Symmetry Breaking in the Evolution of World Economic Structure

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Abstract. Over the centuries, world economic system and the corresponding economic structure have been in a state of continuous evolution. In this paper, through the empirical analysis on the evolution history of world economic structure, we show that the underlying driving force for the evolution of world economic structure is Technology Innovation. Specifically, we find that symmetry breakings not only emerge in the whole economic structure, but also take place in the local economic relation and economic status of inner countries along the long evolution history of world economic structure. We also elaborate the detailed mechanism of symmetry breaking of world economic structure. That is, in the evolution of world economic structure, all those countries participating in world economic open market are affected to varying degrees by symmetry breaking that is caused by technology innovation, which eventually determines current world economic structure with competitive countries evolving into economic centers and countries completely marginalized evolving into 'singularities' of world economic network.

Keywords: world economic structure, symmetry breaking, technology innovation, economic long wave, international division of labor.

1 Introduction

World economic system is an open and complex system. One of defining features of such systems is its continuous evolution. It is theoretically and practically meaningful to find out the mechanism of evolution of the system and characterize the evolution orbit of the system by exploring the structure and function of the economic system. Thus, people can continuously optimize resource allocation of the economic system, improve the economic structure and strengthen its functions.

'World system' theories have attracted considerable attentions since their birth [1-3]. One of important branches following the theory is the Immauel Wallerstein and Braudel research center, which studies world economy and its transformation from the perspective of structuralism. In light of the underlying theory, their notions are not too much different with that of Andre Frank's [4]. That is, they also believe that the origin of world economic system can be traced back to Age of Discovery. However, their theory emphasize on world economic structure that is made up of economic

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center, half periphery market and periphery market, namely the center-half periphery-periphery structure. Hereafter, different opinions on the formation of the world economic system are proposed in the subsequent papers [5-10]. Kasja Ekholm and Jonathan Friedman think the center-periphery structure lie in world economic system since ancient times, which is also an important organization form in the ancient economy [11]. However, center-periphery means different things in different times. In ancient times, it is the center and periphery position in the sense of economic geography, while at present it means center-periphery structure in the international division of labor and is codetermined by the economic geography and industrial structure. Besides these efforts to understand the structure of world economic system, Robert Cox further employed "History structure" concept to analyze the world economy and its transformation, which make a significant contribution to the innovation of methodology on International Political Economy [12-14].

Although we can easily describe the evolutional history of world economic system, it is not trivial to explain the mechanism of the evolution of world economic system. In recent years, symmetry and symmetry breaking has attracted certain interest in the study of structure of complex systems [15-18]. It is widely believed that the evolution of the system is caused by symmetry breaking [16]. Hence, it is meaningful to investigate the evolution of world economic system from the perspective of symmetry and symmetry breaking of world economic structure.

Symmetry in physics has been generalized to characterize invariance-that is, lack of any visible change-under any kind of transformations. It is a significant property to describe the state of the system. It is believed that symmetry dominates modern natural science [19-20]. Hence, it's necessary to analyze symmetry of the system when exploring static or dynamic properties of systems [21]. Symmetry is also shown to be one fundamental property of world economic structure [18]. Symmetry breaking can be described as a phenomenon where small fluctuations acting on a system crossing a critical point decide a system's fate, by determining which branch of a bifurcation is taken [21]. It is symmetry breaking motivate the system to evolve. The evolution of the cosmos, life and society all experience the process from complete symmetry to local symmetry, and eventually asymmetry [21].

Similar to concepts of other symmetries in physics, symmetry of network structure characterizes the invariance under certain transformations. Symmetry in network structure characterizes the invariance of adjacency of vertices under the permutations on vertex set, which implies that 'invariance' of the symmetry in network structure is the relation among vertices and the 'transformation' is permutations on vertex set [18].

With the increase of the openness of the world economy and high degree of economic interdependence, the world economic system evolved from early bilateral structure to present multilateral network. National countries are not independent but coexistent in the world economic network which is increasingly complicated. Once the economic behaviors and trade start, and subsequently markets come into being, the original homogeneous and symmetric nodes will evolve into economic center or periphery market spontaneously. Due to different position in the geographical and international division of labor, countries are located in different hierarchy of the economic network. However, national countries in the same hierarchy are symmetric in terms of their economic spatial position, their status and function in the world economic network are also similar.

2 Technology Innovation – The Driving Force for Symmetry Breakings Emerging in World Economic Structure

In 'Innovation Theory', Schumpeter elaborated great effect of technology innovation on the economic development for the first time, which pioneered the studies about the correlation between technology innovation and the evolution of the economic system [22]. Hereafter, a number of economists including R.Solow, T.W.Schultz, K. Arrow, G.Grossman, E. Helpman, R.Barro, P.Aghion, P.Krugman, A.Young, G.Becker, demonstrated that technology progress is a decisive factor to promote economic continuous growth from the perspective of human capital accumulation, product variety increase, product quality improvement, technology imitation, specialized division of labor, respectively.

The function of technology innovation in the economic history is similar to that of gene mutation in the biological evolution. Enormous energy conserved in the process of economic development burst out, consequently, the equilibrium and symmetry of the system is broken. In the long development history of world economic structure, technology innovation motivates the economic structural transformation, leading to continuous symmetry breaking of the economic structure, and accordingly continuously evolution of the economic system.

The economic history has periods of dramatic transformation, which is the same as human evolution history. Multi-factors will affect dramatic transformation of economic system. The most important factor is always technology innovation, which is "the kernel engine to drive the capitalistic economic growth" and "the driving force for the transformation of economic pattern". During the last 100 years, the world economic system has experienced five dramatic transformation periods. Each transformation period is characterized by certain fundamental technology innovation.

In the first economic long wave, the use of steam engine leads to fundamentally improvement of instruments for production, which give rise to the fist leap of industrial productivity. In this period, the central country of the first industrial revolution is UK.

In the second economic long wave, iron and steel industry and coal mining industry stand out from the various industries, growing to be leading industries with rapid growth. In this period, the center is still UK; while French, US, Germany, Russia and other countries in the half periphery region achieved economic 'take-off'.

The third economic long wave is marked by the electric power in the 1880s. The developments of electric power result in the renovation of vehicles and communication tools. Automobiles, airplanes, telegraph, telephone, fax and radio appeared in succession. With the wide usage of new technique, electric industry, chemical industry, machinery manufacturing, and other heavy industries have replaced the light industry represented by textile industry, becoming the new leading industries. In this period, Germany and US become economic leaders. Japan and Canada cut a figure at this time.

In the 1950s, with the advent of the fourth economic long wave, new technologies, including computer, atomic energy and space technology, are emerging. In this period, instruments of production, transportation and communication system have

reached a new level. As the initiator of new industries, US further consolidate its role as world economic center.

In the 1970s, information, network technology suddenly come to the force, and result in a new economic long wave coming unconsciously.

From the past five economic long waves, we can see that each of the major technological innovations arising from fluctuations in the economic cycle change world economic structure at least in two aspects: first, changing industry structure, which is caused by technology innovation and adjustment of supply and demand; second, changing of relative economic strength and corresponding status among countries, which is caused by the unbalanced innovation and development [23]. With the ups and downs of economic long wave, organization form of the world economy, the patterns of cooperation and competition will lead to some fundamental changes in the economic structure, and consequently, symmetry breaking emerges in the economic structure.

3 Continuous Symmetry Breakings in World Economic Structure

During the past five economic long waves, for world economic system, both its whole structure and internal structure have been in a state of constant evolution and continuous symmetry breakings.

3.1 Symmetry Breakings Emerging in the Whole World Economic Structure

After the former four economic long waves, world economic system take on a traditional center-half periphery- periphery structure (which is illustrated in Fig 1) with US, Japan and EU as the economic centers.

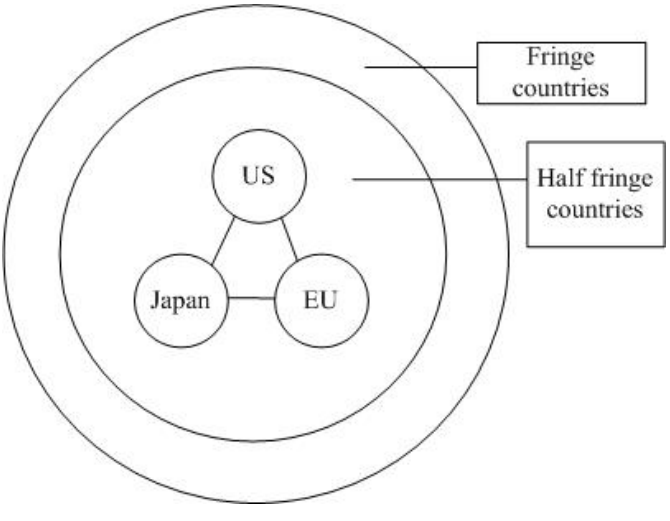

Fig. 1. Illustration of old world economic structure

In the 1990s, with the advent of another technological revolution-information revolution, as well as ensuing changes of production and organization pattern, symmetry breakings of the whole world economic structure emerge, new economic structure comes into being.

At first, owing to the difference in the competitive capacity and adjustment cost of labor market, symmetry breaking took place in the traditional economic centers in the process of economic globalization. US is distinctively outstanding in the upsurge of new economy in the 90s and became a large country inventing and producing information product, consequently, it surpasses other countries in the international division of labor. In light of EU, European countries led by Germany, also have outstanding performance in the process of globalization. They participate in part of the international division of information products. However, for Japan, 90s is the lost ten years. Due to its unsuccessful economic restructuring, Japan's economic still mainly relies on automobile manufacturing industries, which decrease its status in the international division of labor. But in other high-end consumer product manufacturing, Japan still takes priority in the world. It is the formation of vertical structure of international division of labor that results in the ten years of economic boom of US and economic recession of Japan, the richest country in Asia.

Secondly, countries near the three traditional economic centers, including North America, west Europe and east Asia have benefited from economic diffusion to the fullest extent. They get more opportunities than other regions through open economy, which increase their production efficiency and promote their economic growth. These three regional economic groups are the main beneficiary in the process of international division of labor, also become main battlefield of international markets.

Finally, from both geographical and industrial perspectives, periphery participants of international division of labor have become the periphery of the world economic structure. In Europe, Asia and America, represented by Russia, India, Brazil and Argentina, respectively, all these counties have vast land and population. However, due

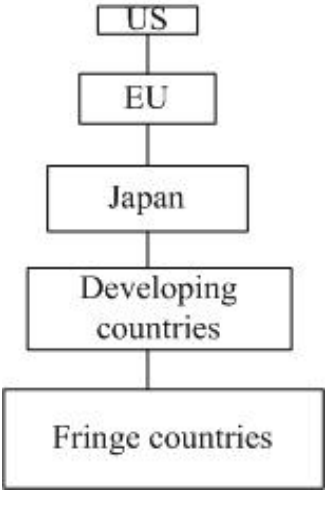

Fig. 2. Illustration of new world economic structure

to lack of enough consuming power or steady political and economical environment, they do not participate in the globalization process completely but also become periphery beneficial groups. Some industries in these periphery countries, such as software industry in India and high technology military industry in Russia, are outstanding and internationalized, however, their globalization index are very low or they participate in international division of labor just as raw material export countries. Even worse cases are irrelevant countries that are completely excluded from globalization. Most of countries in Africa fall into such a predicament.

World economic structure in the current world (illustrated in Fig 2) is similar to the structure of pyramid, which can be described as follows: On the top of the pyramid is US, which creates new economy and steers human being into information society. On the second ladder of the pyramid is EU represented by UK and Germany. UK is a leading financial services provider in international division of labor, while Germany specializes in the capital goods production. On the third ladder of the pyramid are some developed countries represented by Japan. They specialize in final consumer products with intensive capital and high technology and added value. On the fourth ladder of the pyramid are a large number of developing countries. They specialize in final consumer products with intensive labor. On the last ladder of the pyramid are periphery participants in the process of international division of labor.

3.2 Symmetry Breakings Taking Place in Economic Relations and Economic Status between Inner Countries

US, EU and Japan are three traditional economic centers, their status in world economic structure are symmetric. However, symmetry breaking emerges in their relative economic status with the advent of the information age. US are expanding its economic predominance, and still maintain the economic center in the world economic structure. As for EU, its inherent rigidity of systems (labor market, capital market) result in innovation deficiency, even worse, the “brain drain” is intensified. However, However, EU is carrying out positive eastward expansion and integration strategy. Although in the short run, there are still great obstacles such as instability and structural adjustment cost, but from the source of economic growth, long-term effects driven by markets expansion are obvious. Hence, EU can be classified into the second ladder of international division of labor. Japan, on the one hand is the same as EU in structural defects in the labor and capital markets, which takes her a decade to adjust the economic structure. Even worse, neither its currency policies nor financial policies, turn out to be effective. Hence, it is difficult for Japan to go through a renaissance. On the other hand Japan is different from EU in its physical space which is relatively narrow, and consequently the absolute space for economic enlargement is limited. Besides these negative factors, East Asian countries are traditionally dubitable in foreign policies to Japan. All these factors together are great obstacles for Japan to develop its economy rapidly in the East Asian markets, which caused Japan to drop from the economic center into the third ladder. In the 90s, the economic growth (annual percent change) of three traditional economic centers is illustrated in fig.3.

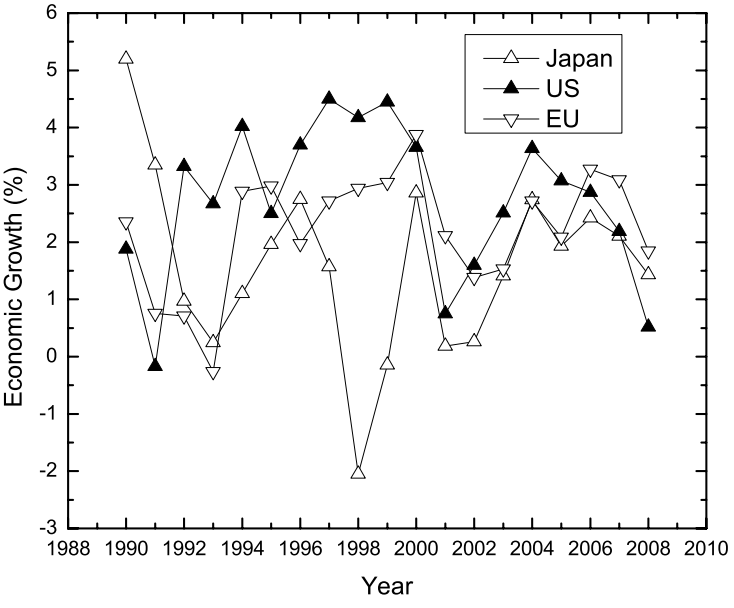

Fig. 3. The economic growth (annual percent change) of US, EU and Japan (Data source: www.imf.org. and www.oecd.org)

In the 1990s, the status of developing countries is advancing in world economic system. The eye-catching change in the world economy is the development of developing countries. Taking advantage of their cost advantages, developing countries get more and more opportunities to participate in international division of labor, consequently, they get more benefits from spill-over effects. For example, they are acquiring more advanced technologies and improving supply and demand of labor force. They enter the export market of technology-intensive production which they can not produce previously, and become part of international production system. In 2001, China, Mexico, Singapore and Turkey became big countries with high foreign direct investment (FDI), while FDI in US, UK, Canada and Germany were slowing down.

The international competition of some country can be evaluated in the following aspects: 1) the ability of economic restructuring and technical capacity under conditions of globalization; 2) the ability of entering big competitive open markets, such as markets of developed countries; 3) the price gap between production cost of original place and the price of target markets, which determines the potential profits in the future; 4) the political prospects and development policies. It is very difficult to measure the above-mentioned aspects directly. Therefore, we choose two comprehensive indicators, the total amount of FDI and total imports and exports, which can be quantified to evaluate the international competition of a country.

China is the biggest winner among developing countries benefiting from international production system. It plays increasing role in the world economic system. China used to be an economically-backward country in the Third World. But now the Chinese market has a pivotal position in the East Asian region. As is evident from

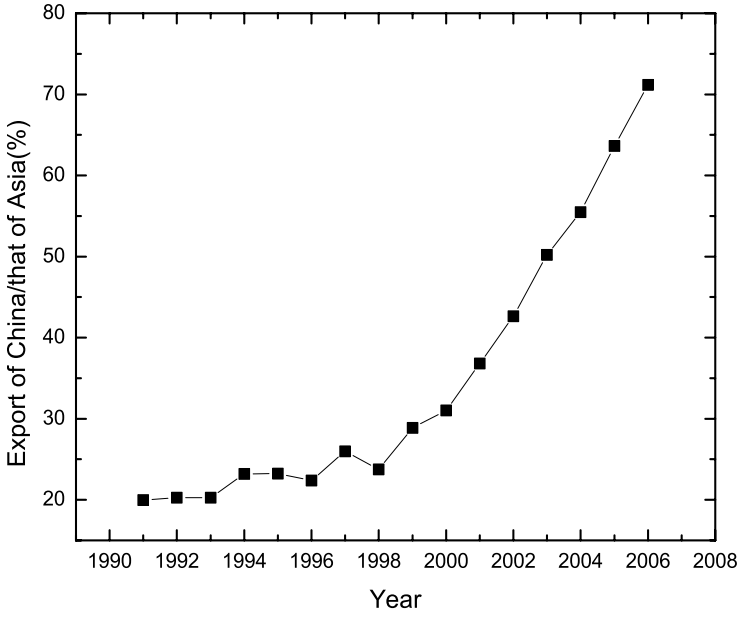

Fig. 4. Exports of China as a share of newly industrialized Asian economies (Data source: www.imf.org. and www.oecd.org)

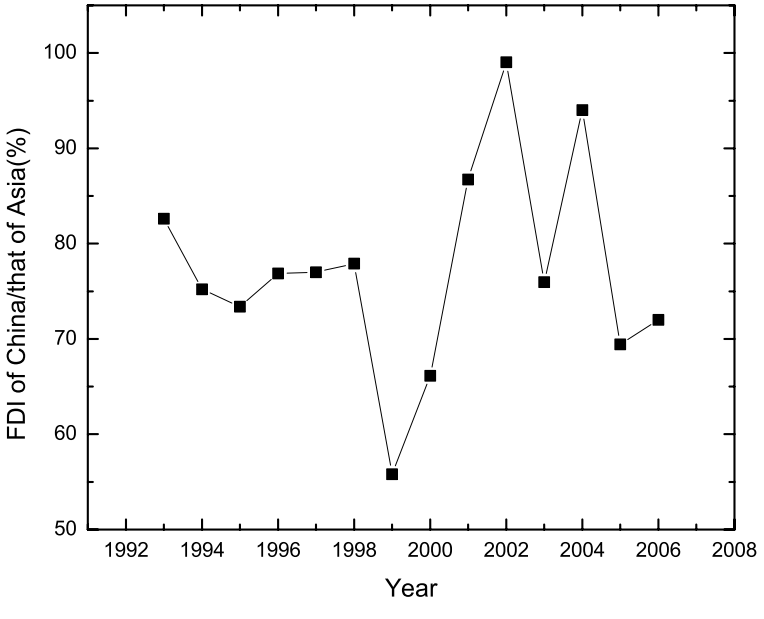

Fig. 5. Inflows of foreign direct investment of China as a share of developing Asia (Data source: www.imf.org. and www.oecd.org)

Fig.4 and Fig.5, exports of goods and inflows of foreign direct investment of China all account for a large proportion of the Asian developing countries. It is no exaggeration to say that China has become regional economic center of East Asia, and will has far-reaching influence on the Asian regional economical evolution.

4 Conclusions

Symmetry breakings emerge continuously in the evolutional process of the world economy. Symmetry breakings took place both in the overall economic structure and economic power of interior countries. The most active factor of the economic system is technology innovation, which motivates symmetry breakings emerge in the economic structure. The developments of transportation and communication resulting from technology innovation break through the limitations of the space distance, and consequently, production structure must be reconstructed in the worldwide range and resource allocation must be optimized, so that symmetry breakings will emerge, and economic system will evolve.

In the evolution of economic system, not only emerging industrial regions can get opportunities to catch up by adoption of new production and organization patterns, but also old industrial regions are also facing new opportunities brought by 'symmetry breaking'. Once the transformation of production and organization patterns is successful, the economy of the whole old industrial regions may get recovery.

In this economic network, countries that can take advantage of economy of scale and economic externalities will be outstanding in the competition, In other words, those economic nodes having both comparative advantage and absolute advantage will get more opportunities. Asymmetric rules of technology diffusion determine that a lot of countries and regions with economic developments of low speed would be completely marginalized and become "singularities" of the world economic network in the process of economic development.

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