How to Decompose Production Chain and Utilize It to Unveil GVC Connections Among Countries

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Abstract. This paper aims to contribute to the literature by developing a calculation method which can be used to explore GVC connections among countries. The present work introduces International Production Stage Length as an indicator of a country’s involvement into the global production. The developed calculation method is employed to test GVC connections between China, USA, Germany, and their neighboring countries. The empirical study confirms a higher level of production sharing among countries which belong to the same region which indicates the existence of several regional value chains rather than a one global value chain.

Introduction

Global production and trade in the 21st century has experienced substantial changes. The essence of those changes lie in production fragmentation and trade in intermediate products [1]. According to Baldwin, [2] rapid improvement in communication and transportation technologies significantly contributed to production fragmentation. This phenomenon of production sharing has been elaborated throughout literature concerning Global Value Chains (GVCs). The term Global Value Chain encompasses the idea that production sharing is scattered worldwide and that a majority of countries are involved. However, numerous studies have concluded that world production is rather regional than global [3,4,5,6]. According to Beverelli, [5] small economies exhibit strong linkages into GVCs that are located close to the GVC hubs such as China, Germany, and the United States.

This work aims to develop a calculation method which can be used to provide insight on GVCs connections among countries or groups of countries. Our objective is to demonstrate how global production can be decomposed into domestic production stages and international production stages; and how the measurement of international production stages can be employed to explore which countries have closer GVC connections. Therefore, we construct an indicator (measurement) named International Production Stage Length (IPSL) which measures the length of international production stages. In order to construct IPSL, we follow Wang and Koopman’s [7,8] decomposition method and adapt it to the objective of this study.

Construction of the Indicator

Production length, as a basic measure of GVCs, is defined as the number of stages in a value chain that reflect the complexity of the production process [7]. Literature on GVCs offers several instruments for measuring production length and each of them has its own economic interpretation. Earlier work conducted by Fally [9] proposes the average number of stages between production and final consumption as a measurement of production upstreamness; and the average number of production stages embodied in each product as a measurement of production downstreamness. Antras et al. [10] develop these measurements further. A study by Wang et al. [7] defines the
average production length of a value chain as the average number of times the value-added created by the production factors in a country-sector has been counted as gross output in the sequential production process. Thus equaling, the ratio of the accumulated gross outputs to the corresponding value-added that induces the output. They distinguish four production activities: (1) those whose value added is both generated and absorbed within a country; (2) those whose value-added crosses borders only once for consumption; (3) those whose value added crosses borders only once for production; (4) and those whose value added crosses borders more than once. Accordingly, four segments of the production length are defined as: (1) pure domestic production activities; (2) traditional trade activities; (3) simple GVC activities; (4) and complex GVC activities. This study relates to the last two segments which involve production sharing among countries. Furthermore, we apply IPSL as a measurement of production stages before components are imported to an importing country (downstream) and after components leave the origin country for further production (upstream). For example, if China exports components which are used in a foreign country for further production those production stages in a foreign country represent China’s IPSL. Secondly, if China serves as an importer of components whose production stages were conducted in a foreign country (before importing to China); such stages are represented in China’s IPSL.

By following existing literature, we construct the IPSL indicator in the following manner.

Firstly, we consider a global input-output model consisted of 𝑁 countries with 𝐾 industries. The function expression of the production segmentation length for any country 𝑖 sector 𝑘 is:

\[ P_{ki} = 1 + \sum_{j \neq i} x_{ik}^{ji} p_{i}^{j} \]  

Matrix form of the Eq. (1) can be expressed as: \( P = U + A^T \). When transformed into inverse Leontief matrix it becomes: \( P = (I - A)^{-1} U = BU \). Where \( P, U, \) and \( A \) represent: the vector of embedded in global production phase; the vector of unit columns; the intermediate input-output relationship matrix, respectively. For \( N \) countries the block matrix can be expressed as:

\[ P = BU = \begin{pmatrix} B^{11} & \cdots & B^{n1} \\ \vdots & \ddots & \vdots \\ B^{1n} & \cdots & B^{nn} \end{pmatrix} \begin{pmatrix} u_1 \\ \vdots \\ u_n \end{pmatrix} \]

\[ P_{i} = \begin{pmatrix} B^{i1} & \cdots & B^{in} \end{pmatrix} \begin{pmatrix} u_i \\ \vdots \\ u_n \end{pmatrix} = (B^{ii} - H^{ii} + H^{ii})u + \sum_{j \neq i} B^{ji} u \]

\[ = H^{ii}u + (B^{ii} - H^{ii})u + \sum_{j \neq i} B^{ji} u. \]  

Because \( B^{ii} - H^{ii} = \sum_{j \neq i} H^{ij} A^{ij} B^{ji} = \sum_{j \neq i} B^{ij} A^{ji} H^{ii}, \) when substituted into Eq. (3) we get:

\[ P_{i} = H^{ii}u + \sum_{j \neq i} H^{ij} A^{ij} B^{ji} u + \sum_{j \neq i} B^{ji} u. \]  

In Eq. 4 \( H^{ii}u \) measures the number of domestic production stages; \( H^{ii} = (I - A^{ii})^{-1} \) represents the local Leontief inverse matrix of \( I. \) \( \sum_{j \neq i} H^{ij} A^{ij} B^{ji} u \) measures the number of country \( i \)’s domestic embedded production stages caused by the intermediate demand of other countries. It represents production stages of country \( i \)’s intermediate products exported to other countries and used for further production. \( \sum_{j \neq i} B^{ji} u \) measures the number of domestic embedded production stages of source countries caused by the demand of country \( i \) for foreign intermediate products. It represents production stages of foreign intermediate products conducted before importing to country \( i. \) Considering that the latter two reflect trade in intermediate goods between country \( i \) and other countries, the sum of these two is used to measure international production fragmentation. As far as the index interpretation is concerned, the longer the industrial chain is the more intermediate links there are in the production. The greater the number of production stages in an industry reflects higher amount of relative complexity for the production structure. In summation, an IPSL numerates production stages of exported components which are completed within importing countries.
countries (forward linkages) and production stages of components imported to a country (backward linkages).

**Methodology and Mechanism**

After defining IPSL, we introduce a mechanism to calculate GVC connections among countries. Hence, we develop a simple model which in the first stage assumes existence of only two countries, and in the second stage the existence of three countries.

In the first stage, we assume that there are only two economies and there is no trade in components between those two economies (see Fig. 1). In this case, total production of both countries is domestic. As a result, an IPSL cannot be formed or calculated. In the next step, we allow for trade amongst components (see Fig. 2). Thus, economy A’s IPSL includes production stages conducted within economy B by using components imported from economy A (forward), and production stages conducted within economy B to produce components which are imported to economy A; which are used for further production (backward). In order to demonstrate the existence of production sharing between the two economies, we question what would happen with the IPSL if we combine the two economies and observe them as a single economy. The combination of two economies is purely for calculation purposes. In the input-output matrix, their bilateral trade is considered as trade within one single economy.

![Figure 1. Situation when countries do not trade components.](image1)

![Figure 2. Situation when countries trade components.](image2)

All production stages can be considered as domestic after combining economies A and B and observing them as a single AB economy (see Fig. 3). There is no opportunity for the exportation or importation of components since there are no third countries. As a result, economy AB cannot have an IPSL which reveals insights on mechanisms used for exploring GVC connections among countries. In this mechanism, we first calculate the IPSL of countries individually. If a country participates in production sharing through GVCs, it will have an IPSL. In the next step, we observe two economies as a single economy and calculate its IPSL. A conclusion to whether countries are sharing production (are connected through GVCs) is made after comparing values of the IPSLs of individual countries with the IPSL obtained after combining them into a single economy. If countries do not share production they do not have an IPSL. A newly formed economy does not have an IPSL as well. However, if two economies share production they have an IPSL; but after combining them and observing them as a single economy a newly formed economy does not have an IPSL. Thus, it can be concluded that the two economies do share production.

![Figure 3. Situation after combining A and B into a single AB economy.](image3)
In the second stage, we assume there are three economies which can share production (see Fig. 4). Here, economy C can represent the rest of the world; thus, options for production sharing are much wider. Economies A and B can share production between themselves or with economy C. Accordingly, the IPSL of economy A can be the result of trade in components with both economy B and economy C. Here, we shed light on three situations: (I) the IPSL of economies A and B is formed through their bilateral trade; (II) the IPSL of economies A and B is formed through trade with economy C; (III) and the IPSL of economies A and B is formed through their bilateral trade and trade with economy C. As demonstrated above, if economy A’s and economy B’s IPSLs are a result of their bilateral trade, a newly formed AB economy will not have an IPSL. However, if economy A’s and economy B’s IPSLs are formed through their trade with economy C, a newly formed (economy AB) will still have an IPSL which will reflect their production sharing with economy C. Finally, if economies A and B share production between themselves and with economy C, their IPSL will have a double origin. In this case, after combining economies A and B and calculating a new IPSL for economy AB its value will depend on the intensity of production sharing with each of the two trade partners. If economies A and B have more intensive bilateral production sharing than production sharing with economy C, value of a new IPSL for newly formed economy (economy AB) will significantly reduce. This is due to the fact that it is dominantly formed through their bilateral trade. On the contrary, if economies A and B predominantly share production with economy C, the IPSL for economy AB will not change significantly because it is formed throughout trade with economy C. The mechanism of measuring the IPSL of individual countries and groups of countries is tested in the succeeding paragraph.

**Empirical Study**

The empirical study of the present paper uses the afore mentioned mechanism to explore GVC connections among countries in order to test results from existing literature which suggests the existence of regional value chains concentrated around GVC hubs such as China, USA and Germany [3, 4, 5, 6]. To test the existence of Asian, North American and European regional value chains, we select three groups of countries: (1) Japan, South Korea and Vietnam; (2) Canada and Mexico; (3) and Eastern European countries (EEC); to test their GVC connections with the three GVC hubs. Based on the literature review, it can be expected that the three Asian countries have the strongest GVC connection with China. Canada and Mexico are the closest GVC partners of the USA; and the EEC is dominantly connected to Germany. The data used in the present study is from the GTAP9[11] dataset which includes input-output tables of 122 countries and 43 industries in years 2004, 2007 and 2011. We firstly calculate the IPSLs of the three GVC hubs individually; then the IPSLs of the three Asian countries combined, Canada and Mexico combined and EEC combined. In the following step, we combine each of the three GVC hubs with each of the three groups of countries and calculate their IPSLs. Finally, we compare values of IPSLs obtained before combining the GVC hubs and the corresponding groups of countries with the IPSLs calculated after combining them. The following are the results of the calculations:
Figures above illustrate values of the IPSLs of the three GVC hubs, three groups of their trade partners, and the IPSLs of each combination of GVC hubs and their trade partners. By observing values of the IPSLs we can distinguish which countries have higher level of production sharing. A rapid decrease of IPSLs after combining China with the three Asian countries indicates strong GVC connections (see Fig. 5). A significant reduction of IPSLs is observed when USA is combined with Canada and Mexico indicating the presence of major GVC connections (see Fig. 6). Furthermore, a striking drop of IPSLs is exhibited after combining Germany and EEC which demonstrates their strong GVC connections (see Fig. 7).

**Conclusion**

In conclusion, this study was designed to contribute existing literature by offering a method for exploring GVC connections among countries. Hence, we have developed the IPSL as an indicator
which measures the level of an economy’s involvement in the international production. The values of the IPSLs indicate complexity amongst production sharing. The higher the complexity of international production sharing produces higher values of IPSLs. In order to measure GVC connections among countries we observe how IPSL values change after combining two or more economies. Lower values of the IPSLs of two economies combined compared to values of their individual IPSLs indicates a higher level of production sharing between the two economies. The value of the IPSLs of two economies combined was not lower than values of their individual IPSLs which indicate that the two economies do not have high levels of production sharing.

To test the developed calculation mechanism, we have conducted an empirical study which hypothesizes high levels of production sharing between GVC hubs such as China, USA and Germany with their neighboring countries. The empirical results of the present study confirm stronger GVC relations among countries which belong to the same geographical region. Hence, China demonstrates higher level of production sharing with Japan, South Korea and Vietnam than with Canada and Mexico, or EEC. USA shows major GVC connections with Canada and Mexico while Germany presents the strongest GVC integrations with EEC. The empirical study confirms that the calculation mechanism can be used to explore GVC connections amongst countries. Further studies with different groups of countries would further strengthen the understanding of the international production fragmentation.

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