the world production of patents and articles. Thus, α is the elasticity of T to deviations of country level of competitiveness C_i from the global level of competitiveness $C_g = \sum(C_i M_i)$. k is the step of iteration. Note that in our model there is no a dynamic process, since what we are seeking is the adjust of interaction of countries. In the future we intend to substitute this constant parameter by another one, dependent on the relations between the agents of the NSI system of each country, as described by Bernardes and Albuquerque [2].

The second variable that produces the interaction of countries is the weight of the country in the global market, i. e., the part of the global market (in our model the global richness) that belongs to a country:

$$M_i^{(k+1)} = M_i^{(k)} \left\{ 1 + \sigma \times \left(\frac{C_i}{C_g} - 1 \right) \right\} \tag{4}$$

where σ adjusts the weight of a country in the global market. Note that for all iterative steps $\sum M_i = 1$.

The iterative process is given by the production of goods (richness over prices) and the demand of them (market share times global richness). The adjustment of the interactions of each country with all others is constrained by three cases: (i) when demand is equal to the production, all goods are sold (no inventory) and there is no savings (income not spent), thus the system is in equilibrium. (ii) In the second case, when demand is greater than production there is an excess of demand, thus there is no inventory ($V_i = 0$) and consumers do not spend all their income, which means that some savings S_i is added to the global savings $S_g = \sum S_i$ ($S_g > 0$). (iii) In the third case there is an excess of supply, thus stock is positive ($V_i > 0$) and all income is spent ($S_i = 0$). An equilibrium configuration is attained when all $V_i = S_i = 0$ and $T_i^{(k+1)} = T_i^{(k)}$, what means that $C_i = C^*$ for all i.

As one can see in Figure 2, different values of α and σ lead to different final configurations. In that figure, the correlation between the final configuration and the real world is plotted as a function of that parameters. Correlation here represents how close the final configuration (GNP of each country) is of that initial. It is clear that for small σ the final state is very similar to the initial one, it does not matter the value of α. However, by increasing σ one observes that for higher α values a final state less similar to that previous one is obtained, but the lower is the α value the more different is the final state. We can conclude that α and σ operate as competitive adjustment forces. Lower technological adjustment will provoke the lost of initial characteristics of the system.

In this paper, a model describing the role of innovation in the economic differentiation is introduced and the effects of the competing adjustment forces (market adjustment and technological introduction in the production of goods) are discussed. This work is in progress and a complete discussion will be published elsewhere.

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