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The Impact of Technology Level on Global Value Chain Formation

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Abstract

In this paper, we theoretically investigate the role of technology level in Global Value Chain (GVC) formation from two aspects: position and participation volume. We develop a simple two-country model where countries are heterogeneous with respect to their technology level and labor force. In GVC, there are a number of intermediate production stages with different technology thresholds. A country can produce at a stage if its technology level is higher than the stage's threshold. The unit labor requirement of a country in each stage is assumed to be inversely proportional to the difference between the technology level of the country and the technology threshold of the stage. According to this framework, the country with higher technology level will be producing at the stage with higher technology threshold. In contrast to previous studies that emphasize countries' position in GVC only, our work focuses on both the "position" and "volume" of participation. We find that GVC participation volume of a country, measured in terms of the number of production stages it holds, will increase if there is an increase in either the country's technology level or labor force.

Keywords: Global Value Chain, technology level, spider-like structure
JEL: F12, F15, O33

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Abstract: In this paper, we theoretically investigate the role of technology level in Global Value Chain (GVC) formation from two aspects: position and participation volume. We develop a simple two-country model where countries are heterogeneous with respect to their technology level and labor force. In GVC, there are a number of intermediate production stages with different technology thresholds. A country can produce at a stage if its technology level is higher than the stage's threshold. The unit labor requirement of a country in each stage is assumed to be inversely proportional to the difference between the technology level of the country and the technology threshold of the stage. According to this framework, the country with higher technology level will be producing at the stage with higher technology threshold. In contrast to previous studies that emphasize countries' position in GVC only, our work focuses on both the "position" and "volume" of participation. We find that GVC participation volume of a country, measured in terms of the number of production stages it holds, will increase if there is an increase in either the country's technology level or labor force.

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1. Introduction

Recent developments in the measurement of internalization of production via so-called Global Value Chain (GVC) gave rise to an intensive discussion of the formation of GVC. Nation's reliance on the imported intermediate goods, as well as nations' export to international production networks can be thought to be strongly related to the technology level of countries that participate in GVC. Despite the importance of this topic and readily available data there appears to be a lack of the study that explores a mechanism of how technology level of countries forms the structure of GVC.

In this paper we aim at contributing to the literature by theoretically investigating the role of technology level on GVC formation from two aspects: position and participation volume.

From a theoretical point of view, this work is closely related to the recent works on the theory of GVC (Costinot et. al 2013 (CVW hereinafter), Baldwin and Robert-Nicoud 2014). These works, and in particular, CVW model attempt to examine the role of countries in the GVC, and how this role is related to the technological change. CVW are more interested in the order of countries and their position in the chronological process of GVC. Our work, in contrast, focuses on both the "amount" and "position" of GVC participation, and examines how this contribution is related to economic development via technology level.

From an empirical point of view, the subject of this paper is related to the work of Altomonte et. al (2017). They revisit the relationship between trade and income, taking into account the increasing role of GVC. They find evidence of an income premium for countries that upgrade their positioning in GVC, whereas the degree of participation to GVCs does not seem to play a role. Our paper is also related to several statistical analysis of trade in value added (UNCTAD 2013a, Kowalski et al. 2015). UNCTAD (2013a) is inclined to examine the patterns of GVC participation, and its simple correlation with economic development. Kowalski et al. (2015) focuses on the determinants of GVC participation.

In particular, in this paper, we develop a simple two-country model where countries are heterogeneous with respect to their technology level and labor force. Countries are involved in GVC of producing a single final good through a number of intermediate production stages. Each stage, performed by a single country, has a technology threshold such that a country cannot produce at the stage unless the country's technology level is higher than that threshold level. The unit labor requirement of a country in each stage is assumed to be negatively proportional to the difference between the technology threshold of the stage and the technology level of the country. With this framework, we find that the country with higher technology level takes place in the stage with higher technology threshold. Participation volume of a country in GVC, measured in terms of the number of production stages it holds, will increase if there is an increase in either the country's technology level or labor force.

The novelty of our work, if any, consists at least in the following. First, this is one of the first attempts to examine how technology level of countries shape the structure of their participation in GVC. Second, we suggest a mechanism that may explain this relationship. We believe that our work contributes to the recent debate on the importance and effect of the global economy on GVC participation.

The remainder of the paper is organized as follows. Section 2 constructs a model with a two-country framework to characterize the effect of technology level on GVC participation volume of each country. Section 3 presents some findings. Section 4 details the conclusions and extensions.

2. The model

2.1 The settings

In this section, we develop a simple two-country model that shows how a country's technology level affects its participation in the GVC.

In the basic model, we consider a world with two countries, North (N) and South (S). The North is assumed to have higher level of technology than that of the South, $F_N > F_S$. Both countries are endowed with different quantities of labor, the sole factor of production, L_k, where $k \in \{N, S\}$. Size of the labor force in each country is assumed to remain unchanged over time. The labor wage in each country is w_k. Taking that labor wage of the South as numeraire, this means that the wage of the North becomes the relative wage between the two countries. Denote this relative wage as ω, we have $\omega = w_N$.

The two countries are involved in a GVC of producing just a single final good. One unit of the final good is assembled from one unit of each intermediate good. In terms of Baldwin and Venables (2013), this is a "spider-like" structure. This is one of the interesting points of this model which reflects the different characteristics of GVC from non-GVC production. In non-GVC production, production volume of each good is determined by its preferences. However, in this model, once the volume of the final good is decided, the production volume of each intermediate good produced at each stage is automatically determined. For example, if we decide to produce an automobile, it automatically becomes that we need the stage of tires production to provide a set of four tires, the stage of wiper production to provide a set of two wipers for the front glass, and the stage of engine production to provide one engine. Assembling is cost free.

Each intermediate good j is produced at each stage j. The number of production stage is continuous from zero to one, $j \in [0,1]$. We assume that each stage j produces one unit of intermediate good, and is performed by a single country. Every stage has its own technology threshold, A_j, such that a country cannot produce at the stage unless its technology level is higher than the stage's technology threshold, $F_k \geq A_j$.

Stages are ordered such that this threshold, A_j, is strictly increasing across the GVC. Note that now this GVC here is not a sequence of processes taking place chronologically as in reality. With

the example of producing an automobile above, the final good is assembled from a set of four tires, a set of two wipers, and an engine. The engine production stage requires a considerably high technology level to produce, thus the technology threshold of this stage stays at the highest place in the sequence. The second place comes to the tire production, and the third place comes to the wiper production. Thus, the sequence of the wiper, the tier, and the engine production stages follow the increasing order that we are mentioning about. The technology threshold is assumed to be distributed uniformly between zero and one, i.e. $A_j = j$ where $j \in [0,1]$. Here for simplicity, we assume that both countries have level of technology higher than one, i.e. $F_k > 1$ for all k. This secures that both countries are able to produce at all intermediate stages. At each stage, the amount of labor required for one-unit production is assumed to be inversely proportional to the difference between the technology threshold, A_j, and the technology level of the country, F_k. That is the unit labor requirement increase in the technology threshold, but decrease in the technology level of the country. This assumption is very natural. If a country's technology level is high, it does not need much labor to produce one unit of good. On the other hand, production at a stage with a high technology threshold is more difficult and requires more labor. Letting $a_{j,k}$ denote the unit labor requirement of country k at stage j, this assumption is shown as follows.

(1) $$a_{j,k} = \frac{1}{F_k - A_j} = \frac{1}{F_k - j}.$$

Here, note that because each stage produces one unit of intermediate good, the amount of GVC participation is defined to be the number of stages country k operates.

Lemma 1: The higher the country's technology level, the higher stage of GVC the country takes part in.

Proof: Consider two stages i and j, where $i > j$ in GVC. To find which of the two countries has comparative advantage in producing at stage i relative to stage j, we need to compare $\frac{a_{i,N}}{a_{j,N}}$ and $\frac{a_{i,S}}{a_{j,S}}$. By the definition of $a_{j,k}$, we find that $\frac{a_{i,N}}{a_{j,N}} = \frac{F_N - j}{F_N - i} < \frac{F_S - j}{F_S - i} = \frac{a_{i,S}}{a_{j,S}}$. This is because the rearrangement of the inequality, which is $(F_N - F_S)(i - j) > 0$, is always true. This means that among any two stages in the GVC, the North always has comparative advantage over the South in producing at stages with higher technology threshold; or in other words, the North operates at the higher stage of the GVC. **QED.** ■

2.2 The number of production stages of each country in GVC

We now want to clarify which country takes charge in which stage in the GVC. Following the Lemma 1, there will be a threshold stage j^* at which the North only produces at stage higher

than j^* and the South only produces at stage lower than j^*. Thus, j^* is the number of production stages that the South holds, and $1 - j^*$ is the number of production stages that the North operates. At stage j^*, production costs of one unit of intermediate good j^* in both countries are indifferent.

$$w_S \times a_{j^*,S} = w_N \times a_{j^*,N}$$

Thus, the relative wage between the North and the South is rewritten as

(2) $$\omega = \frac{F_N - j^*}{F_S - j^*}$$

Budget constraint for each agent in both countries requires that consumption of the final good must equal the wage income.

(3) $$p \times c_k = w_k, \ k = N, S$$

where p is the price of the final good, determined at the free trade equilibrium, c_k is the volume of the final good consumed by each agent in country k.

Under the goods market clearing condition, net output must equal the total consumption of all individual in both countries.

(4) $$x = L_N \times c_N + L_S \times c_S = \frac{1}{p}(\omega \times L_N + L_S)$$

where x is the volume of the final good.

Now, consider the labor market clearing condition. The North participates from production stage j^*, each stage requires as much as $a_{j,N}$ to contribute to one unit of final good. Thus, to produce x units of the final good, the total labor demand of the North is $x \times \int_{j^*}^{1} a_{j,N}\, dj$. Here, we assume the full employment of labor, thus the labor market clearing in the North is given by

$$x \times \int_{j^*}^{1} a_{j,N}\, dj = L^N$$

By the definition of $a_{j,k}$, this equation is rewritten as

(5) $$x \times \ln \frac{F_N - j^*}{F_N - 1} = L^N$$

The same is applied for labor market in the South, the labor market clearing condition is as follows

(6) $$x \times \ln \frac{F_S}{F_S - j^*} = L^S$$

Using the cost-indifference condition at the threshold j^* in equation (2), budget constraint for agents in both countries in equation (3), good market clearing condition in equation (4), and labor market clearing condition in equation (5) and (6), to solve for j^*, ω, x, p, c_S and c_N. There are 6 unknowns and 6 equations, thus the system is solvable.

3. Findings

There exists a unique interior solution. The following two propositions have been established.

Proposition 1: *For both countries, the higher the technology level of a country is, the more the number of stages it operates.*

Proof: From equation (5) and (6), we can solve for j^*. Divide equation (5) by equation (6), we have

$$\frac{\ln\frac{F_N - j^*}{F_N - 1}}{\ln\frac{F_S}{F_S - j^*}} = \frac{L^N}{L^S}. \tag{7}$$

This equation has only one unknown j^*. The left hand side of the equation is a decreasing function of j^*, goes to infinity as j^* goes to zero, and goes to zero as j^* goes to one. On the other hand, the right hand side is a positive (finite) constant. Therefore, the solution for j^* is unique, strictly between zero and one.

The left hand side of the equation will increase with increases in F_S and will decrease with increases in F_N. As a result, j^* will increase with increases in F_S and will decrease with increases in F_N. For the South, this is clear that an increase in technology level will increase the number of production stages that the South holds. However, for the North, note that the number of production stages that the North holds is $1 - j^*$, thus we obtain the same result as the South. **QED.** ■

This result is very intuitive. The higher the technology level is, the cheaper the producing cost at all stages becomes. As a result, the country occupies more stages.

Proposition 2: *For both countries, the larger the labor force a country has, the more number of stages that it operates.*

Proof: Using equation (7), we find that an increase in L^N will increase the right hand side, thus decrease the j^*. For the North, a decrease in j^* leads to an increase in $1 - j^*$; or in other word, this is an increase in the number of production stages. For the South, an increase in L^S will decrease the right hand side, leading to an increase in j^*. Thus, for both countries, we obtain the result that an increase in the labor force will increase the number of production stages that the

country holds. **QED.** ■

This proposition is also very intuitive. An increase in labor force does not only increase the labor capacity that meets the production requirements, but also decrease the labor wage, leading to a reduction in producing cost. As a result, the country occupies more stages.

4. Conclusions and extensions

This paper attempts to theoretically explain the role of technology level on GVC formation from two aspects: position and participation volume. We develop a simple two-country model where countries are heterogeneous with respect to their technology level and labor force. The paper yields some interesting results. First, the country with higher technology level takes place in the stage with higher technology threshold. Second, the number of production stages in GVC of a country increases if there is an increase in either its technology level or labor force.

This paper can be extended in some directions. First and foremost, intelligible extension is some empirical analysis to confirm hypotheses raised in the paper. Second, this model can be extended into a version of multi-country. We can characterize the solution by considering the South as the rest of the world (ROW). After solving for the participation volume of the North, we take a country which has the highest technology level in ROW, suppose it a new North and the rest is a new ROW. Through this arrangement, it turns back to the basic model of two-country model. We continue this iteration until the first stage to solve for the GVC participation volume of all countries. With this extension, we can examine the effect of a change in technology level and labor force of any country in the GVC on the whole GVC formation. Third, in the model, we currently assume that both countries can produce at any stage, i.e. $F_k > 1$ for all k. However, we can introduce an assumption that a country with lower technology level is not able to produce at some stage with high technology threshold. We can show this assumption mathematically as $F_S < 1 < F_N$, thus the South cannot produce at stages with technology threshold higher than F_S. This assumption is closely connected with the reality and is expected to bring some interesting results. Last, there are also some rooms to address labor-related issues such as unemployment, income premium, and labor productivity. Specifically, assessing the causal impact of GVC formation on unemployment issue among countries may emerge several new insights.

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