Agent-Based Modelling for International Trade

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Dr. Ahmed Okasha; Asmaa El-Refaee and Dr. Salwa Abdelaziz

Abstract

The system of the world economy has recently become more efficient and integrated due to the globalization effect. This effect results in driving the progression of both the technology and the liberalization of trade and capital markets. The technological improvements reduce the costs of transportation and communication between the countries. On the other hand, liberalization of trade and capital markets reduces the forms of unfair foreign competition . The main objective of this study is to design an agent-based modeling that unravels the role of technological improvement in changing the international trade structure between the developed and developing countries. The study also tackles the effect of capital mobility on the structure of international trade. These two objectives are achieved through proposing different scenarios. Furthermore, the proposed agent-based modeling is based on two assumptions, the Samuelson's analysis of outsourcing between the developed and developing countries assumption and the capital mobility assumption. Traditionally, technological progress is considered the cornerstone of international trade flows. The general pattern of trade flows is from the developed country, to the developing country. Applying a set of ABM scenarios on the international trade schemes revealed a general pattern of trade flows from the developing country to the developed country. This was attributed to the gradual technological shocks introduced to the developing country's industrial sector. Furthermore, the results showed that the developing countries possess the capability of turning into new economic powers in all fields shall they properly invest in technological progress.

Keywords: International Trade theories, Agent-Based Modeling, Technological Gap Theory, Comparative Advantage Theory, Capital Mobility.

1 Introduction

International trade has an important role in the formation of the Gross Domestic Product of different countries. Enterprises from different countries search for new growth or expansion opportunities outside their countries' boarders. The key sectors of any economy –such as industries and information and communication sectors- can be motivated by the international trade. The economic enterprises can thus increase their profits, reduce their dependence on local markets and expand the outreach of their businesses. This way, the consumers and other enterprises would be subjected to a wider range of repositories of products and services (Surugiu and Surugiu, 2015).

International trade is widely affected by the forces of globalization. Globalization refers to the increasing interdependencies between countries resulting from the growing integration of trade, finance, people, and thoughts in one worldwide commercial center (Boskov and Lazaroski, 2011). It is motivated by two fundamental elements. The first includes technological improvements that have brought down the costs of transportation, communication, and commutation. The second element is related to the liberalization of trade and the expansion of capital markets. However, there is still an increasing number of governments who impose a set of tariff and non-tariff barriers on the imported commodities and services. They use this as a tool of protection to their economies from foreign competition through imports. (Boskov and Lazaroski, 2011).

Classical trade theories usually illustrate that opportunities of mutually beneficial trade exist through specialization that is based on relative efficiency. While, the modern theories of trade point to other sources of gains from trade among countries. Among these sources; the economies of scale in the production, the competition in production, broader access to variety of goods and the difference in the technology levels between countries (Morgan and Katsikeas, 1997). Sawyer and Sprinkle (2015)

have also asserted that the dynamic technological improvement among countries could be considered as a major determinant for international trade.

All the classical and most of the modern theories of trade postulates traditional models for international trade. These models are developed based on the assumptions of homogeneity, perfect rationality and anonymity. The interactions between the economic agents in these models are characterized by their linearity (Tesfatsion, 2006). On the other hand, the international trade system does not ultimately fit the aforementioned setting. It is considered as a complex adaptive system that comprises interacting heterogeneous, bounded rational, autonomous agents (countries, firms, consumers, workers…). The agents' interactions are complex and nonlinear (Mills, 2010). The agent-based modeling (ABM) serves as a suitable tool for studying the behavior of complex, nonlinear stochastic systems. Agent-based modeling has been successfully used, in combination with social simulation, for modelling complexity in international trade system and examining the concept of emergence and evolution. Several differences exist between the traditional modelling methods (e.g., Computable General Equilibrium models (CGE), gravity models, global vector auto-regression (GVAR)) and Agent-based modeling technique.

First, traditional modelling assumes that all agents are profit-maximizing agents. They always seek to optimize their utilities, according to some constraints. They have full information about their reality, and take decisions based on this information. Thus, the agents are homogenous (similar) in all behaviors and actions (Byrne, 1998). On the other hand, the ABM assumes that agents are heterogeneous. This means that they behave in a different way in the same situation based on their preferences, knowledge and interactions with the environment and themselves. Second, traditional modelling approaches such as differential equations and dynamic stochastic general equilibrium (DSGE) models cannot model

complex relationships or interactions between agents. While, the ABM can simulate any kind of relationships, enabling for simulating social behaviors and direct or/and indirect interactions among agents (Ramanath and Gilbert, 2005).

Third, traditional modelling focuses on reaching the system's equilibrium state. However, in ABM the dynamic patterns of the behavior are more important than the equilibrium since the results of the model can change over time when changing any parameter value. Fourth, the main focus of traditional models is describing the baseline or common overall behavior. Whereas an interesting capability of Agent-based modeling is to study the emergent behavior or phenomena. Finally ABMs are able to mimic real life features of agents in a more efficient way than conventional approaches (Kaisler and Madey, 2009).

This research targeted exploring the significance of the technological improvements and the capital mobility on the international trade flows between the developed and developing countries. To achieve this purpose, an ABM was developed to study and test the different economic theories and the applicability of economic assumptions on the trade flows. This study is considered as an extension of the Gulden`s (2013) model of international trade.

In this study, the original model was extended by means of two extensions. The first extension model, represented new scenarios for the concept of technology shocks in Samuelson's comparative advantage theory. The second extension model investigated the impact of capital mobility on international trade based upon Samuelson's theory. The validation process for the two simulated models was developed by comparing the real trade data of CRS (Congressional Research Service) report 2017 with Gulden`s research results to reach a more realistic analysis of the international trade system.

The Gulden`s model mainly assumed that the classical theories such as the comparative and the absolute theories were the appropriate framework for trade between developed and developing countries. This study adopted instead a modern framework that was based on the product life cycle and technological gap theories which are the current dominant theories of trade flows between developed country (U.S.) and developing country (China).

The general objective of this research was to formulate a model of the international trade system as a complex system. The specific objectives of this paper could be categorized as follows:

- Studying the role of technological improvement within the developed and developing countries in changing the international trade structure.
- Studying the effect of technological improvement on the labor distribution between the developed and developing countries by examining different scenarios.
- Evaluating the applicability of capital mobility assumption and its effect on Samuelson's theory through different simulated scenarios.
- Validating Samuelson's comparative advantage theory and its main assumptions using the real trade data.
- Changing one of the key assumptions of Gulden`s trade model which is the absolute advantage theory that governs the relationships between the developed and developing countries to the technology gap theory that governs the relationships between the developed and developing countries and studying the effect of this change.

This study is organized as follow: section 1 provides an introduction to international trade system. Section 2 represents the theoretical framework for international trade system. It discusses the theories of international trade and the main models for simulating international trade system. Section 3 represents the ODD protocol for the international trade model. While, section 4 discusses the results of the proposed models for studying

the impact of technological improvements. Finally, in section 5 the conclusion and the directions for future research are presented.

2 A theoretical Framework for The International Trade System

The literature of international trade representation theories and models revealed that they are classified into three main categories; classical theories, modern theories and complexity theories. Among the most acknowledged classical and modern models were: The Gravity Model of Trade Flows (Shahriar et.al, 2019); Global Vector Auto-Regression Models (GVAR) (Kepaptsoglou et.al, 2010) and the Computable General Equilibrium Models (CGE) (Gourdon and Jean, 2016). As for the complexity perspective, this has been approached using computational modeling. One of the key approaches for computational modeling is agent-based modeling approach.

2.1 Classical Trade Theories

The earliest classical trade theory is the "mercantilists" (Salvatore, 2011). Mercantilists believed that trade is a zero-sum game. According to that theory, the objective of foreign trade was to achieve surplus in balance of payments. Adam Smith then emphasized the importance of free trade in increasing wealth of all trading nations. His theory of international trade was based on the principle of absolute advantage (Langdana and Murphy, 2014). Adam Smith's theory was strongly criticized by many scholars such as David Ricardo. Ricardo argued that it is the differences in comparative costs which forms the basis of international trade. His theory was based on the principle of comparative advantage (Vijayasri, 2013). According to him, each country will specialize in the production of those commodities in which it has the greatest comparative advantage or the least comparative disadvantage. The credit of developing modern theories of international trade (in early 20th century) goes to the economists Heckscher and Ohlin (van Meerhaeghe, 1986). Heckscher – Ohlin have explained the basis of international trade in terms of factor endowments.

The Ricardian theory and Heckscher – Ohlin theory were relevant till the first half of the twentieth century. Up till then, these theories could account for the prevalent pattern of world trade.

Later on, several economists modified the Heckscher – Ohlin theory by introducing the concepts of the role of economies of scale, imperfect competition, differences in technology to it. For instance, Posner's technological gap theory and Vernon's product cycle theory have analyzed the effect of technical changes on the pattern of international trade. Another important development in the theories of international trade in the late 1970s was the development of intra – industry trade models. The intra – industry trade models emphasized that economies of scale and imperfect competition could give rise to trade even in the absence of comparative advantage. Some of the important intra industry models were developed by Krugman (1979) and Brander & Krugman (1983). The strategic trade policy models developed in the second half of 1980s act as extensions of intra-industry trade models. Krugman (1984) and Brander & Spencer (1985) have made notable contributions to the strategic trade policy models.

2.2 Modern Trade Theories

Modern trade theories include many theories such as: (1) Linder`s Theory of Representative Demand (Sha and Hughes, 2009), (2) Technological Gap Theory (Blanchard, 2017), (3) The Product Life Cycle Theory (Jensen and Thursby, 1986). The modern trade theories confirmed that the technological progress, the diffusion of knowledge and the investment in human capital are explicit variables that determine the economic growth. As a result, there are differences between countries in the nature and application of technology and innovations due to the variances in quality of the education systems and research and development capabilities. These theories explain the high levels of intra-industry trade and the large

proportion of world trade that takes place between similar countries (Lam, 2015).

According to the technological gap theory, the competitive advantage of trade among industrialized countries is based on the introduction of differentiated products and new production techniques and technologies. These give the innovative firm and the country a monopoly position and power in the world market. This monopoly power often depends on the patents, copyrights and the applications of technology in the production process. Accordingly, the dynamic changes in technology among countries can be an independent determinant of international trade. That's why modern theories can be regarded as a dynamic extension of H-O theory. A shortcoming of this theory is that, it does not explain the size of technological gaps, the main reasons of these gaps and how to measure it between the countries. While the Product Life Cycle Theory claims that the main reason for the trade is the large gap between developed and developing countries in technology, knowledge, research, and development of new marketable products. This theory includes three general stages of product development: (1) the introduction, where developed and developing countries exporting a particular product to foreign markets. (2) The standardization, where inventing countries lose export market shares to the other countries who imitate the innovation. (3) The maturation, where the inventing countries became net importers of the new product (Jensen and Thursby, 1986).

2.3 Complexity Theories

Economic systems are dynamic and complex systems. These systems have many interacting agents. The interaction between agents is non-linear. Each agent motivates by its own interest. Furthermore, agents are autonomous and heterogeneous and behave based on local information (Tesfatsion, 2006, Okasha and Johnson 2009). Thus, it is obvious that it should be approached as a complex adaptive system. Complexity

increases our understanding of economic phenomena by clarifying how various types of microeconomic structures emerge and aggregate to form the economic phenomena. One of the most important methods of the science of complexity is Agent-based modeling. ABMs are used to solve problems across many fields, for instance; economic systems, financial markets, international trade …etc. Agent-based modelling has been developed based on the concepts and techniques of complexity theory. ABMs allow researchers to model complex sets of relationships that cannot be explicitly modelled using traditional modelling approaches such as econometric models. (Okasha and Johnson 2009)

Agent- Based Model (ABM)

The economy is not necessarily in an equilibrium state as economic agents (firms, consumers, and investors) constantly change their behaviors and strategies in response to the outcome they mutually create. The real economic system is complex due to the dynamic behavior and interactions between economic agents (Gilbert, 1995, Okasha and Johnson, 2009). Complexity increases the perception of economic phenomena by explaining the emergence of aggregate patterns from the interactions at the microeconomic to the macroeconomic levels. One of the important techniques of complexity science is the computational technique, which is called Agent-Based Modelling. ABMs have been developed from the ideas and techniques of complexity theory (Okasha and Johnson, 2009).

Gilbert (2007) defined Agent-Based Modelling as "The computational method that enables a researcher to create, analyze, and experiment with models. These models composed of agents that interact within an environment". According to this definition, ABM is populated by agents that are interacting inside the model according to some behavioral rules. Agents interact locally with each other and with the surrounding environment where these local interactions give rise to global regularities (Nikolic and Kasmire, 2013).

3 International Trade Model

The model is populated by two types of agents; citizens and nations. Each citizen is associated with nation and worth one unit of each labor and capital. Each citizen agent chooses to deploy in one of two national industries. his choice depends on which industry pays higher wage or return to capital. The wage and return to capital form the income for the citizen agent. Then, citizen agents use their income to demand goods.

Each nation has two industries that produce goods. The Cobb-Douglass production function is used to represent the production for both industries. The production function uses the labor and capital that the citizens provide. Each citizen agent calculates the wage, return to capital and prices for the goods produced. Then, agents are engaged in trade. If the price of goods is lower in the other country, then they import goods from this country.

To explain the mechanisms involved with international trade model, the ODD protocol is used. The ODD protocol is a way to describe an agent-based modeling (Müller et.al, 2013). It provides more logical justifications and reduces criticism to the model. The ODD protocol have been adopted by many social researchers. The standard ODD protocol consists of three main parts; Overview, Design Concepts and Details. In the following section, the ODD protocol of the international trade model used in this study will be represented.

3.1 The ODD Protocol for International Trade Model

3.1.1 Overview

The proposed model is based on Gulden`s trade model (Gulden, 2013). Two theories of Gulden`s trade model will be studied to evaluate the technology`s importance; the Samuelson's analysis of outsourcing and Daly`s observations on capital mobility. As mentioned earlier, the model tackles the role of technological improvement and capital mobility on

mutual beneficial trade between the developed and developing countries in the international trade system. The Gulden`s model is used to study the technological change in the form of gradual multi-shocks. In addition, results will be tested and validated with real trade data. Furthermore, the impact of technological progress on the distribution of labor inside each industry will be tested according to the Solow residual of the technological impact on the effective labor force (Blanchard, 2017).

- **Model Assumptions**

The main assumptions of the proposed model are the following:

1 The model mainly depends on the technological gap theory rather than the comparative advantage theory which was assumed to be the dominant theory by Gulden`s model.

2 The model uses the standard version of Hecksher-Ohlin trade model, which consisted of two countries [U.S (developed), China (developing)] and two industries (One and Two). The labor and capital are the main factors of production, according to Cobb-Douglas production function (Low, 2016).

3 China has an absolute advantage in the production of industry One. So, it can export products from Industry One and import products from industry Two from U.S.

4 The U.S is the leader in the technological improvement in the industry One and has an absolute advantage in the production of this industry. The technology coefficient is at the highest level of 2 as assumed in the model.

5 For Samuelson`s theory in the model, the technological improvement in China's industry Two will occur as a multi-shock in a continuous time where, the coefficient of technology will be simulated with a different value started from 0.05 (the start value) till the level of developed country of 2 (the highest level of technology as assumed in the model). Unlike Gulden model in which the technological

improvement in China's Industry Two happened as a single sudden shock in a discrete time where the coefficient of technology was changed from 0.05 to 0.8 once a time.

- **Entities, State Variables, and Scales**

The agents are classified into two types: citizens and countries. The citizen agent has two state variables: a job or an investment. The country agent has different state variables: the structure of production (which is determined by a Cobb-Douglas production function), the quantity, the factors of production for each industry and the total factor productivity A or (TFP).

Citizens choose to work or invest in one of two national industries depending on which pays the highest wage or return to capital. They use these wages or returns - their income- to demand goods. Countries own local industries (One, Two) that produce goods. The calculation of wages and returns to capital is based on the comparison with the prices for the goods produced. When trade is supported, countries also are involved in trade. They import more of the goods if the price of imported goods is lower than the prices of its production of the same goods. They pay for these imports by exchanging with goods from the local industry where the local price is lower.

3.1.2 Design Concepts

- **Emergence**

The emergent phenomenon in the proposed model for trade mainly depends on the behavior of each agent in (his/her) own nation. The general trend of the results confirms the superiority of the developed countries (U.S) in all fields over the developing one. This superiority includes the levels of technological improvement in the industries. The flow of trade according to Gulden`s assumptions was in favor of a developed nation. In

addition to the control of the developed (U.S) country on the productive capacity in all industries.

- **Adaptation and Objectives**

The two types of agents associated with the model are associated with different set of rules that drive their behavior of maximizing their utility and taking the appropriate decisions. For example; the citizen agent has two state variables, whether to work on (his /her) country in one local industry (One or Two) or to invest in one of these industries based on the higher rate of return (he/she) will gain. The decision to work or invest in the model depends on the trade-off between the higher wages or returns that can be obtained from these industries.

- **Learning and Prediction**

Each agent's learning depends on (his/her) behavior and interactions within the surrounding environment. In the model, at each time step, agents learn how to maximize the optimal utility for their own and their countries, by choosing to work in the suitable job or invest their incomes in the most profitable industry. According to each agent`s behavior and utility, the country can make its own prediction.

- **Interactions and Stochasticity**

The interaction between agents is a stochastic process because interaction partners are chosen randomly. Each agent is free to interact within each industry, whether to work or invest. On the other hand, the interactions between the agents and the environment are determined not randomly assigned. In the initialization process each country has its own determined agents. So, the agents to environment interactions have limited change. The agent-to-agent interactions may be different and assigned randomly.

- **Spatial scales**

In this model, the international trade system is represented where, countries can import and export goods from each other. Temporal scales represent the different stages of the production process.

3.1.3 Details

- **Process Overview and Scheduling**

The model runs the international economies for 2000 time steps. Each run is divided into three main stages of production; autarky[1], trade and development. At the first stage, the developed country (U.S) has an absolute advantage in industry Two production. The developing country (China), correspondingly, has an absolute advantage in industry One production. The absolute advantage in the production means each country can produce high quantities of certain commodity with lower prices compared to another nation. The utility function is the first step for agents to choose the best combinations of the two commodities to consume. The demand function is then applied by the agents for demanding the goods based on the different prices (Rosen, 2005). The utility and demand functions are shown in equation (#1)and (#2) respectively.

- **Equations and Rules of the Model**

In each time step, each agent collects information about the current prices of both goods, the current wage in the industry One and the current return on capital in the industry. Then, the agent calculates the demand for both goods based on the expected income from wage and return on capital in addition to the prices of the two goods using the simple demand function (#2).

[1] Autarky: refers to the state of self-reliance, it is applied to self-sufficiency and closed economies without any sources of external support, trade or aid

The first equation in Gulden`s model is the utility function in the following form:

$$U = (C * W)^{0.5} \qquad \rightarrow (\#1)$$

Where:

- **U** is the utility function which can be calculated as the geometric mean of the consumption of the two goods.
- **C** is the consumption of industry One goods.
- **W** is the consumption of industry Two goods.

The utility function represents the best combinations of both goods that the agents can consume. Then the demand function as shown in (#2) is the second equations in the model.

$$D_i = \frac{Y}{2} P_i \qquad \rightarrow (\#2)$$

Where:

- **Y** represents income from wages and investment.
- **Pi**: represents the price of goods.

Each agent should spend all the earning income from work or investment on the two goods because, the model assumed no savings. This is the principal of utility maximization which means, the agents are seeking to maximize their utility from consuming goods in case of the budget is fully spent. Thus, any combination of the two goods will be the optimal choice. This is the reason for dividing the income by 2 as shown in demand function (#2). This allows the agents to demand two goods. The agent should spend all the income to have incentive to work in the next time step. An agent may re-examine the job and investment choice, changing jobs or shifting to the investment in the industry that provides the higher wage or return to capital. The structure of the nation's industries is given by a pair of Cobb-Douglas production functions as follows:

$$Q_i = A\ L_i^{\alpha}\ K_i^{\beta} \qquad \rightarrow (\#3)$$

Where:

- Q_i is the total production of the two goods, $Q_i > 0$
- L_i is the number of labor dedicated to this production, Li > 0
- K_i is the amount of capital dedicated to this production Ki > 0
- **A** represents the state of technological changes in the production, it is called TFP or total factor productivity as it will be discussed in section four, A > 0
- **α** and **β** are the output elasticity's2 of labor and capital. Hence, as assumed by Gulden that $(\alpha + \beta) = 1$ means the production function has a constant return to scale (CRS).

- **The Capital Mobility Assumption in Gulden`s Model**

Capital mobility assumption means the ability of private assets to move across over country borders for achieving higher returns. This assumption implies no transactions cost or other costs of moving capital from one country to another. While, capital immobility means it is difficult and costly to move capital between countries (Zebregs, 1999). There are numerous determinants for capital mobility, for example; tariffs/taxes on capital flows. Capital flows may be burdened by the government. There might be some restrictions on capital flows where few countries may force limitations on the capital that can be moved inside or outside the country.

The capital mobility phenomenon, as modeled by Gulden`s ABM, was studied with its extreme values (exist/not exist). Gulden examined the capital mobility assumption in his model as follows: The Samuelson`s theory was divided into two parts. The first is Samuelson's pre-development case, that has no technologies. The second is the post-development case that has the technological improvement in the industry Two as a shock process happening at a specific time. In both cases, the

[2] Output elasticity measures the responsiveness of output to a change in levels of either labor or capital used in production. For example, if α =0.15, a 1% increase in labor would lead to approximately 0.15 % increase in output.

U.S is more productive than China in industry Two and China is relatively more productive than U.S in industry One and also more populous (Watsa et al., 2008).

According to Gulden`s model, the capital mobility will occur in two cases: allowing full repatriation of profits[3] or eliminating repatriation of profits. In the first case; with full repatriation of profits and no technologies, both countries' utilities will increase. In the case of allowing full repatriation of profits to the home country this increases the China`s utility as more money transferred to its account (Salvatore, 2011).

4 Results

The model results are divided into two parts; the results of the first proposed model that studied the role of technological improvement in the international trade system according to Samuelson's theory. While the second represents the impact of the capital mobility assumption on Samuelson`s theory in the international trade system. Simulations were run at different development-shock-A settings (0.05, 0.35, 0.65, …,2.15). Each point in the results represents a simulation. A simulation had thirty experiments. Each experiment ran an economy for 2,000 time steps. Each point was taken as an average value over 30 runs at 2000-time step.

4.1 The Impact of Technological Improvement on International Trade

The first proposed model studied the role of technological improvement in the international trade system according to Samuelson's theory. The extension of Gulden's model was used to implement the technological improvement. The technological improvement had a vital impact on the national utilities and the production for each nation while keeping all other variables in the model fixed. The model used "development-shock-A" parameter as the technological improvement for the China's industry Two

[3]Repatriation of profits :The transfer of corporate money or property from a foreign country back to its home country.

which created many scenarios. The final impact of technological improvement in China`s industry Two is shown in Figure (1).

The simulations prompted two main scenarios: The first one entailed studying the technological improvement as multi-shocks at different times. In figure (1) the simulations were executed as a discrete experiment, which means that the technological improvement happened in a specific period and then its effect halted and started a new shock in the next period.

For scenario one, the simulations started at (development-shock-A = 0.05), each experiment was completely separated from the other ones. There were eight experiments. For each experiment the value of development-shock-A was increased by (0.3). In each simulated experiment, some variables were tested and evaluated such as: the national utility for China and U.S, the utility of the world, the Industry One production for China and U.S and finally production of Industry One in China and U.S.

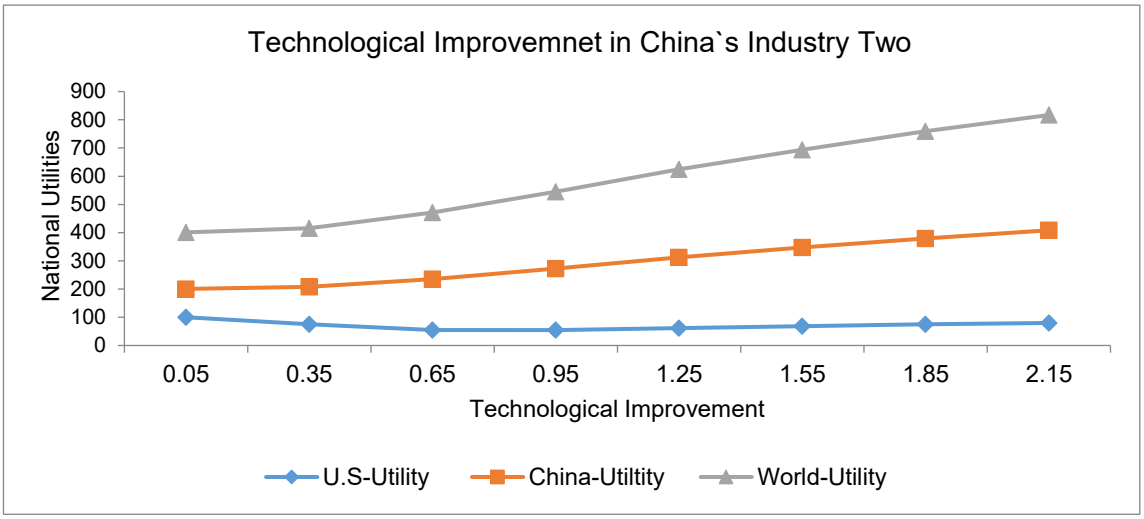

Figure (1): The Effect of the Technological Development on the National Utilities for U.S and China

Figure (1) represents the second scenario where, the technological improvement in the China`s industry Two was introduced as multi-shocks. This means that entering new technologies in the production at a specific time should not prevent the development and change of the old technologies. The process of development and innovation continued till reaching the maximum level of technology. In this scenario, 8 different experiments were run and the development-shock-A had the following values [0.05, 0.35, 0.65, 0.95, 1.25, 1.55, 1.85, and 2.15]. Each value ran the model for 30 repetitions over 2000-time step.

Applying the gradual change of the technology concept in the industry Two, the distribution of labor was totally different than that of the Gulden`s model. When China had its own gradual technological change in the industry Two, more labor could be employed in the industry Two in the first stage of production. On contrast, the number of labor who worked in the industry One decreased as shown in figure (٣). The amount of industry Two production in China was doubled compared to U.S industry Two production. Thus, the U.S preferred to import industry Two products from China with lower cost instead of producing it locally with higher cost. Therefore, the number of labor increased in industry Two production in China.

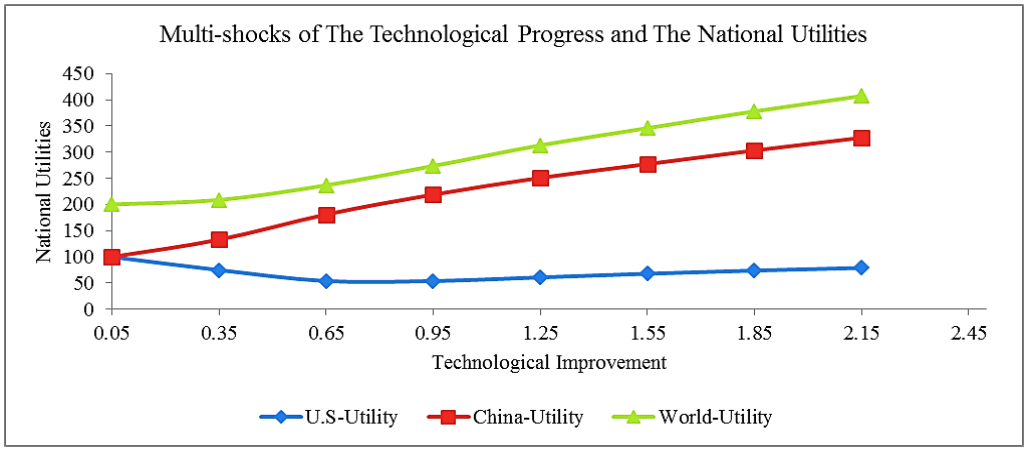

Figure (2): The Effect of the Technological Growth on the National Utilities

The final impact was to remove the absolute advantage in the industry Two from U.S in favor of China. According to the economic theory, when applying the technological progress as a gradual multi-shock in China, the number of labor will increase at the first stage to increase the production quantities. However, after entering new machines, new techniques of production, training to the labor and enhancing their capabilities, the number of labor was reduced in the next step of production. This could be attributed to the fact that there exists effective labor who could produce the same quantities of output with half number of labor force. China is a country with poor enforcement of patent rights. Consequently, China is typically classified as users rather than producers of new technologies (Blanchard, 2017).

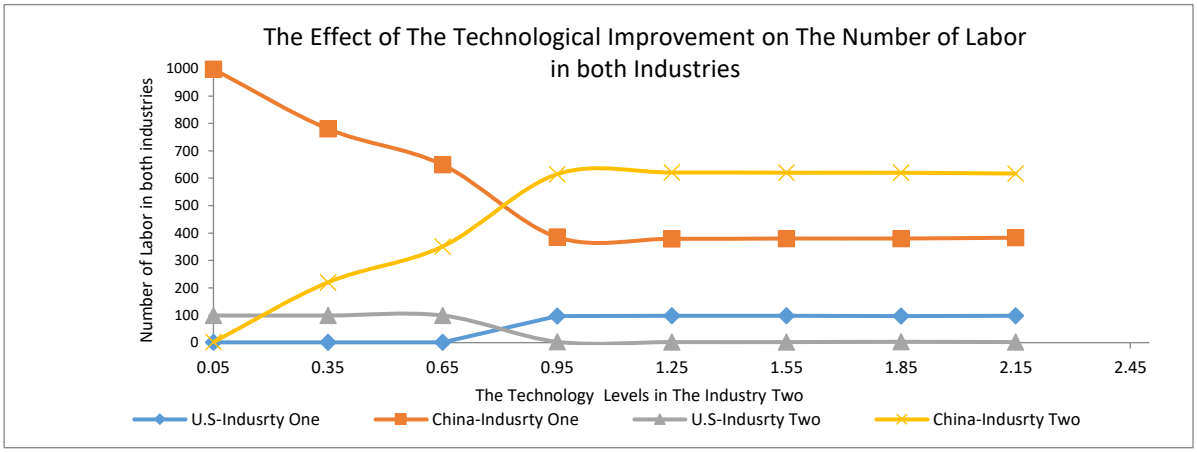

Figure (3): The impact of Technological improvement as multi-shocks on the Number of Labor in both Industries in U.S and China

The research confirms that the technological improvement in the production process is a gradual change not a sudden process. It takes time, costs, and training on applying to apply the new technologies in the production lines for a specific product. Also, the theory applied for the new proposed model was the technological gap theory, which is more relevant for the technological impact on production in developing countries instead of the absolute advantage theory which was assumed by Gulden. The outsourcing of technologies from U.S to China narrowed the technological gap between them and increased the production with low costs as the more technologies the country has the more skilled labor and more qualified products it has (Watsa et.al, 2008).

The second contribution implied changing the structure of trade between U.S and China. The structure of trade was different from Gulden`s results as the absolute advantage in industry Two production transferred from the U.S to China in case of having high technology levels and highly skilled and trained labor. When the quantity produced increased, the costs of production decreased. The U.S stopped the production of industry Two in its borders and it was better to import this product from China. Figure (٤)

represents the industry Two production for the two countries. After the gradual increase in technology, China`s industry Two production was greater than U.S production after running the simulation.

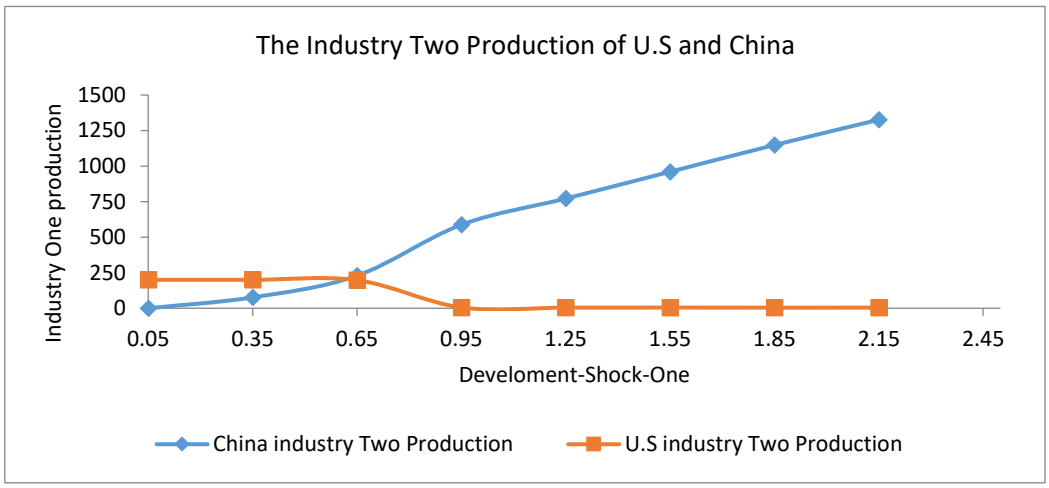

Figure (4): The Industry Two Production in U.S and China after the Technological Progress

To validate the effect of technological improvement in China on the trade between China and US., real trade data between US and China was gripped from USA Census website. Figure (5) shows that trading between China and US increased since 1985 but imports from China increased rapidly than exports from US. This could be attributed to the technological improvement in China industry sectors.

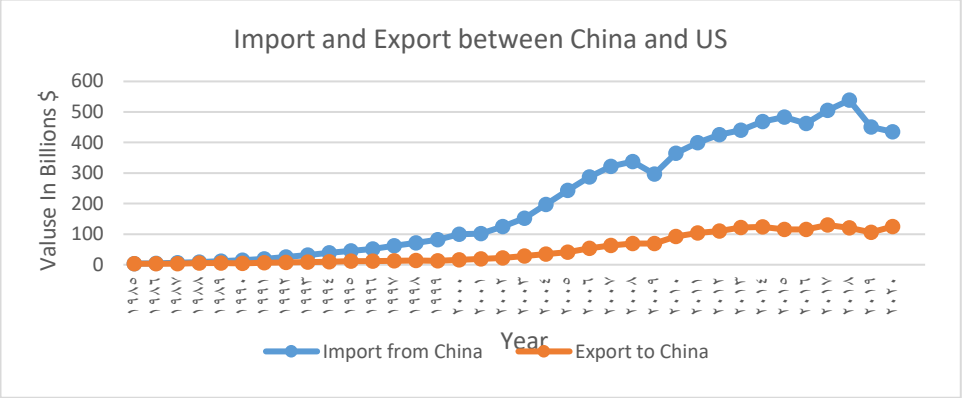

Figure (5): Import and Export between China and US from 1985 to 2020

Data Source: U.S. International Trade Data. https://www.census.gov/foreign-trade/balance/c5700.html.

Following the trading industrial sectors between China and US, it was noticed that the trading gaps were always in favor of China. This means that the technologies used in these sectors were improved gradually and continuously.

4.2 Results of Proposed Model for the Capital Mobility

The second proposed model studied the impact of the capital mobility assumption on Samuelson`s theory in the international trade system. The ABM studied the effect of capital mobility principal in case of having full repatriation of returns on Samuelson`s theory and the results were evaluated. The main concept in this model will be the capital mobility and its effect on the investment in industry One and Industry Two in each nation. In Gulden`s model, the capital mobility concept was studied with its extreme values (exist or not exist), and its effect with utilities for each nation. However, in this study, the experiments were done with different scenarios. A scenario means changing each experiment settings for testing the new conceptual impact through doing eight experiments. It started with the first technology level (0.05) while enabling capital mobility concept with full repatriation of profits, then increased the next following

experiment by (0.3) as mentioned in the first proposed model. The main indicators which were simulated in this model were capital invested in industry Two and industry One production in U.S and China in addition to the utility for each nation. The results were taken as an average value at time step 2000 over 30 runs for each tested value of the capital-mobility concept.

The specification of technology is important to the prediction of the size and direction of international capital mobility. In the simplest case, with the same technology level of all countries, capital moved to the country with the lowest capital-labor ratio. In economics, the Lucas paradox is the observation that capital does not flow from developed to developing countries despite the fact that developing countries have lower levels of capital per worker (Morgan and Katsikeas, 1997). The classical economic theory predicts that capital should transfer from rich to poor countries due to the effect of diminishing returns of capital. The poor countries have lower levels of capital per worker which explains, why they are poor.

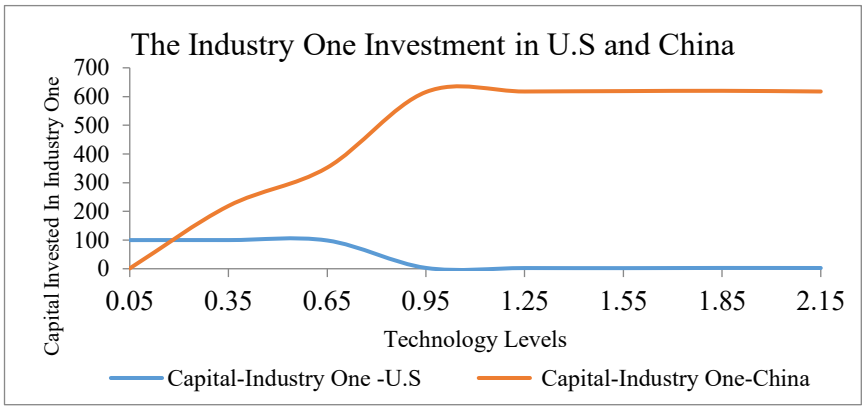

Figure (6): The Effect of the Technological Progress on the Capital Invested in Industry One

Figure (6) represents the relationship between the amounts of capital invested in Industry One in U.S and China with the different values of technology levels in Industry One. The experiments showed that the amount of capital invested in the Industry One in China was greater than the capital invested in the U.S. The same results could be deduced from figure (7) which shows that Industry Two investment in China was greater than the U.S investment in the Industry Two.

The results of the proposed model were completely different from Gulden`s results for capital mobility assumption. The proposed model explained different scenarios from the realistic point of view for international trade. In case of having more capital flows and investment in developing countries (China), the situation will completely change. Gulden explained the capital mobility assumption in terms of a sudden shock of technology in the Industry One (Gulden, 2013).

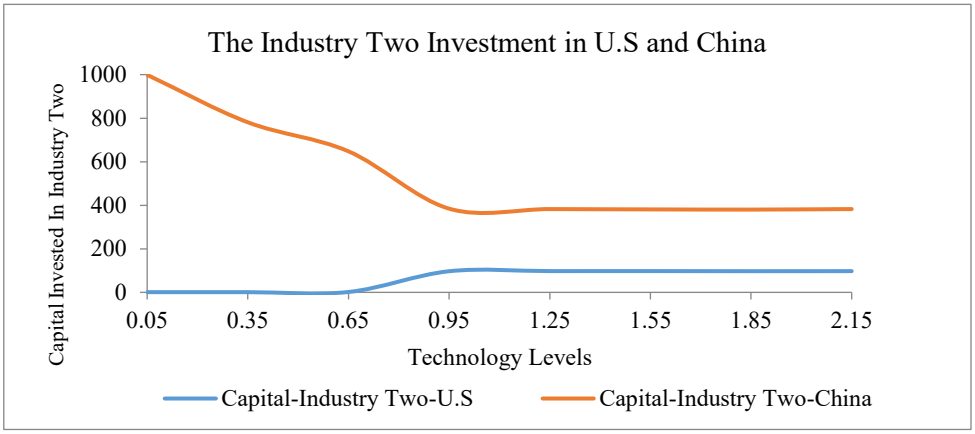

Figure (7): The Effect of the Technological Progress on the Capital Invested in Industry Two

Gulden confirmed that the flow of capitals was from the developing country (China) to the developed one (U.S) to achieve more profits and higher returns on investments according to the classical theories of trade. However, the current situation on international trade system proves the opposite of Gulden`s claim (Kennedy et.al, 2005).

According to the simulations, it was found that more capitals and investments were shifted from the developed country (U.S) to a developing country (China). This happened due to the higher technological level in China, higher returns on investment and skilled labor who enhanced their capabilities to keep up with technological improvements. This result is harmonious with the economic theory and confirmed Lucas paradox of capital mobility which asserted the transfer of capital flows from rich (developed) to the poor (developing) countries (Auboin et.al, 2013). On the contrast, Gulden confirmed that the flow of capitals was from the poor (China) to rich (U.S) countries to achieve more profits and higher returns on investment according to classical theories of trade. However, the current situation of international trade system is well-matched with the results of the proposed model and contradicting with Gulden`s results.

One of the main contributions for the proposed model of capital mobility is proving that the capitals could flow from the developed country to the developing one due to the technological differences and differences in the manufacturing techniques between countries. Also, the applied theory for the proposed model was the technological gap theory. The comparative advantage theory could not be applied due to many reasons, for instance; it assumed the technology was fixed between the countries, zero transportation costs; labor was the only input for production and perfect factor immobility between the countries.

Based On Statista.com Website, Foreign Direct Investment (FDI) is an investment from a company in one country into a company or entity located in another country. Therefore, the direct investment from US in China increased as shown in Figure (8). Also, the direct investment from China in US increased as well. This relation was based on real data which supports the results from the capital mobility assumption in the proposed model. Also, it was found that more capitals and investments were shifted from the developed country (U.S) to a developing country (China).

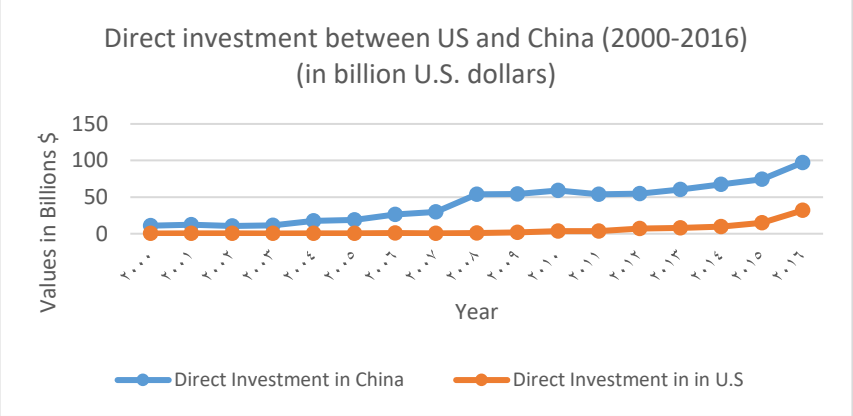

Figure (8): Direct investment between US and China (2000-2016) (in billion U.S. dollars)

Data source, statista.com website.
https://www.statista.com/statistics/188870/foreign-direct-investment-in-the-united-states-since-1990/

5 Conclusion

The main findings can be summarized as follows; the technological improvement plays a vital role in the international trade between developed (U.S) and developing countries (China). Technology and innovation changed the trade structure between two countries in favor of the developing one (China). The simulations studied the technological effect as a gradual change in the developing countries not just as a rapid shock at any time period. This result is compatible with real trade data. Taking China as an example of a developing country that was subject to gradual technological shocks, it can be obviously detected that it has become one of the magistrates' traders in the world market. The technology level also impacted the mechanism of capital transfer between the poor and the rich countries. The simulations showed different results compared to Gulden`s model.

The different levels of technology between countries inside the international trade system are the main incentive for capital transfer between different boarders. Moreover, there has been a trend in China`s trade structure to shift from labor intensive to capital and technology intensive exports. The proposed model succeeded in changing one of the key assumptions for Gulden`s trade model (namely; the absolute advantage theory) which is not applicable to the current trade system. The model was validated using the current trade data of WTO and US international trade data.

The current work can be extended in many dimensions by overcoming several limitations. The first limitation of the ABM proposed in this research is; it was composed of only two countries and only two industries inside the international trade system. It would be of great use to generalize this model to include many industries and many countries. The second limitation is assuming zero transaction costs between developed and developing countries. So, this model could be extended to study the effect of transportation costs on the international trade structure. Also, it might include different kinds of transportation costs between countries and the possibility of exemption from paying any costs.

The third limitation is using the consumption as the only measure of economic welfare and does not take any other factors into consideration such as; the employment rate, job satisfaction, the education levels, the standard of living of citizens, the security in the surrounding environment, and the availability of leisure time.

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النمذجة القائمة على العميل للتجارة الدولية

د. أحمد التابعي إبراهيم عكاشة؛ أسماء منير مبروك؛ د. سلوى محمد عبد العزيز،

ملخص البحث:

لقد أصبح النظام الاقتصاد العالمي مؤخرًا أكثر كفاءة وتكاملًا بسبب تأثير العولمة. يؤدي هذا التأثير إلى دفع حركة التقدم التكنولوجي وتحرير التجارة وأسواق رأس المال. حيث يقلل التقدم التكنولوجي من تكاليف النقل والاتصالات بين الدول. ومن ناحية أخرى، فإن تحرير التجارة وأسواق رأس المال يقلل من أشكال المنافسة الأجنبية غير العادلة. لذا فإن الهدف الرئيسي من هذه الدراسة هو تصميم نموذج قائم على العميل يكشف عن دور التقدم التكنولوجي في تغيير هيكل التجارة الدولية بين البلدان المتقدمة والنامية، وكذلك تأثير حركة رأس المال على هيكل التجارة الدولية. ويتم تحقيق هذين الهدفين من خلال قيام الدراسة باقتراح سيناريوهات مختلفة عن حركة التجارة بين الدول النامية والمتقدمة. وقد استند النموذج المقترح في الدراسة القائم على العميل على افتراضين ؛ افتراض تحليل ساموبلسون للاستعانة بمصادر خارجية للتبادل بين البلدان المتقدمة والنامية وافتراض تنقل رأس المال، ورغم أن التقدم التكنولوجي كان هو حجر الزاوية لتدفقات التجارة الدولية لأنه يملك قدرة تغيير نمط التدفقات التجارية بين البلدان، حيث كان من المعروف ان النمط العام للتدفقات التجارية تكون من البلدان المتقدمة التي لديها أعلى المستويات التكنولوجية والعمالة عالية المهارة إلى البلدان النامية ذات المستويات التكنولوجية المنخفضة والعمالة الأقل مهارة. الا ان نتائج الدراسة جاءت مخالفة لتلك فمن خلال تطبيق مجموعة من سيناريوهات النماذج القائمة على العميل على مخططات التجارة الدولية وجد ان النمط الأكثر انتشارا في هو تدفقات للتجارة من البلدان النامية إلى البلدان المتقدمة وليس العكس. وكان تفسير الدراسة لهذا النمط الذي أصبحت عليه التجارة الخارجية إلى الصدمات التكنولوجية التدريجية التي تعرض لها القطاع الصناعي في البلدان النامية، كما أظهرت النتائج أن الدول النامية تمتلك القدرة على التحول إلى قوى اقتصادية جديدة في جميع المجالات إذا استثمرت بشكل صحيح في التقدم التكنولوجي.

الكلمات المفتاحية: نظريات التجارة الدولية، النمذجة القائمة على العميل، نظرية الفجوة التكنولوجية، نظرية الميزة النسبية، حركة رأس المال.