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NATIONAL SYSTEM OF INNOVATION AND ECONOMIC DEVELOPMENT: A CASE STUDY FROM CHINA

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Abstract: This article aims to elucidate the debate between the National Innovation System (SNI) and its interaction with economic development, emphasizing the characteristics that allowed the prosperity of the Chinese economy and how innovations are capable of affecting the institutional organism and the socioeconomic structure of a country. The research is divided into two sections: i) literature review on the emergence and understanding of the national innovation system, and ii) analysis of economic policies, the role of the State and other institutions that collaborated with the national innovation system or national system of learning from China. Data were collected from the year 2000 onwards, emphasizing that the role of technological progress in Chinese economic development tends to be more linked to its institutional transformation than to the abundance of productive factors with low market value. Contrary to what is usually advocated in the conventional literature, the workforce in China represents a small portion of the GDP composition when compared to the other analysis factors. This characteristic reflects on the country's level of high technology exports, which is a clear indicator of its ability to innovate.

Keywords: chinese economy; economic development; national innovation system; national learning system.

SISTEMA NACIONAL DE INOVAÇÃO E DESENVOLVIMENTO ECONÔMICO: UM ESTUDO DE CASO DA CHINA

Resumo: Este artigo visa elucidar o debate entre o Sistema Nacional de Inovação (SNI) e sua interação com o desenvolvimento econômico, enfatizando as características que permitiram a prosperidade da economia chinesa e como as inovações são capazes de afetar o organismo institucional e a estrutura socioeconômica de um país. A pesquisa está dividida em duas seções: i) revisão da literatura sobre o surgimento e entendimento do sistema nacional de inovação, e ii) análise das políticas econômicas, o papel do Estado e outras instituições que colaboraram com o sistema nacional de inovação ou sistema nacional de aprendizagem da China. Os dados foram coletados a partir do ano 2000, enfatizando que o papel do progresso tecnológico no desenvolvimento econômico chinês tende a estar mais ligado à sua transformação institucional do que à abundância de fatores produtivos com baixo valor de mercado. Ao contrário do que costuma ser defendido na literatura convencional,

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a força de trabalho na China representa uma pequena parcela da composição do PIB quando comparada aos demais fatores de análise. Essa característica reflete no nível de exportação de alta tecnologia do país, o que é um claro indicador de sua capacidade de inovar.

Palavras-chave: economia chinesa; desenvolvimento econômico; sistema nacional de inovação; sistema nacional de aprendizagem.

1 INTRODUCTION

The national innovation system (NIS) can be defined as a complex arrangement that encompasses relationships within and between organizations, institutions and socioeconomic structures that determine the rate and direction of innovation based on science and experience (LUNDVALL *et al.*, 2009, p. 9). Although its emergence is uncertain, Freeman (1982) was a pioneer in the field, building the first formal foundations on the subject.

With the advancement and recognition of the importance of an SNI, it has become essential to think about economic development without considering the complex institutional arrangement that involves it. Important authors on the subject (LUNDVALL at al., 2013; FREEMAN, 1995; DOSSI, 1997; NELSON; ROSENBERG, 1993; LALL, 1992; VIOTTI, 2002) argue that traditional theory is unable to answer questions related to economic development, since they disregard the importance of the SNI.

In this sense, it is essential to understand how a nation's SNI contributed to economic development, analyzing the role of institutions and how their interactions provide learning. The research sought to analyze these characteristics from the Chinese economy due to its rapid growth and economic development, with little literature that focuses on explaining the main components of China's innovation system from the beginning of the century.

Since 1985, China has carried out a series of reforms to its national innovation system or national apprenticeship system. The reforms were concentrated in the sectors of science and technology (S&T) activities and public research institutes in manufacturing of public companies, seeking a greater connection between the sectors (XUE, 1997, p.67). Among the main technological policies, the Key Technologies Research and Development Programs, High Technology Research and Development Program and the National Priority Basic Research and Development Program stand out.

The article collected data between the years 2000 and 2020, dividing the research into two main sections. The first part sought to carry out a literature review on the historical perspective of the SNI and how the definition of a national apprenticeship system fits better for the understanding of countries that are still in the development stage. The second section deals with a case study of the Chinese economy, elucidating how its SNI was an important attractor for development, highlighting spending on research, R&D, State participation in conducting economic policy, high technology exports and incentives for its population dedicated to research and technology activities.

2 CONSOLIDATION OF THE NATIONAL INNOVATION SYSTEM

2.1 Historical perspective

The SNI has as its predecessor the original contributions and ideas of the economist List (1841), although he never mentioned the term in his publications. The author was a pioneer in the construction of a critique related to the subordination of peripheral countries in relation to already industrialized countries, highlighting key aspects that provided the growth and economic development of a nation.

The limitations of classical theory in explaining factors linked to development, in which free trade was massively emphasized, spurred List to dedicate himself to studies related to political economy and nationalist militancy. His constant disagreements with traditional economists was an important factor for the author to dedicate himself to key themes for the promotion of economic development, emphasizing in his writings the role of the State in the process of industrial leverage, as well as the protection of national industries against foreign competitors. List (1841) also contributed to the educational system in Germany, arguing that manufacturing companies need the knowledge of physics, mechanics, chemistry and mathematics from which no progress or invention could be made without qualified professionals in these areas.

List's contributions influenced an entire generation of economists and scholars linked to innovation, leading Freeman (1987) to be the first person to make an explicit reference to the subject, defining SNI as an institutional arrangement that drives technological progress and determines the level of wealth of a country. The concept has gained new interpretations over the years, so that Albuquerque (2004) argues that it can be understood through three rounds of elaboration. Initiated in 1970, the first round is marked by an institutionalist approach, emphasizing science and technology. Renowned authors on the subject such as Freeman (1994) and Dosi (1997) provided the theoretical and empirical bases capable of establishing an interpretation on SNI, being seen as an institutional arrangement, in which there is a relevant set of interacting participants.

The second round is marked by the moment of synthesis, which originated in the late 1980s. There were important publications of empirical and theoretical work on case studies that aimed to expand and understand the SNI. The term started to be used by managers in the promotion of public policies in several countries, showing the maturity and importance that the discussions gained in the understanding of economic development.

The last round begins with the work of Freeman (1995), and can be understood as a research agenda to be implemented. The author looked for different characteristics of the national innovation systems, delimiting the research between the years 1980 and 1990. The study explores several themes, seeks scientific explanations and raises numerous questions that drive the most diverse scholars to the present day. Freeman (1995) was able to clearly answer questions that still generate discord among economists, highlighting the economic success of Japan and South Korea against the economic failure of the former Soviet Union.

The research agenda linked to the national innovation system remains open, new discussions have emerged and challenges tend to mobilize researchers from different areas,

and from the second round and with the consolidation of the term, its definition has become broad. Each definition is seeing a specific area, with no "right" or "wrong" term, and it is up to researchers to use the definition that best fits their research objective.

For Freeman (1987) SNI is a network where public and private institutions interact, import and disseminate new technologies. This was the first formal definition of the subject, influencing Nelson and Rosenberg (1993) to define the national innovation system as a set of institutions whose interactions determine the innovative performance of national firms. The definition by Niosi *et al.* (1993) is related to a system of interaction between private and public companies, universities and government agencies aimed at the production of science and technology within national borders. The authors also argue that this interaction can be technical, commercial, legal, social or financial, whose main objective is development.

Although each author defines the national innovation system differently, we can highlight similar aspects in the contribution of each definition. The use of the words institutions, interactions, technology and science appears frequently, so that the definitions complement each other. Faced with the difficulty in defining such a complex topic, Lundvall *et al.* (2013) explain that since its inception, research related to the SNI has covered two different perspectives, which can be divided into narrow and broad definitions.

By strict definition, it is understood the research that seeks to link Science, Technology and Innovation (STI), covering innovations based on R&D, so that the innovation process occurs based on experiments in research laboratories. Differently, the broad definition is related to the Doing, Using and Interacting (DUI) method, which emphasizes the interactive structure of the company between employees and suppliers. The two methods complement each other and have different ways of being measured, while the STI has a consolidated empirical measurement, the DUI method is still being improved, in view of its expanded form and measurement difficulties.

Despite advances and recognition of the importance of national innovation systems for economic development, there are many barriers that can be overcome. A case that has been attracting the attention of researchers is related to the difficulty that peripheral countries faces in building their own system. Because they have different characteristics from developed countries, many authors have suggested the use of the term "national learning system".

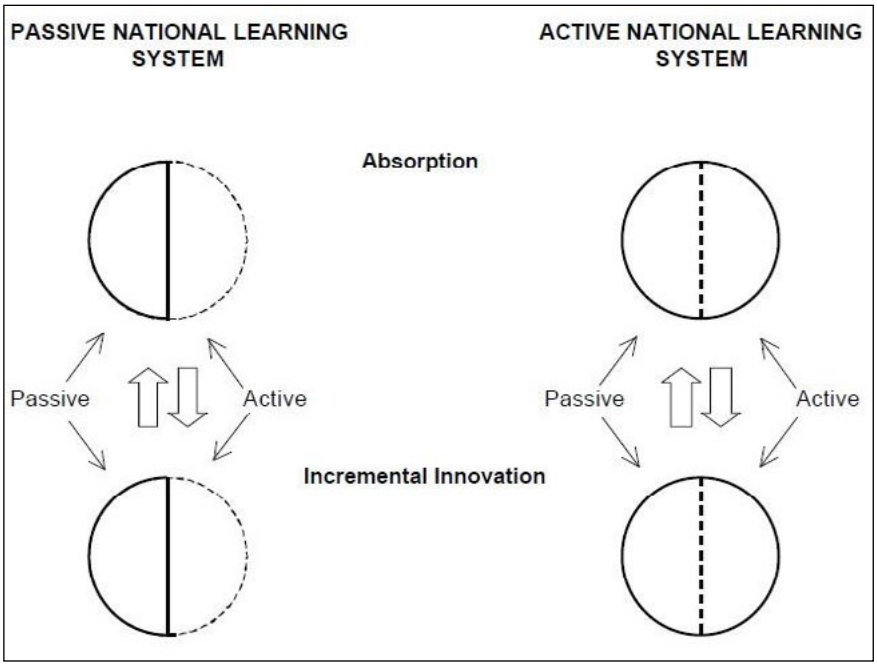
2.2 National apprenticeship system

Several scholars have argued that developing countries should use the term "national apprenticeship system". According to Viotti (2002), the national innovation system should be restricted to competing countries, arguing that only economies that are in this stage are capable of promoting innovations, while developing countries would only promote incremental innovations.

To support his argument, the author distinguishes between active and passive learning systems, as illustrated in Figure I. An active system can be considered ex-ante, promoting innovation in the institutional body, unlike a passive system that is ex-post,

promoting only incremental innovations. By establishing an active apprenticeship system, the socioeconomic structure of a country is favored and leverages economic development.

Figure I: National active and passive learning systems



Source: Prepared by Viotti (2002).

Viotti contribution (2002) is fundamental when he suggests that late industrialization countries should adopt the term national learning systems instead of national innovation system. The term learning is defined by the process of absorbing existing techniques produced elsewhere, that is, innovation in the periphery occurs incrementally and countries start to have a common element, technological learning. The difference between national innovation systems and learning systems consists in the fact that the latter considers the activities, institutions, and relationships associated with learning, rather than innovation (VIOTTI, p. 7, 2002).

The challenge is to consolidate economic policies for industrial development that emphasize the role of learning produced in already developed countries and how institutions relate to obtaining new techniques. It is evident that each country faces different difficulties in relation to the development process, but the national apprenticeship system approach makes it possible to compare different countries that have a common factor, difficulties in establishing technological learning.

3 CHINA'S NATIONAL INNOVATION SYSTEM

3.1 State programs for the development of science and technology

In 1985 China initiated a set of reforms on its national innovation system or national apprenticeship system, approving the Resolution of the Central Committee of the Communist Party of China [CCCPC, 1985]. The reforms were concentrated in the sectors of science and technology (S&T) activities and public research institutes in manufacturing of public companies, seeking a greater connection between the sectors (XUE, 1997, p.67).

According to Fan (2010) R&D institutes were pressured to adapt to the market environment based on three stages: i) mergers of R&D institutes with companies in 1987, ii) financial incentives in 1988 for sharing R&D results, iii) transformation of R&D institutes into entities with economic functions from 1990 onwards. In addition, the government adopted a series of technological policies aimed at changing production in the country, namely the Key Technologies Research and Development Program, the of High Technology Research and Development and the National Priority Basic Research and Development Program.

Started in 1982, the Key Technologies Research and Development Program was the first and largest Chinese science and technology program of the 20th century. With a focus on economic and social development, the program focused on the sectors of agriculture, health care, electronic information, resource exploration and transportation. The program involved tens of thousands of people and more than 1,000 scientific research institutions across the country, so far it was the largest national scientific and technological plan [...] (CHINA NET, 2007).

The High Technology Research and Development Program was elaborated in 1986, being a science and technology policy project whose objective focused on promoting high quality research in China from the areas of biotechnology, aerospace, information, laser, automation , energy resources, new materials and oceanology. According to Ke (2012) the program was a clear example and learning of how collaboration between scientists and public policy makers results in better decisions for a country.

Approved in 1998, the National Priority Basic Research and Development Program aimed to advance China's scientific and technological competitive power into the 21st century. According to the Government of China (2007) the tasks of the program included: i) carrying out integrated multidisciplinary research and providing theoretical and scientific foundations for scientific questions, ii) implementing relevant basic research, iii) training a skilled workforce in scientific areas, iv) establishment of high-level research bases and multidisciplinary research centers.

In addition to the three aforementioned plans that formed the main bases of the state plans, the Spark and Torch programs were also adopted with the aim of improving the capabilities in science and technology of the Chinese economy.

The Spark Program launched in 1986 aimed to rejuvenate the rural economy based on scientific and technological progress, while the Torch Program launched in 1988 became China's most important high-tech industrial development plan. The program prioritized

projects of new materials, biotechnology, electro-information, integration of technology and electromechanics, new energy resources and energy-saving technology (CHINA NET, 2007).

3.2 R&D activities, technological progress and technology export

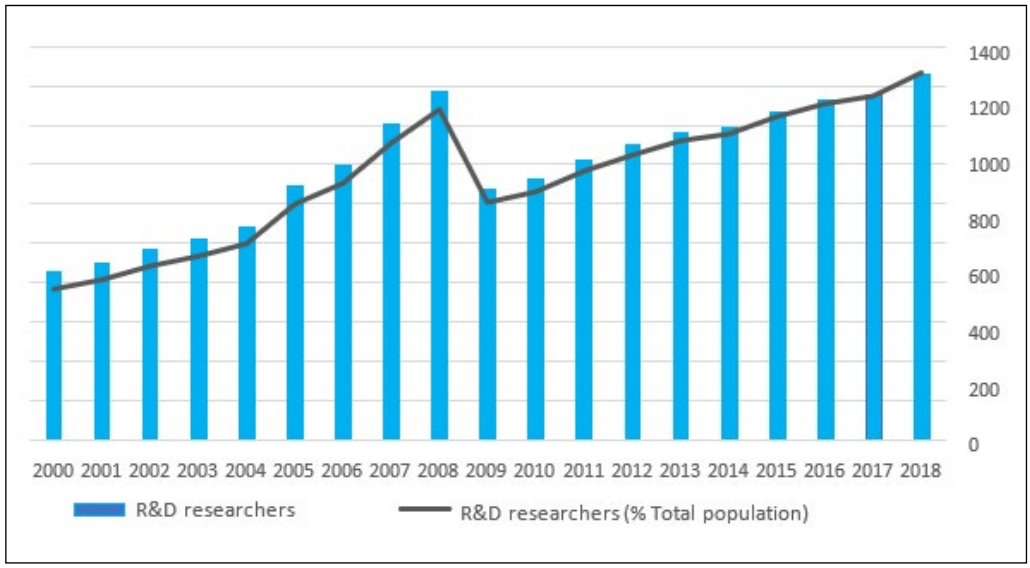
A nation's economic development is strongly correlated with its degree of patent creation, bearing in mind its distinctive feature of "free transferability", creating an overflow of knowledge for the different institutions that make up the national innovation system.

According to Haase *et al.* (2005), patents have four distinctive characteristics: i) inventors have temporary marketing exclusivity, which allows recovering R&D expenses, ii) international protection mechanism, iii) obtaining a legal monopoly, guaranteeing protection against imitations, iv) patents provide greater dynamic efficiency, leveraging R&D spending resulting in greater technical progress.

In China, the first patent law was created only in 1985 with the aim of carrying out spillovers to government laboratories. The high volume of patent applications has aroused the interest of several specialists, seeking to understand how the Chinese protection system works. According to Sun (2003), China's patent system focuses on technological diffusion rather than protecting the rights of inventors, in addition, domestic patents focus on the country's industrial design.

Since the beginning of the century, researchers involved in R&D activities in China have grown radically, with the exception of the year 2009 as a result of the global financial crisis. Graph I shows the number of Chinese researchers who carry out research and improve or develop concepts, theories, instrumentation of modeling techniques and operational methods software.

Graph I – Researchers in R&D activities in China between the years 2000-2018 (Data in millions)



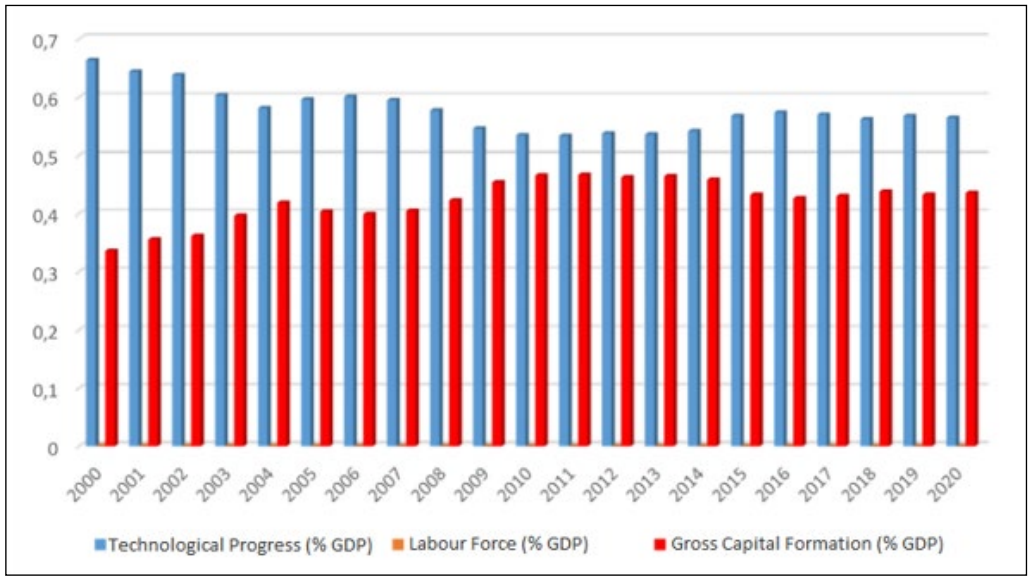
Source: Own elaboration based on World Bank data.

The share of the Chinese population involved in R&D activities is part of the country's development strategy, increasingly driving technological progress on the composition of GDP. According to the results of Fan (2010), since 1986 technological progress had already become the main growth factor of the Chinese economy, improving its comparative advantages.

According to Fan and Watanabe (2006), technological progress can be calculated from the total productive growth of factors and the composition of GDP between capital, labor and technology. In this case, technical progress is a proxy for technology. The results contained in Graph II suggest that despite the reduction of technological progress from the beginning of the century, its participation continues to be crucial for the composition of GDP.

The growth of gross capital formation over the years has affected the share of technological progress, but the labor force in China has contributed little to GDP growth. At the beginning of the reform era, between 1981-1985, Chinese capital was the main driver of growth, contributing to GDP growth by 4.5% per year, while technology increased GDP growth by 3.9% per year. year (FAN, 2010, p. 53).

Graph II – Participation of technological progress in China's GDP growth between 2000-2020

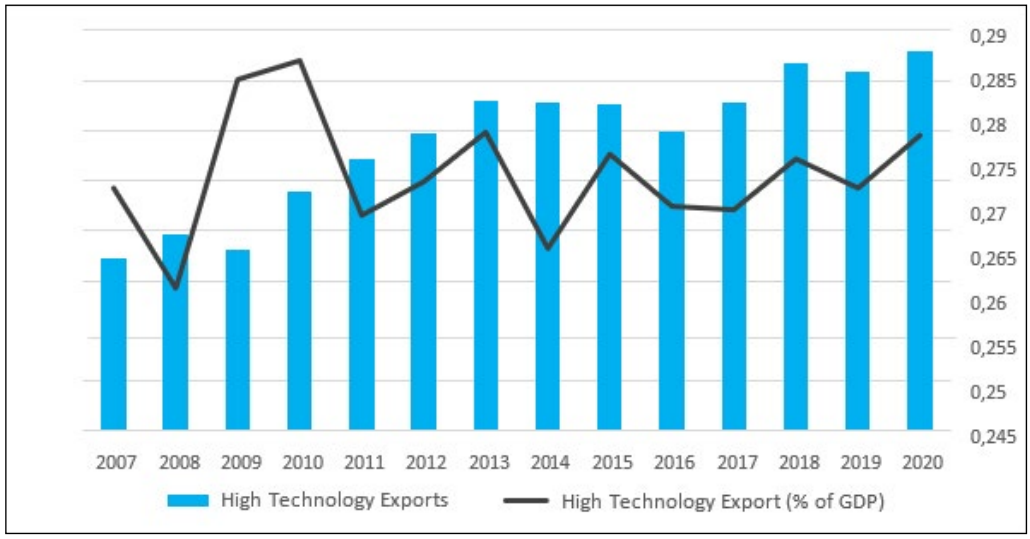


Source: Own elaboration based on World Bank data.

According to Gökmen and Turen (2013) the technological capacity of a country can be explained by its potential for exporting inputs and high-tech goods. In this sense, it is essential to analyze the degree of high technology exports from China, since these products are highly intensive in R&D.

As shown in Graph III, China's high technology exports grew until 2013, with the exception of the 2009 crisis, despite the fact that exports as a percentage of GDP did not decrease with the crisis. The year 2020 represents the highest value exported during the analysis period, corresponding to U$$ 757 billion.

Graph III – China's high technology exports between the years 2007-2020



Source: Own elaboration based on World Bank data.

Activities linked to R&D, share of technological progress and exports of high technology products in China suggest that innovation is linked to the country's high economic performance in recent years. However, Fan (2010) argues that it is still necessary to adopt caution between the eventual causality of R&D and innovation, since factors such as private property, decentralized economies lead to more efficient R&D activities (QIAN; XU, 1998; HUANG; XU, 1998; ZHANG *et al.*, 2003).

4 FINAL CONSIDERATIONS

The understanding of the national innovation system as an attractor for economic development has become indispensable in contemporary capitalism. The elaboration of China's SNI can be understood from its first Five-Year Plan (1953-1957), with hard efforts for the country to intensify its industrial structure. The State Plans for the economic development of the country were also crucial, and from 1985 China's technological transformations began to modify the entire productive structure of the provinces and key states.

As R&D activities represent a clear sign of innovation, analyzing the researchers involved in this branch was fundamental to understanding China's SNI. The results show that since the turn of the century the number of Chinese working in R&D activities has grown significantly, reaching its peak in 2018 by counting on more than one million scientists and researchers. Despite efforts to integrate their population into research activities, the number of scientists in China is still low when compared to OECD countries, this being one of the future challenges of the Asian giant.

China's impressive economic performance in recent years is related to its high technological progress, although gross capital formation has gained strength in recent years.

Contrary to what is usually advocated in the conventional literature, the labor force in China occupies a small portion of the composition of GDP when compared to the other factors of analysis. Since the turn of the century, technological progress has been the main attractor of Chinese development, this characteristic reflects on the degree of exports of high-tech goods, which is a clear indicator of the ability to innovate.

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