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Abstract

This paper constructed a simple model to illustrate the global supply chain profit sharing and industrial upgrading mechanism, from which it was found that the average profitability distribution in the different supply chain stages was determined by two main factors: (1) the average product of the labor in the firms at each production stage; and (2) the ratio of the output elasticity of capital to the output elasticity of labor in each stage. This paper also proposed a new industrial upgrading mechanism, the 'inter-supply chain upgrading', for supply chain firms. Rises in production complexity and increased factor intensity in each production stage were found to be the two essential conditions for the inter-supply chain upgrading. The empirical study results were found to be broadly consistent with the proposed theories.

Keywords: global supply chain; smile curve; profit sharing mechanism; upgrading mechanism; average product of labour; inter-supply chain upgrading; factor intensity.

JEL Classification Codes: F1, D2, D4.

1. Introduction

Globalization has led to a fragmentation in manufacturing production across national borders, with trade economists using varying terminologies such as “intra-product specialization” or “the unbundling of production” (Arndt, 1997, 1998; Baldwin and Gonzalez, 2012) to describe the new supply chain driven global division of labor trade patterns in which each country specializes in a particular stage of a good’s production (Costinot et al., 2013).

As a result, trade in intermediate goods has gradually become a dominant global trade pattern as evidenced by the dramatic rise in the percentage share of intermediate products in world trade flows, which have been more than half of all non-fuel world exports since 2000. Consequently, global supply chain (GSC) issues with a particular reference to multinational corporations (MNCs) have been widely investigated in international economics and international business literature

This paper examined how profits are shared between the different firms involved in global supply chains from a ‘smile curve’ perspective, a focus that has been widely discussed in international business literature but rarely explored in economics literature. Management and international business research has examined how the Global Value Chain (GVC) value-added in each stage has been distributed, and developed a U-shaped distributional pattern hypothesis (Mudambi, 2007, 2008; Shih, 1996; Ming et al., 2015).[6] The core theme of the ‘smile curve’ is that there is a U-shaped curve for the firms’ value-added distribution across the three supply chain stages: R&D, assembly, and marketing.

[6] The concept of “smile curve“ was firstly coined Taiwanese entrepreneur Shin (1996) who is the founder of ACER in the 1990s.

For example, in the semi-conductor global supply chain, most upstream production stages involves innovation and knowledge-intensive R&D activities, such as integrated circuit (IC) design, the midstream stage involves low-value added activities, such as wafer production, precision testing and assembly, and the downstream chain stage activities involve marketing and post-sale services. Therefore, the U-shaped pattern hypothesis was mainly because the upstream and downstream firms have higher-value added than the middle stage wafer fabrication, which is subject to manufacturing subcontracts.

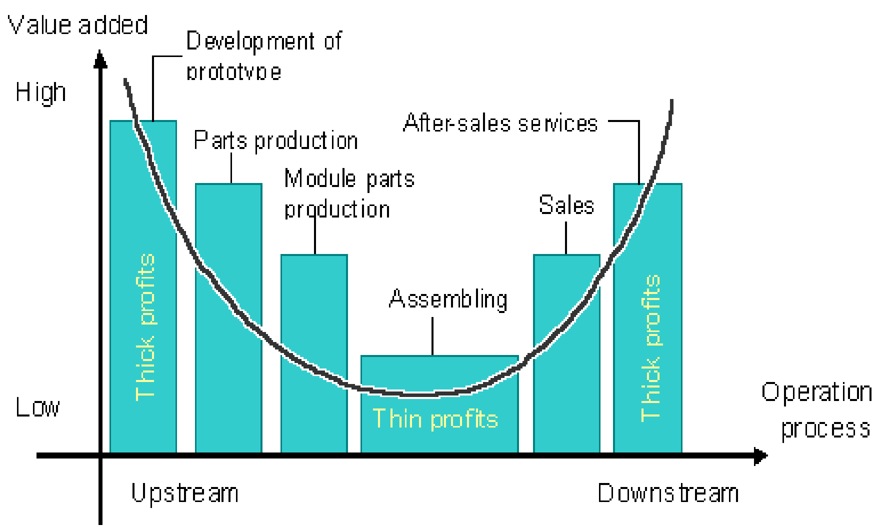
The main problem with the smile curve hypothesis is that there have been no theoretical analyses that have corroborated the assumptions that the firms that provide the higher supply chain value-added are also those that are more profitable. As it is generally believed that value-added and profitability are two different concepts that cannot be equated, in this paper, the profit-sharing patterns in global supply chains are investigated to determine whether high-value added supply chain firms also have higher profit levels.

There have seen some attempts to empirically test the U-shaped "smile curve"[7] hypothesis using the high-tech industry as a case study. For example, Shin et al. (2012) found that the leading firms and component suppliers in the upstream stages had much higher gross and net profit margins than the manufacturing contractors in the middle production stage, and concluded that: the smile curve could be verified only if the value added was defined as the gross margins; that the cost of sustaining a position on either end of the curve (upstream or downstream) could be too high to make the returns on investment

[7] This concept was recently empirically tested by Ming et al. (2015). They adopted time-series data from the WIOD with explicit consideration of both the benefits and the position of the participating countries and industries in the global supply chain to examine the hypothesis of "smile curve". Although this paper was the first paper in the field that used rigorous econometric tools to test the U-shaped hypothesis of smile curve, they did not come up with a theoretical framework.

higher than the middle of the curve because of the long investment gestation in high-tech industries; and that it was ambiguous whether specialist firms at the two ends of the curve were more profitable than those in the middle.

Therefore, what sets this paper's analyses apart from this other work is that first, it investigates the extent to which the smile curve moves in the same direction after "profitability" and value added are incorporated into the model and second, this paper further explores the effect on supply chain firm profitability of a rise in technological capabilities; that is, this paper examined the industrial upgrading mechanism through which firms could obtain higher profitability. Figure 1 illustrates the smile curve operations.



Sources: Aoki Masahiko and Ando Haruhiko (2002)

Figure 1. Smile Curve

In contrast to previous research on industrial upgrading strategies for supply chain firms, as this paper does not consider an inter-stage supply chain upgrading mechanism, the curve does not flatten out to the same extent, and the exclusion of the inter-stage upgrading ensures that the focus is only on an upward parallel shift for the whole global supply chain, which means that the firms remain within the same production stage, but a higher profitability level is captured, as shown in Figure 2.

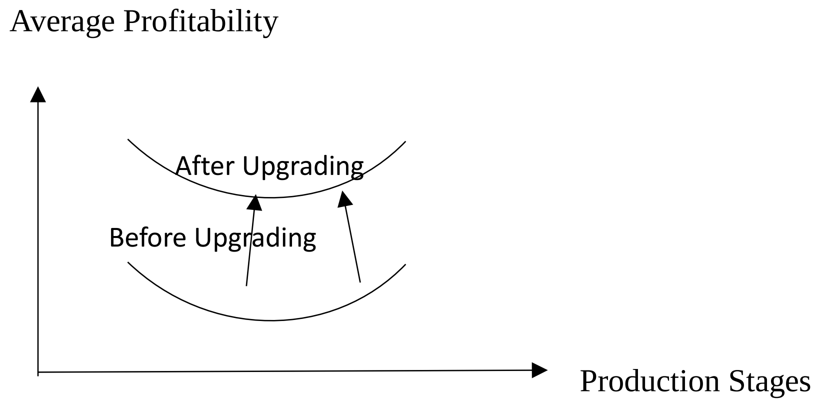


Figure 2. Inter Supply Chain Upgrading Mechanism

Therefore, the above diagram contributes to a new understanding of the supply chain upgrading mechanism as it demonstrates that the upward shift in the whole supply chain results in a positive spillover for all firms in the low-profitability stages, which is called *inter-supply chain upgrading* in this paper. In the proposed model in the following section, it is shown that with increased production complexity and higher factor intensity in each stage in the chain, all the firms producing along the chains learn elements such as technology advancement, branding and marketing management, which results into the fact that all firms in all production and distribution stages are more profitable than before.

The remainder of this paper is organized as follows. Section 2 reviews the pertinent literature. Section 3 gives the model solution. Section 4 is our empirical analysis, and Section 5 gives the concluding remarks.

2. Literature review

2.1 Past studies on profit sharing mechanisms

2.1.1 Global supply chain

As early as 1994, Gereffi and Korzeniewicz (1994) suggested that countries specializing in different supply chain stages had different production control rights and therefore there were role of inequalities across the supply chain stages. Consequently, the countries located at the dominant stages had higher production control rights and higher profits. Gereffi and Kaplinsky (2001) then investigated an upgrading strategy for non-lead firms from developing countries participating in the supply chain, from which it was found that to gain greater profit, the firms specializing in the lowest value added chain stages could upgrade within the same stage or expand their supply chain functions. Kaplinsky (2004) used four chain case studies: fresh fruit and vegetables, canned deciduous fruit, footwear, and automobile components: to examine the value chain contributions, and found that there were three factors influencing the global value chain profitability distribution mechanism: (1) barriers to entry and rents (2) governance, and (3) systemic efficiency. Then, using a value chain analysis framework based on these three factors, Kaplinsky (2004) reviewed the unequal distribution gains and characterized the key global value chain concepts.

2.1.2 Market structure theories

Industrial organization theories have also been used to examine the unevenly distributed gains obtained by different countries in the supply chain from a dynamic market structure perspective. Pioneering work in this area was presented by Morris and Hay (1991), who established the “ladder pricing model” to analyze two production stages: one production stage consisting of m upstream firms and the other consisting of n downstream firms producing intermediate inputs and selling the final products to the market. Within this model, it was presumed that the firms producing the same products or the intermediate inputs were homogenous, there was no production stage collusion, and each firm equally shared the market. The ladder pricing model explained how uneven firm benefit distribution was contingent upon the market structure in each production stage, which was related to the number of firms in each production stage in the model.

Ju and Su (2013) developed a global supply chain model to study how profits were shared between the intermediate input suppliers and the final goods producers, from which they concluded that the differences in upstream and downstream stage market structures determined the profitability differences in the different firms along the global supply chain. Using Melitz and Ottaviano's (2008) heterogeneous firm framework, it was assumed that the downstream market firms operated within a monopolistic competition environment, and the upstream market operated within an oligopolistic (Cournot) competition environment, and because of the obvious exogenous market structure settings, they also illustrated the effects that market structure dynamics could have on the profit-sharing patterns in a vertical production structure.

Similarly, using Chinese industry level input-output data, Ju and Yu (2015) also found that entry cost increases in the upstream market and final good market segmentation increased (decreased) the market power of the intermediate input (final good) producers, which in turn increased (decreased) their profitability, and that the prices determined from demand increases for the final good had effects on the profit sharing system along the whole global supply chain.

Therefore, to some degree, this paper is in line with previous research in this area that examined profit-sharing in global supply chains, except that this paper assumes that as the market structure in each stage is in the forms of monopolistic competition and there are no sunk costs for entry or exit in any stage, and all firms including incumbents and new entrants in each production stage have access to the same level of technology in each particular production stage. The assumption of monopolistic competition market structure of each production stage is in line with the spirit of Shen et al. (2019).

2.2 Upgrading mechanisms

The global supply chain upgrading mechanism discussed in this paper is mostly based on Costinot et al. (2013) and Humphrey and Schmitz (2002). This paper also tried to capture the impacts that local technology had on the global supply chain upgrading processes. Costinot's et al. (2013) claimed that there were two local technological changes; one associated with a labor-augmenting technical progress, and the other related to a decrease in a country's failure rate, which was called "routinization". In this paper, however, inter-supply chain upgrading was used to describe these two technological advancement forms, and it is proposed that inter-supply chain upgrading is possible if there is an increase in a firm's factor intensity or there is an advancement in the production complexity at a particular stage.

The inter-supply chain upgrading definitions have been generally similar to the upgrading mechanism concepts discussed in management research such as the one by Humphrey and Schmitz (2002), who divided the upgrading mechanism into four categories: (1) firms that reorganize the production system or introduce superior technology to more efficiently transform the inputs into outputs; (2) product upgrading -

firms that upgrade by moving into more sophisticated product lines that have increased unit values; (3) functional upgrading where firms acquire new chain functions, such as design or marketing; and (4) inter-sector upgrading- firms that apply the competencies acquired from a particular chain function (e.g competence in producing particular inputs, or in export marketing) to a new sector (Humphrey and Schmitz, 2002). As the first two upgrading patterns are more compatible with the inter-supply chain upgrading discussed in this paper, only these two are considered here.

3. Model

3.1 Profit Sharing mechanisms in global supply chains

The model developed in this paper is in line with the hierarchy assignment model techniques used in Lucas (1982), Kremer (1993), and Garicano & Rossi-Hansberg (2004, 2006) except that this technique is integrated into the global value chain sequential production framework, as also attempted by Costinot et al. (2013) and Shen, Deng and Tang (2019). The difference between the model in this paper and these previous models is that capital input is also incorporated into the sequential production process. Suppose that there exits the symmetrical market structure of each stage spanning the supply chains. This is to say, $n_{s_1} = n_{s_2} = n_{s_3} == \cdots = n_{s_n} = n^*$. The reason of assuming the symmetrical market structure is to ensure that the variation of market structure would not affect the profit sharing along the supply chains as firms operating in a more competitive market would inevitably earn less than those operating in a market that is more monopolistic. This means the business stealing effect coined by Mankiw and Whinston (1986) is ruled out. Second, the assumption of symmetrical market structure along each production stage of the chains ensures that firms at each stage get same access to the technology thus exhibiting the same level of productivity. Hence, it could be assumed that the productivity level of a representative firm at each stage represents the average aggregate level of productivity of a stage in the chains.

Suppose that the representative firm at a stage s_i seeks to maximize their own profit:

$$\mathrm{\pi}(s_i, \mathrm{q}(s_i)) = \mathrm{p}(s_i)\mathrm{q}(s_i) - \mathrm{w}(s_i)\mathrm{L}(s_i, q) - \mathrm{r}(s_i)\mathrm{K}(s_i, \mathrm{q})$$

(1)

where $\mathrm{\pi}(s_i, \mathrm{q}(s_i))$ is the profit level for the firm at stage s_i . $\mathrm{L}(s_i, q(s_i)$ indicates the amount of labour employed by the representative firm at stage s_i. $\mathrm{K}(s_i, q((s_i))$ is the amount of capital deployed by the firm at stage i. $\mathrm{q}(s_i)$ is the output for this representative firm at stage s_i , which is its chosen variable. $\mathrm{p}(s_i)$ is the price for each unit of output of the representative firm at stage s_i, which could be described as the demand schedule for this representative firm at stage s_i. $\mathrm{w}(s_i)$ is the wage rate for the representative firm at stage s_i, and $\mathrm{r}(s_i)$ is the cost of capital for the representative firm at stage s_i.

Taking the derivative of $\mathrm{q}(s_i)$ on both sides,

$$\frac{\partial \pi(s_i, q(s_i))}{\partial q(s_i)} = p(s_i) - w(s_i)\frac{\partial L(s_i, q(s_i))}{\partial q(s_i)} - r(s_i)\frac{\partial K(s_i, q(s_i))}{\partial q(s_i)} = 0$$

(2)

This means,

$$\mathrm{p}(s_i) = w(s_i)\frac{\partial L(s_i, q(s_i))}{\partial q(s_i)} + r\frac{\partial K(s_i, q(s_i))}{\partial q(s_i)}$$

(3)

In line with Dalamzzo et al. (2007) as well as Kremer (1993), it is assumed that the labor demand function for the representative firm at stage s_i is expressed as the following exponential function:

$L(s_i, q(s_i)) = [q(s_i)]^{\lambda(s_i)} l(s_i)$

(4)

where $\lambda(s_i)$ is the production stage complexity at stage s_i. Here $0 < \lambda(s_i) < 1$, and the higher $\lambda(s_i)$ is, the lower the level of complexity in each production stage as a higher value indicates a higher need for more labor and a greater labor-intensiveness, which normally indicates a lower production complexity compared with more capital-intensive firms. $l(s_i)$ is the inverse value for the average product of the labor at stage s_i in the chain.

The representative firm at each stage in the value chain adopts Cobb-Douglas production technology with constant return to scale:

$q(s_i) = K(s_i)^{\alpha(s_i)} L(s_i)^{\beta(s_i)}$

(5)

Where $\alpha(s_i) + \beta(s_i) = 1$

Plugging Equations (4) into (5), the capital demand function at stage s_i is obtained as follows: $K(s_i, q(s_i)) = q(s_i)^{\frac{1-\beta(s_i)\lambda(s_i)}{\alpha(s_i)}} l(s_i)^{-\frac{\beta(s_i)}{\alpha(s_i)}}$

(6)

Plugging (4) and (6) into (3), the price charged by a representative firm at stage s_i is obtained as follows:

$p(s_i) = \lambda(s_i)(q(s_i))^{\lambda(s_i)-1} w(s_i) l(s_i) + \frac{r(1-\beta(s_i)\lambda(s_i)}{\alpha(s_i)} (q(s_i))^{\frac{\beta(s_i)}{\alpha(s_i)}} l(s_i)^{-\frac{\beta(s_i)}{\alpha(s_i)}}$

(7)

Now dividing both sides of (1) with the quantity $q(s_i)$, the average profitability for a representative firm at stage s_i in the chain is obtained as follows:

$\frac{\pi(s_i, q(s_i))}{q(s_i)} = p(s_i) - \frac{w(s_i) L(s_i, q(s_i))}{q(s_i)} - \frac{r(s_i) K(s_i, q(s_i))}{q\,(s_i)}$

(8)

Plugging (7) into (8), the average profitability of a representative firm at stage s_i in the chain is expressed as follows:

$$\frac{\pi(s_i,q(s_i))}{q(s_i)} = \frac{r(s_i)\beta(s_i)(1-\lambda(s_i))}{\alpha(s_i)} l^{-\frac{\beta(s_i)}{\alpha(s_i)}}(s_i) q(s_i)^{\frac{\beta(s_i)(1-\lambda(s_i))}{\alpha(s_i)}} - (1-\lambda(s_i))\frac{w(s_i)L(s_i,q(s_i))}{q(s_i)}$$

(9)

(9) can be rewritten as follows:

$$\frac{\pi(s_i,q(s_i))}{q(s_i)} = \underbrace{\frac{r(s_i)\beta(s_i)(1-\lambda(s_i))}{\alpha(s_i)}\left[\frac{q(s_i)^{1-\lambda(s_i)}}{l(s_i)}\right]^{\frac{\beta(s_i)}{\alpha(s_i)}}}_{technological\ gains} - \underbrace{(1-\lambda(s_i))\frac{w(s_i)L(s_i,q(s_i))}{q(s_i)}}_{labour\ cost\ gains}$$

(10)

From (10), we could aggregate the firm-level profitability into the industry or stage level profitability in the supply chains. The aggregate average profitability of representative firm at stage s_i in the chain thus could be expressed as follows:

$$\frac{\Pi(s_i,q(s_i))}{q(s_i)} = n^*\left\{\underbrace{\frac{r(s_i)\beta(s_i)(1-\lambda(s_i))}{\alpha(s_i)}\left[\frac{q(s_i)^{1-\lambda(s_i)}}{l(s_i)}\right]^{\frac{\beta(s_i)}{\alpha(s_i)}}}_{technological\ gains} - \underbrace{(1-\lambda(s_i))\frac{w(s_i)L(s_i,q(s_i))}{q(s_i)}}_{labour\ cost\ gains}\right\}$$

(11)

Therefore, in Equation (11), the average profitability for each stage is made up of two parts: technological advancement, which is related to the average product of labor and production complexity, and labor costs. To ensure model tractability, an additional assumption is made that the labor cost gains are the same for all stages along the global value chain. Although this assumption deviates from reality, as the main purpose of this paper was to examine the effect different technological capabilities had on the profitability of each firm in each stage in the global supply chain, without making this additional assumption, it would be more difficult to compare the average profitability across different stages in the chains as these two types of gains may interact or even sometimes counteract each other, making the model unnecessarily complex. In the later empirical section, we will show that our theoretical results still hold conditional upon countries with different levels of human capital. This means, within countries that have similar human capital and wage level, our theoretical findings are still robust. Therefore, we make the following assumption in this paper:

Assumption 1. $(1-\lambda(s_i))\frac{w(s_i)L(s_i,q(s_i))}{q(s_i)}$=C,

From Assumption 1, it is known that equation (11) can be rewritten as follows:

$$\frac{\Pi(s_i,q(s_i))}{q(s_i)} = n^* \left\{ \underbrace{\frac{r(s_i)\beta(s_i)(1-\lambda(s_i))}{\alpha(s_i)}\left[\frac{q(s_i)^{1-\lambda}}{l(s_i)}\right]^{\frac{\beta(s_i)}{\alpha(s_i)}}}_{technological\ gains} - C \right\}$$

(12)

From Equation (12), the following proposition in this paper is developed:

Proposition 1: *Given the symmetrical equilibrium of market structure of each production stage in the chains as well as the fixed labour cost gains at each stage, the smile curve hypothesis only holds if and only if* $\frac{q(s_1)}{L(s_1,q(s_1))} \geq \max\{\left[\frac{\beta(s_2)\alpha(s_1)(1-\lambda(s_2))}{\beta(s_1)\alpha(s_2)(1-\lambda(s_1))}\right]^{\frac{\alpha(s_1)}{\beta(s_1)}}\left[\frac{q(s_2)}{L(s_2,q(s_2))}\right]^{\frac{\beta(s_2)\alpha(s_1)}{\beta(s_1)\alpha(s_2)}}, 1\}$, *at which time the average profit in the high value-added stages is larger than in the low value-added stages, where* s_1 *is the high value-added stage and* s_2 *is the low value added stage. The two necessary conditions and one sufficient condition are :*

$$\begin{cases} \frac{q(s_1)}{L(s_1,q(s_1))} > \frac{q(s_2)}{L(s_2,q(s_2))}\ (NC) \\ \lambda(s_1) < \lambda(s_2) \\ \frac{\beta(s_1)}{\alpha(s_1)} < \frac{\beta(s_2)}{\alpha(s_2)}\ (SC) \end{cases}$$

Proof for proposition 1:

Step 1.

Consistent with smile curve literature, the production stages are classified into high value added stages and low value added stages, which is defined by the boundary values for the average product of the labor; therefore, a boundary value of 1 is decided on, where the high value-added stages could be described as those whose average product of labour is bigger than 1 ($\frac{n^{*}q(s_i)}{L(s_i,q(s_i))} \geq 1$) and vice versa for the low value-added stages.

Suppose that the high value-added stage is s_1, and the corresponding capital and labour elasticity of output for the representative firm at high value-added stage be $\alpha(s_1)$ and $\beta(s_1)$. Let the low value-added stage be s_2, and the corresponding capital and labour elasticity of output or each firm at low value-added stage be $\alpha(s_2)$and $\beta(s_2)$.

It could be seen that there are three main factors determining the profitability distribution between high and low value-added stages in the chain. The first one is the average product of labor determines the stage that has the higher average profit. The second one is $\frac{\beta(s_i)}{\alpha(s_i)}$ which also determines whether high value-added stage has the higher average profit. The third one is the production complexity of the representative firm producing respectively at high and low value-added stages.

Step 2.

Based on the derivation in step 1, the average profit in the high value-added stages is higher than the average profit in the low value-added stages when

$$\frac{\Pi[s_1,q((s_1)]}{q(s_1)} > \frac{\Pi[s_2,q(s_2)]}{q(s_2)}$$

(13)

putting (12) into (13),

$$n^*\left\{\frac{r\beta(s_1)(1-\lambda(s_1))}{\alpha(s_1)}\left[\frac{q(s_1)}{L(s_1,q((s_1))}\right]^{\frac{\beta(s_1)}{\alpha(s_1)}}\right\} > n^*\left\{\frac{r\beta(s_2)(1-\lambda(s_2))}{\alpha(s_2)}\left[\frac{q(s_2)}{L(s_2,q((s_2))}\right]^{\frac{\beta(s_2)}{\alpha(s_2)}}\right\}$$

(14)

Rearranging (14), the following could be obtained:

$$\frac{q(s_1)}{L(s_1,q(s_1))} > \left[\frac{\beta(s_2)\alpha(s_1)(1-\lambda(s_2))}{\beta(s_1)\alpha(s_2)(1-\lambda(s_1))}\right]^{\frac{\alpha(s_1)}{\beta(s_1)}}\left[\frac{q(s_2)}{L(s_2,q(s_2))}\right]^{\frac{\beta(s_2)\alpha(s_1)}{\beta(s_1)\alpha(s_2)}}$$

(15)

From (15), it could be demonstrated that,

When $\frac{q(s_1)}{L(s_1,q(s_1))} \geq \max\{\left[\frac{\beta(s_2)\alpha(s_1)(1-\lambda(s_2))}{\beta(s_1)\alpha(s_2)(1-\lambda(s_1))}\right]^{\frac{\alpha(s_1)}{\beta(s_1)}}\left[\frac{q(s_2)}{L(s_2,q(s_2))}\right]^{\frac{\beta(s_2)\alpha(s_1)}{\beta(s_1)\alpha(s_2)}}, 1\}$, the average profit in the high value-added stages is higher than the average profit in the low value-added stages.

Proof Completed.

The basic intuition behind proposition 1 is that the profitability distribution between the high value-added and low value-added firms is contingent upon two factors: the average product of labor in each stage and the ratio of the output elasticity of capital to the output elasticity of labor in each stage. In particular, it is demonstrated from proposition 1 that if the output elasticity ratio at high value-added stages is lower than the one at low value-added stages, $\frac{\beta(s_1)}{\alpha(s_1)} < \frac{\beta(s_2)}{\alpha(s_2)}$, then it must be the case that $[\frac{q(s_1)}{L(s_1,q(s_1))}]^{\frac{\beta(s_1)}{\alpha(s_1)}} \geq [\frac{q(s_2)}{L(s_2,q(s_2))}]^{\frac{\beta(s_2)}{\alpha(s_2)}}$ and $\lambda(s_1) < \lambda(s_2)$ to ensure the higher profitability at high value-added stages. However, this condition is not necessary but only sufficient. This means even $\frac{\beta(s_1)}{\alpha(s_1)} < \frac{\beta(s_2)}{\alpha(s_2)}$ is not satisfied, as long as the boundary definition of distinguishing the high value-added and low value-added stages in terms of the average product of labour as well as the production complexity holds, the profitability level at high value-added stage will be higher than the one of low value-added stages. This is to say, the necessary condition for high value-added stages to possess higher profits than low value-added stages is $\frac{q(s_1)}{L(s_1,q(s_1))} > \frac{q(s_2)}{L(s_2,q(s_2))}$ and $\lambda(s_1) < \lambda(s_2)$

3.2 Upgrading mechanism for firms along the global supply chain (Comparative Statics)

From the average profit function indicated in equation (12), a comparative static analysis could be conducted to derive the following two propositions for the inter-supply chain upgrading mechanism.

Proposition 2: *An increase in the production complexity at production stage s_i leads to an increased average profitability for production stage s_i*

Proof for Proposition 2:

$$\frac{\partial \frac{\pi(s_i,q(s_i))}{q(s_i)}}{\partial \lambda(s_i)} = -\frac{n^* r(s_i)\beta(s_i)}{\alpha(s_i)}\left[\frac{q(s_i)}{L(s_i,q(s_i))}\right]^{\frac{\beta(s_i)}{\alpha(s_i)}} < 0$$

(16)

Proof Completed.

The intuition behind Proposition 2 is that as $\lambda(s_i)$ represents the production complexity at each production stage in the chain, when $\lambda(s_i)$ is smaller, the production complexity at that production stage is higher. It could be derived from $L(s_i, q(s_i)) = q(s_i)^{\lambda(s_i)} l(s_i)$ that when $\lambda(s_i)$ is smaller, less labor is demanded in each stage , which implies that the average product of labor $\frac{q(s_i)}{L(s_i,q(s_i))}$ is higher, which in turn increases the average profit of each stage in the chain.

Proposition 3: *The higher the factor intensity* $\frac{K(s_i,q)}{L(s_i,q)}$ *at stage* s_i *, the higher the average profit at production stage* s_i.

Proof for Proposition 3:

From $\mathrm{L}(\mathrm{s_i}, \mathrm{q}(s_i)) = \mathrm{q}(s_i)^{\lambda(s_i)} l(\mathrm{s_i})$ and $\mathrm{K}(\mathrm{s_i}, \mathrm{q}(s_i)) = \mathrm{q}(s_i)^{\frac{(1-\beta(s_i))\lambda(s_i)}{\alpha(s_i)}} l(s_i)^{-\frac{\beta(s_i)}{\alpha(s_i)}}$, it could be obtained that

$$\frac{\mathrm{K}(\mathrm{s_i},q(s_i))}{\mathrm{L}(\mathrm{s_i},q(s_i))} = [\frac{\mathrm{q}(s_i)}{\mathrm{L}(\mathrm{s_i},\mathrm{q}(s_i))}]^{\frac{1}{\alpha(s_i)}}$$

(17)

Plugging (17) into the average profit function of at stage s_i when all the firms at this stage indicated by (12), then we could take the derivative of it with respect to $\frac{\mathrm{K}(\mathrm{s_i},q(s_i))}{\mathrm{L}(\mathrm{s_i},\mathrm{q}(s_i))}$, the following could be obtained:

$$\frac{\partial \frac{\Pi(s_i,q(s_i))}{q^*}}{\partial \frac{\mathrm{K}(s_i,q(s_i))}{\mathrm{L}(s_i,\mathrm{q}(s_i))}} = \frac{n^* r(s_i)\beta(s_i)^2(1-\lambda(s_i))}{\alpha(s_i)} [\frac{\mathrm{K}(\mathrm{s_i},\mathrm{q}(s_i))}{\mathrm{L}(\mathrm{s_i},\mathrm{q}(s_i))}]^{\beta(s_i)-1} > 0$$

(18)

Proof Completed.

The intuition behind Proposition 3 is that an increase in the factor intensity ratio $\frac{\mathrm{K}(\mathrm{s_i},\mathrm{q}(s_i))}{\mathrm{L}(\mathrm{s_i},q(s_i))}$ leads to a higher average product of labor, which in turn increases the average profit at production stage s_i. However, it must be noted that for these theoretical results to hold, it must be assumed that there are no sunk costs for entrants to enter any stage in the chain, an assumption that is in aligned with Shin et al. (2012), in which the correctness of the smile curve hypothesis became insignificant if the costs of sustaining the position at the two ends of the curve are considered.

Being embedded into a particular global supply chain stage provides opportunities for industrial upgrading for developing countries (Gereffi, 1999; Schmitz and Humphrey, 2002) as the firms gain tacit or explicit technological and management knowledge and additional resources, which would enable them to industrially upgrade and gain greater income. As corroborated in propositions 2 and 3, gaining greater profits from inter-supply chain upgrading depends on production complexity and the factor intensities at a particular stage. Proposition 2 is also consistent with Costinot et al. (2013) in which technological change was defined as a rise in production complexity, and one of the implications of proposition 3 is that a dynamic change from being labor-intensive to being capital intensive in the comparative factor endowment advantage for a country (firm) at a particular stage was found to play an important role in the supply chain upgrading process. This theoretical result is compatible with the recent debate in development economics in which Lin (2012) discussed the importance of dynamic changes in comparative factor endowment advantages when determining the efficiency of industrial firms from developing countries.

4. Empirical Evidence

4.1 Data sources and variable descriptions

The main country-industry data source was the World Input-Output Database (WIOD) , the Input-output tables (WIOT) tables in which track current prices from 2000 to 2014, and cover 42 countries (17 developed countries and 25 developing) and 68 industries, with the rest of the countries regarded as a model for the rest of the world (RoW). The data for the 68 industries were classified based on the International Standard Industrial Classification revision 4 (ISIC Rev. 4), with the socio-economic accounts (SEA) providing industry-level data for employment, capital stock, gross output and value added at current and constant prices. The data for the control variables, which considers the heterogeneous country characteristics, were extracted from the World Bank database. The detailed information on the variables and sources are listed in table 1, and table 2 gives the descriptive statistics.

Table 1. Variable Definitions and Data Sources

Variables	Definition	Measure	Data Sources
Explained variable			
PRO	Profit	The difference between value added and total capital compensation and labor compensation. (takes the logarithm and adjusts price level using 1995 as baseyear)	World Input-Output Database
Explanatory variables			
LP	Labor productivity	The ratio of gross output to employees in each industry. (takes the logarithm and adjusts price level using 1995 as baseyear)	World Input-Output Database; Authors' calculation
CI	Capital intensity	The ratio of capital stock to employees in each industry. (takes the logarithm and adjusts price level using 1995 as baseyear)	
TFP	Production complexity	Total factor productivity calculated using the LP method.	
forwardindex	GVC position	domestic value added embodied in foreign exports as share of gross export	TiVA Database
backwardindex	GVC position	Ratio of foreign added in gross export	TiVA Database
Control variables			
Infra	Infrastructure	Overall country infrastructure construction level, using fixed telephone subscriptions (per 100 people). (takes the logarithm)	World Bank
Tech	Technological development	High-tech exports as a percentage of manufactured exports. (takes the logarithm)	
Popu	Population	All residents regardless of legal status or citizenship in a country. The values shown are midyear estimates. (takes the logarithm)	
GDPg	GDP growth	GDP growth rate.	

Open	Trade freedom	Exports of goods and services as a percentage of GDP. (takes the logarithm)	
FDI	Foreign direct investment	Net inflows of foreign investors (new investment inflows minus withdrawals) as a percentage of GDP. (takes the logarithm)	
Subsample criteria			
Economies	Economies	High income (OECD) group are developed countries; the medium to upper income group (UMC), medium to lower income group (LMC) and the low-income group (LIC) are developing countries.	World Bank
HC	Human capital	Percentage of working age population with an advanced level of education that are in the labor force.	

Table 2. Summary Statistics

Variables	Observation	Mean	Std. dev.	Min	Max
PRO	28,777	4.846755	5.642609	-37.59797	19.76814
LP	32,540	5.905857	2.13787	2.538653	13.08889
CI	32,091	5.685075	2.375388	2.082743	13.48473
TFP	28314	20.69591	26.73051	0.730376	343.7862
Infra	35,280	3.547875	0.598727	0.735626	4.314052
Tech	35,280	2.508725	0.69588	0.388009	4.271072
Popu	35,280	16.69455	1.873323	12.87413	21.03389
GDPg	35,280	2.795517	3.614614	-14.8142	14.23139
Open	35,280	3.673969	0.589291	2.201999	5.359446
FDI	33,208	1.150786	1.347619	-6.52287	6.113053
forwardindex	19131	0.588227	0.6450463	0	3.37
bacwardindex	19131	21.05972	12.76617	0	60.53

4.2 Profit-sharing mechanism test

The sample data used in this study were strongly balanced panel data, with the cross section being p (p=c×j, c∈{1,2,3,…}, i∈{1,2,3,…}, where c was country and j was industry, and the time series was from 2000 to 2014. Because of the heterogeneity of the basic country-level conditions, subsamples were established to conduct the regression analysis on the developed and developing countries. The human capital level was taken as the criterion and the sample countries divided into three sub-samples based on the quantile. The reasons of testing our theories within the groups of countries with different level of human capital level is because we have assumed the constant labour cost gains in our model. Therefore, in order to test whether our theories could be also generalized to countries with the same wage level and human capital investment, we further conduct the sub-sample analysis to be the robustness check of our empirical model.

Equations (19) and (20) was applied to explore the effects of industrial labor productivity and TFP which we used as the proxy for the production complexity on the profits,[8] the specific empirical designs for which are ;

$$PRO_{ict} = \alpha + \beta LP_{ict} + \sum_m r_m Country_{ct} + \theta_i + \theta_c + \theta_t + \varepsilon_{ict}$$

(19)

$$PRO_{ict} = \alpha + \beta TFP_{ict} + \sum_m r_m Country_{ct} + \theta_i + \theta_c + \theta_t + \varepsilon_{ict}$$

(20)

where the explained variable PRO_{ict} was the logarithm for the difference between the value added and total capital compensation and labor compensation in industry *i* in country *c* in year *t*, which was the proxy for the profit gained. The explanatory variables were the logarithm for labor productivity LP_{ict} and production complexity TFP_{ict}. $Country_{ct}$ was a set of control variables at the country level: infrastructure, scientific and technological level, population, GDP growth, openness and foreign direct investment. θ_i, θ_c and θ_t were the industry, country, year fixed effects to control for individual invariant characteristics and ε_{it} was the error term. The OLS method was used for the regression and a robust standard error added to control heteroscedasticity.

Figures 3 and 4 are the scatter diagrams and fitting curves for the labor productivity (*LP*) and production complexity TFP_{ict} related to the profit (*PRO*), which indicates that there were obviously positive relationships for all country-industry pairs.

[8] Using the total factor productivity (TFP) as the proxy for the production complexity is in line with the spirit of Hausmann and Hidalgo (2010).

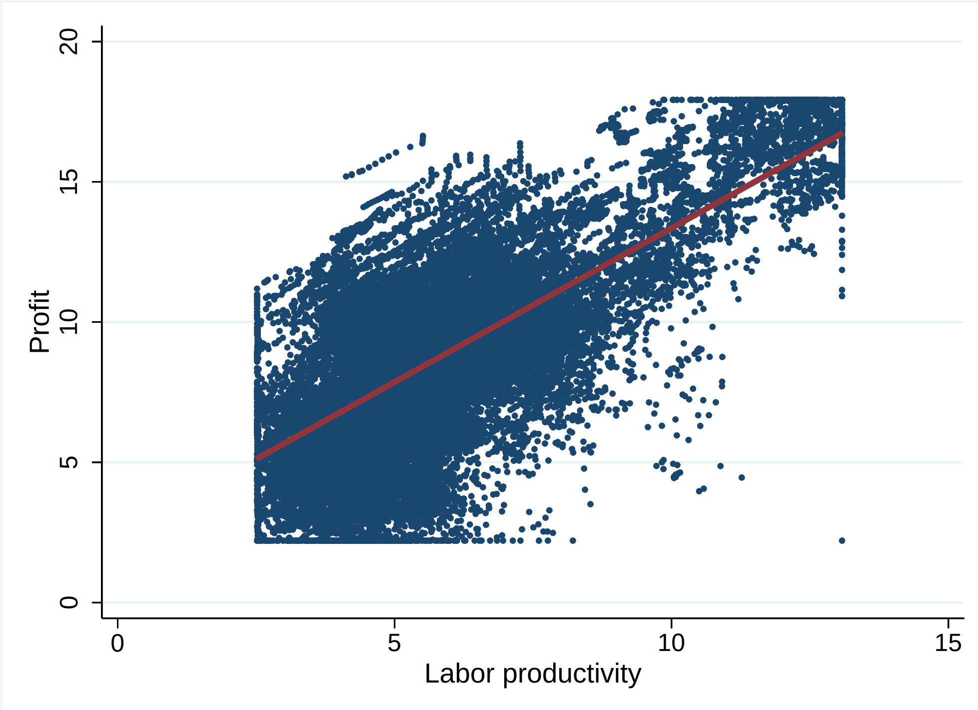


Figure 3. Scattered Plot for the positive relationship between Labor productivity and profit

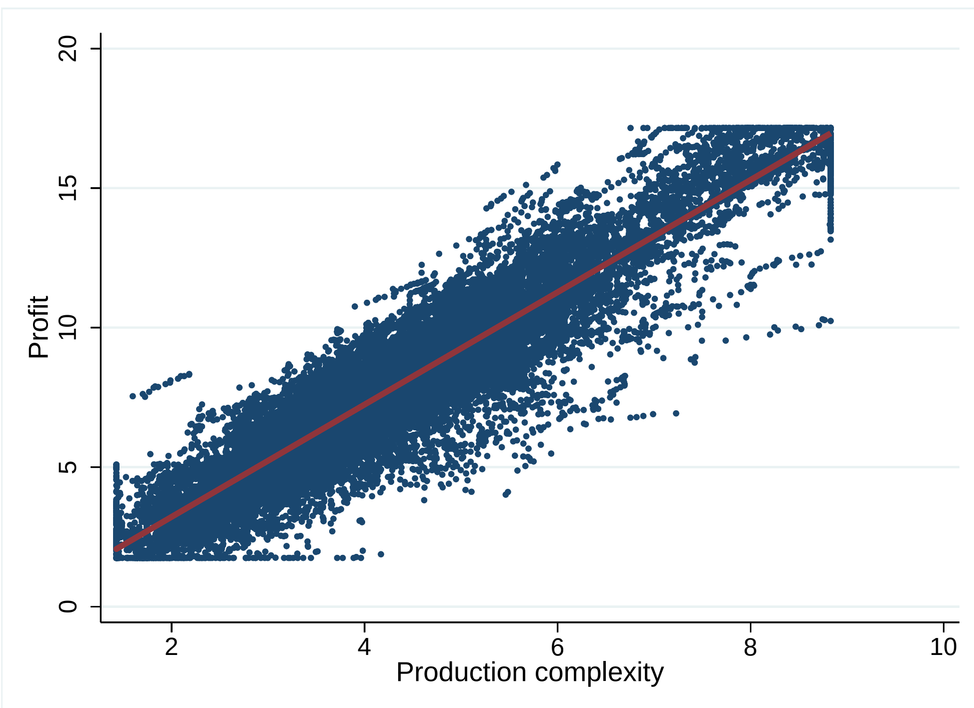


Figure 4. Scattered plot for the positive relationship between production complexity and profit

4.2.1 Full sample results

Table 3 shows the results for regressions on Equations (19) and (20). In columns (1) and (4), the fixed effects were not considered in the regression; in columns (2) and (5), only the time fixed effects were controlled for; and in columns (3) and (6), industry fixed effects and country fixed effects were added. Across all specifications, the coefficients for *LP* and *TFP* are significantly positive, which indicate that the higher the labor productivity and production complexity of an industry, the higher the profit. In order to address the endogeneity problem, we run two stage regression on Equation (19) again using population as instrumental variable to replace *LP*. Hausman test was then conducted and the *p* value refused the null hypothesis (p=0.406) which assures there is no endogenous issue. Proposition 1 is corroborated.

Table 3. Labor productivity, production complexity and profit

VARIABLES	(1) *PRO*	(2) *PRO*	(3) *PRO*	(4) *PRO*	(5) *PRO*	(6) *PRO*
LP	0.706***	0.699***	0.136***			
	(0.00537)	(0.00537)	(0.00876)			
TFP				1.871***	1.867***	0.959***
				(0.0243)	(0.0244)	(0.0414)
Tech	0.348***	0.377***	0.0817***	0.438***	0.450***	-0.209***
	(0.0167)	(0.0167)	(0.0168)	(0.0410)	(0.0413)	(0.0698)
Infra	0.402***	0.447***	0.394***	-0.391***	-0.394***	0.223
	(0.0217)	(0.0221)	(0.0342)	(0.0532)	(0.0545)	(0.141)
GDPg	-0.0115***	0.00650	0.00472**	-0.00780	-0.00967	0.00118
	(0.00309)	(0.00403)	(0.00227)	(0.00772)	(0.0101)	(0.00944)
Popu	1.191***	1.162***	-1.841***	0.529***	0.521***	-3.589***
	(0.0108)	(0.0109)	(0.171)	(0.0309)	(0.0313)	(0.698)
FDI	-0.123***	-0.121***	0.0410***	-0.227***	-0.231***	0.0233
	(0.00873)	(0.00906)	(0.00580)	(0.0217)	(0.0226)	(0.0241)
Open	0.568***	0.436***	-0.545***	0.691***	0.658***	-0.702***
	(0.0304)	(0.0317)	(0.0497)	(0.0755)	(0.0795)	(0.203)
Constant	-19.96***	-19.58***	39.05***	-14.20***	-14.02***	66.81***
	(0.293)	(0.297)	(2.972)	(0.770)	(0.785)	(12.09)

Observations	30,556	30,556	30,556	26,653	26,653	26,653
R-squared	0.729	0.732	0.936	0.437	0.438	0.635
Year FE	NO	YES	YES	NO	YES	YES
Industry FE	NO	NO	YES	NO	NO	YES
Country FE	NO	NO	YES	NO	NO	YES

Notes: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

4.2.2 Subsample results

Our theory sets two scenarios in terms of how the output elasticity ratio of each stage could affect the profit sharing mechanism along the global supply chains. One is the necessary condition where $\frac{\beta(s_1)}{\alpha(s_1)} < \frac{\beta(s_2)}{\alpha(s_2)}$ is satisfied. The other scenario is that this necessary condition is not satisfied. We are now going to test whether our theoretical hypothesis still holds with or without the presence of this necessary condition.

To proceed, it is known that in our model, one is the high value-added stage, s_1 and its corresponding capital and labour elasticity of output is $\alpha(s_1)$ and $\beta(s_1)$. The other low value-added stage is s_2 and its corresponding capital and labour elasticity of output is $\alpha(s_2)$ and $\beta(s_2)$. To estimate capital and labour elasticity under these two scenarios. We consider the following two regressions

$\ln output_{cit} = \alpha_0 + \alpha \ln cap_{cit} + \varepsilon_{cit}$

(21)

$\ln output_{cit} = \beta_0 + \beta \ln lab_{cit} + \varepsilon_{cit}$

(22)

where $\ln output_{cit}$ is the logarithm of total output for industry i in country c in year t, deflated to the 1995 level using relevant price indices provided by the SEA dataset. We proxy for capital input using the logarithm of capital compensation ($\ln cap_{cit}$) and labour input using the logarithm of labour compensation ($\ln lab_{cit}$). Data are obtained from the

WIOD SEA. We then run the regression separately for each country-industry pair. The estimated coefficient α measures the capital elasticity with respect to total output and β measures the labour elasticity with respect to total output respectively.

The necessary condition of proposition1 should be met when the output elasticity ratio at high value-added stages is lower than the one at low value-added stages, that is $\frac{\beta(s_1)}{\alpha(s_1)} < \frac{\beta(s_2)}{\alpha(s_2)}$. We quantile the total value-added (VA) for each country-industry pair into three groups. Industries with total value added in the first quantile of the distribution are identified as the ones in the lower value-added stage. Those with a value in the second quantile of the distribution are identified as in the middle value-added stage. Those with a value in the third quantile of the distribution are identified as in the higher value-added stage. After regression Equations (21) and (22), we could derive the coefficient α and β to formulate the elasticity ratio in different value-added stages. It is expected that the elasticity ratio which meets this necessary condition $\frac{\beta(s_1)}{\alpha(s_1)} < \frac{\beta(s_2)}{\alpha(s_2)}$ proposed by our model could be treated as one of the two sub-sample groups and the one does not satisfy this necessary condition could be treated as another sub-sample group. Table 4 gives the average elasticity ratio $\frac{\beta}{\alpha}$ for the three quantiles for each country-industry pair. It can be seen that only second quantile and third quantile of the distribution meets the condition of proposition 1. We then run regression (19) and (20) taking second and third quantile of the sample distribution again as the sub-group that satisfy the condition, *while the first quantile as* the lower VA stage that does not satisfy the condition.

Table 4. Average labour elasticity over average capital elasticity to total output

First Quantile (lower VA stage)	Second Quantile (middle VA stage)	Third Quantile (high VA stage)
0.04	2.28	0.61

Table 5. Labor productivity and profit with conditions

	Second and Third Quantile			*First Quantile*		
VARIABLES	*PRO*	*PRO*	*PRO*	*PRO*	*PRO*	*PRO*
LP	0.664***	0.645***	-0.00577	0.096***	0.0346**	-0.220**
	(0.00575)	(0.00577)	(0.0101)	(0.0141)	(0.0140)	(0.0973)
Tech	0.460***	0.571***	0.208***	-0.0287	0.071***	0.0444***
	(0.0212)	(0.0216)	(0.0285)	(0.0216)	(0.0213)	(0.0144)
Infra	0.161***	0.195***	0.493***	0.424***	0.703***	0.263***
	(0.0238)	(0.0239)	(0.0349)	(0.0501)	(0.0525)	(0.0686)
GDPg	0.0154***	0.067***	0.014***	0.051***	-0.048***	-0.000883
	(0.00421)	(0.00554)	(0.00304)	(0.00361)	(0.00504)	(0.00194)
Popu	0.871***	0.804***	-0.373*	0.780***	0.736***	-3.817***
	(0.0139)	(0.0140)	(0.215)	(0.0188)	(0.0186)	(0.417)
FDI	-0.167***	-0.159***	0.0780***	0.0829***	0.0857***	-0.00812
	(0.0108)	(0.0111)	(0.00676)	(0.0113)	(0.0117)	(0.00739)
Open	0.434***	0.244***	-0.651***	0.701***	0.497***	-0.375***
	(0.0347)	(0.0357)	(0.0510)	(0.0433)	(0.0463)	(0.0981)
Constant	-12.80***	-11.95***	14.46***	-11.32***	-11.10***	70.72***
	(0.367)	(0.368)	(3.692)	(0.468)	(0.466)	(7.391)
Observations	20,297	20,297	20,297	10,259	10,259	10,259
R-squared	0.630	0.639	0.921	0.256	0.292	0.417
Year FE	NO	YES	YES	NO	YES	YES
Industry FE	NO	NO	YES	NO	NO	YES
Country FE	NO	NO	YES	NO	NO	YES

Notes: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 6. Production complexity and profit with conditions

	Second and Third Quantile			*First Quantile*		
VARIABLES	*PRO*	*PRO*	*PRO*	*PRO*	*PRO*	*PRO*
TFP	1.811***	1.794***	0.806***	1.250***	1.293***	1.000***
	(0.0265)	(0.0269)	(0.0453)	(0.0736)	(0.0791)	(0.0916)
Tech	0.538***	0.585***	-0.0313	0.176**	-0.186	-0.266**
	(0.0485)	(0.0499)	(0.111)	(0.0785)	(0.128)	(0.110)
Infra	-0.597***	-0.586***	0.347**	0.488***	-0.290	-0.370
	(0.0542)	(0.0550)	(0.135)	(0.180)	(0.456)	(0.391)
GDPg	0.0123	0.0389***	0.0136	-0.0272**	-0.0322	-0.0284
	(0.00976)	(0.0129)	(0.0117)	(0.0132)	(0.0207)	(0.0177)
Popu	0.419***	0.393***	-1.714**	0.428***	-2.083	-2.198
	(0.0348)	(0.0354)	(0.829)	(0.0705)	(1.744)	(1.495)
FDI	-0.289***	-0.293***	0.0547**	-0.175***	-0.00506	-0.0180
	(0.0251)	(0.0262)	(0.0267)	(0.0413)	(0.0547)	(0.0468)
Open	0.838***	0.770***	-1.047***	0.298*	0.736	0.744
	(0.0814)	(0.0850)	(0.196)	(0.155)	(0.696)	(0.597)
Constant	-11.87***	-11.48***	35.72**	-12.01***	34.02	39.63
	(0.882)	(0.896)	(14.22)	(1.705)	(30.52)	(26.18)
Observations	17,730	17,730	17,730	8,923	8,923	8,923
R-squared	0.390	0.391	0.638	0.067	0.141	0.373
Year FE	NO	YES	YES	YES	YES	YES
Industry FE	NO	NO	YES	YES	NO	YES
Country FE	NO	NO	YES	YES	NO	YES

Notes: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

The regression results of Equation (19) are represented in Table 5. The coefficients of *LP* are significantly positive in columns (1), (2), (4), and (5) for both groups that satisfy the conditions and those not. In general, higher labor productivity generates higher profit in all stages. Only in column (6), higher *LP* of observations that do not fulfill the conditions have significant lower profit. The regression results of equation (20) are represented in Table 6. It can be seen that the coefficients of *TFP* are significantly positive across all specifications, which means higher production complexity always generates higher profit. The results indicate that higher value-added industries are more profitable than the lower ones for both groups but the relationship for those sub-samples satisfying the conditions is much stronger. This result shows that $\frac{\beta(s_1)}{\alpha(s_1)} < \frac{\beta(s_2)}{\alpha(s_2)}$ is indeed the necessary condition for the high value-added stages to have the higher profitability than the one of low value-added stages. Overall, our results in Table 5 and 6 show some supportive evidence of proposition 1. Tables 7 , 8, 9 and 10 give the results when the samples were classified into different economic and human capital levels. Across all subsamples and specifications, *LP* and *TFP* showed significant positive correlations with profit, and were not affected by the country-level economic heterogeneity or the human capital discrepancies.

Table 7. Labor productivity and profit (developed vs developing)

VARIABLES	(1) *developed* *PRO*	(2) *developed* *PRO*	(3) *developed* *PRO*	(4) *developing* *PRO*	(5) *developing* *PRO*	(6) *developing* *PRO*
LP	0.624***	0.611***	0.983***	0.707***	0.679***	0.989***
	(0.0179)	(0.0182)	(0.0151)	(0.0250)	(0.0252)	(0.0222)
Tech	0.799***	0.802***	0.475***	0.626***	0.724***	0.344***
	(0.0556)	(0.0560)	(0.0438)	(0.0796)	(0.0813)	(0.0682)
Infra	-1.214***	-1.369***	-0.773***	0.182*	0.167	-0.119
	(0.135)	(0.142)	(0.110)	(0.108)	(0.109)	(0.0911)
GDPg	0.0669***	0.0997***	0.0747***	0.0164	0.0484***	0.0300**
	(0.0129)	(0.0196)	(0.0152)	(0.0132)	(0.0165)	(0.0137)
Popu	1.189***	1.215***	1.065***	1.554***	1.513***	1.151***
	(0.0350)	(0.0367)	(0.0285)	(0.0585)	(0.0588)	(0.0497)
FDI	-0.345***	-0.370***	-0.150***	-0.240***	-0.312***	-0.345***
	(0.0270)	(0.0283)	(0.0221)	(0.0439)	(0.0470)	(0.0391)
Open	0.555***	0.635***	0.0948	2.219***	2.114***	1.226***
	(0.0914)	(0.0987)	(0.0769)	(0.173)	(0.180)	(0.151)
Constant	-17.35***	-17.44***	-13.71***	-34.74***	-34.41***	-19.99***
	(0.921)	(0.938)	(0.744)	(1.640)	(1.655)	(1.423)
Observations	16,254	16,254	16,254	8,498	8,498	8,498
R-squared	0.341	0.342	0.607	0.424	0.429	0.609
Year FE	NO	YES	YES	NO	YES	YES
Industry FE	NO	NO	YES	NO	NO	YES

Notes: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 8. Production complexity and profit (developed vs developing)

VARIABLES	(1) *developed* *PRO*	(2) *developed* *PRO*	(3) *developed* *PRO*	(4) *developing* *PRO*	(5) *developing* *PRO*	(6) *developing* *PRO*
TFP	1.763***	1.753***	1.823***	1.807***	1.771***	1.885***
	(0.0290)	(0.0293)	(0.0287)	(0.0441)	(0.0445)	(0.0453)
Tech	0.563***	0.565***	0.534***	0.391***	0.477***	0.376***
	(0.0513)	(0.0518)	(0.0436)	(0.0754)	(0.0769)	(0.0692)
Infra	-1.160***	-1.248***	-1.166***	-0.416***	-0.411***	-0.555***
	(0.124)	(0.131)	(0.109)	(0.104)	(0.106)	(0.0936)
GDPg	0.0380***	0.0526***	0.0968***	0.00738	0.0401**	0.0399***
	(0.0120)	(0.0181)	(0.0152)	(0.0126)	(0.0158)	(0.0139)
Popu	0.364***	0.380***	0.341***	0.636***	0.606***	0.513***
	(0.0365)	(0.0380)	(0.0331)	(0.0646)	(0.0647)	(0.0598)
FDI	-0.257***	-0.269***	-0.245***	-0.266***	-0.320***	-0.400***
	(0.0245)	(0.0257)	(0.0217)	(0.0420)	(0.0449)	(0.0395)
Open	0.214**	0.258***	0.116	1.683***	1.549***	1.516***
	(0.0848)	(0.0917)	(0.0768)	(0.163)	(0.169)	(0.152)
Constant	-6.499***	-6.491***	-2.213***	-18.97***	-18.68***	-12.58***
	(0.878)	(0.896)	(0.769)	(1.667)	(1.680)	(1.540)
Observations	16,178	16,178	16,178	8,426	8,426	8,426
R-squared	0.426	0.426	0.606	0.476	0.480	0.602
Year FE	NO	YES	YES	NO	YES	YES
Industry FE	NO	NO	YES	NO	NO	YES

Notes: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 9. Labor productivity and profit (different levels of human capital)

VARIABLES	(1) *Low-HC* *PRO*	(2) *Mid-HC* *PRO*	(3) *High-HC* *PRO*
LP	0.920***	1.026***	1.075***
	(0.0319)	(0.0319)	(0.0235)
Tech	0.390***	0.232***	-0.0523
	(0.0957)	(0.0604)	(0.0700)
Infra	-0.515***	0.407***	0.692***
	(0.0965)	(0.105)	(0.107)
GDPg	-0.0425*	-0.0133	-0.00241
	(0.0241)	(0.0140)	(0.0182)
Popu	1.128***	1.285***	1.354***
	(0.0456)	(0.0470)	(0.0537)
FDI	-0.158***	-0.295***	0.0669
	(0.0357)	(0.0337)	(0.0470)
Open	0.186	0.777***	1.254***
	(0.139)	(0.134)	(0.165)
Constant	-14.92***	-23.25***	-26.81***
	(1.305)	(1.255)	(1.458)
Observations	5,884	11,856	5,973
R-squared	0.570	0.476	0.644
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Notes: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 10. Production complexity and profit (different levels of human capital)

VARIABLES	(1) *Low-HC*	(2) *Mid-HC*	(3) *High-HC*
	PRO	*PRO*	*PRO*
TFP	1.857***	1.507***	1.940***
	(0.0565)	(0.0538)	(0.0446)
Tech	0.368***	0.380***	-0.218***
	(0.0914)	(0.0605)	(0.0710)
Infra	-0.946***	-0.229**	0.000259
	(0.0893)	(0.103)	(0.105)
GDPg	-0.0683***	-0.0205	0.00597
	(0.0234)	(0.0142)	(0.0185)
Popu	0.419***	0.859***	0.749***
	(0.0505)	(0.0583)	(0.0623)
FDI	-0.208***	-0.349***	0.130***
	(0.0347)	(0.0340)	(0.0477)
Open	0.319**	1.160***	1.656***
	(0.135)	(0.134)	(0.165)
Constant	-4.408***	-16.39***	-17.72***
	(1.278)	(1.378)	(1.546)
Observations	5,863	11,780	5,917
R-squared	0.592	0.466	0.636
Year FE	YES	YES	YES
Industry FE	YES	YES	YES

Notes: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

4.3 Testing the Inter-supply chain upgrading mechanism

In order to better proxy for the position of different stages in global value chain, we use the "economic status" index constructed by Koopman et al. (2012, 2014). This method can accurately measure the forward and backward correlation of a country's industries in GVC, and then reflect its GVC integration degree and status. Unlike the method designed by Antras et al. (2012) who constructed upstreamness index and downstream index to measure the specific physical location of a production section in GVC (Antràs et al., 2012; Fally, 2012), Koopman put forward a more effective value-added trade accounting method (the

KWW method) (Hummels et al., 2001). It is an optimization algorithm based on World Input - Output Database (WIOD) to separate a country's total exports (Lv, Luo, & Liu, 2016). It does not only accurately measure the use of imported intermediate goods in a country's domestic consumption and export products, but also further integrates indirect value added and re-import value added into the accounting system. Since the smile curve classification of production stages is more based on the value-added approach, we believe that Koopman et al. (2012, 2014)'s approach is more appropriate for our empirical design. The sub-divisional results are shown in Figure 5. On this basis, we assess industries' position in GVC by setting $forwardindex$ and $backwardindex$ to be the measure of an industry country pair, which also reflects the relative importance of the country as an intermediate goods supplier and buyer within the value chains. The detailed calculations are as Equations (23) and (24).

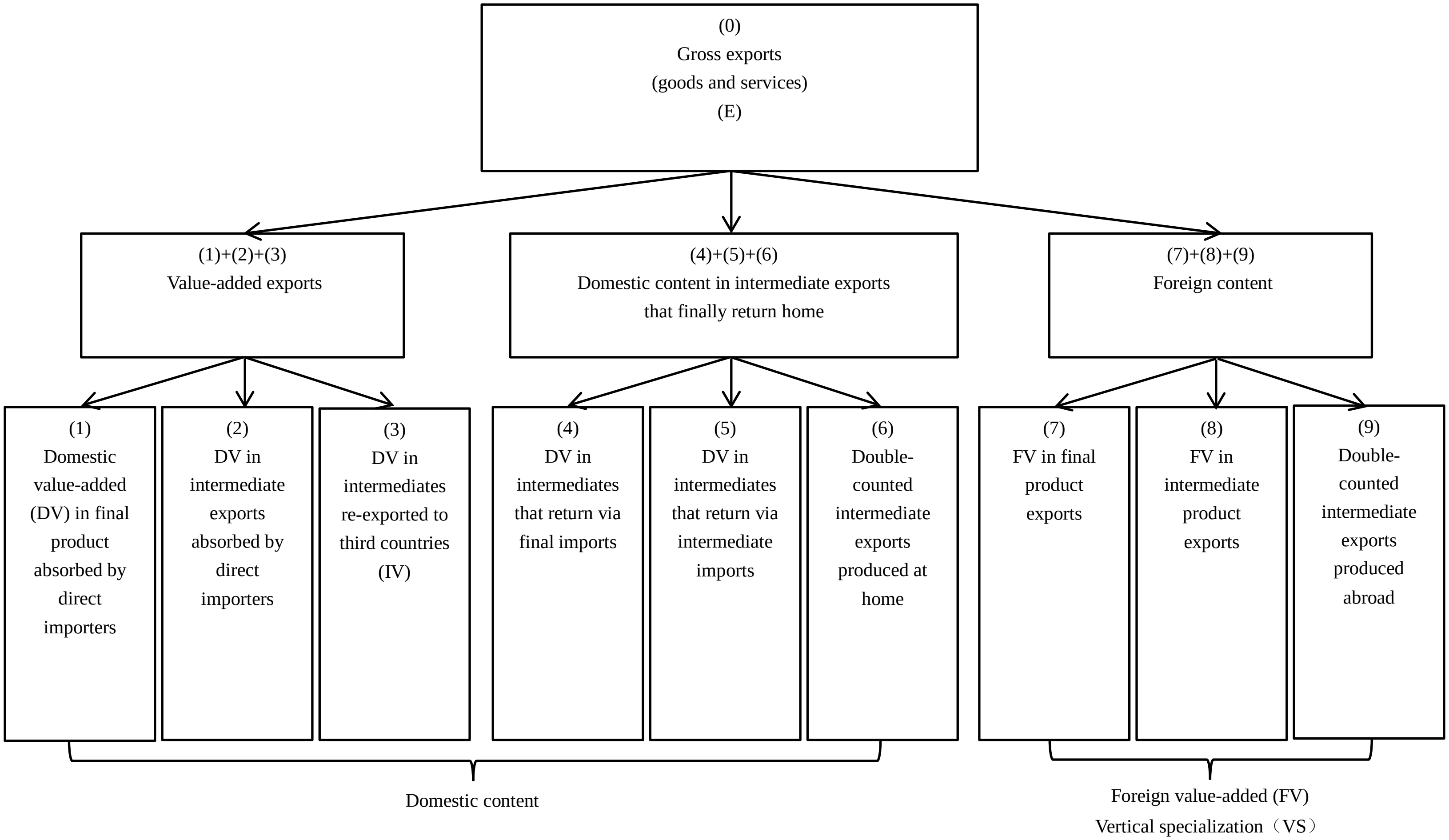


Figure 5. Decomposition of gross exports

$$forwardindex = \frac{\text{IV}}{\text{E}}$$

(23)

$$backwardindex = \frac{\text{FV}}{\text{E}}$$

(24)

where E refers to gross exports. IV refers to indirect value-added, which is part (3) in the decomposition. FV refers to foreign value-added, which equals to part (7+8+9). $forwardindex$ is larger if a country locates in the front end of GVC and its main way to participate in the international production line is to provide intermediate products to other countries, while industries with higher $backwardindex$s are more likely to locate at the back end of GVC (Koopman et al., 2008).

The Organization for Economic Cooperation and Development (OECD) and the World Trade Organization (WTO) in 2018 jointly released Trade in Value Added (TiVA) report, which we could use to measure the indices of GVC embeddedness at the country and industry level. This version covers the period from 2005 to 2015 and 64 economies; other countries are classified as ROW. It covers 36 unique industrial sectors, which are classified based on the industry list in the fourth revision of the *International Standard Industry Classification (ISIC).*

4.3.1 Testing the existence of "smile curve"

In this part, we first test the existence of profitability-driven "smile curve" which is the U-shaped relationship between GVC position of each industry country pair with profit using Equations (25) and (26). We expect the positive coefficient on $forwardindex_{ict}^2$

and negative coefficient on $backwardindex_{ict}^2$.

$$PRO_{ict} = \alpha + \beta 1 forwardindex_{ict} + \beta 2 forwardindex_{ict}^2 + \theta_c + \theta_t + \varepsilon_{ict}$$

(25)

$$PRO_{ict} = \alpha + \beta 1 forwardindex_{ict} + \beta 2 backwardindex_{ict}^2 + \theta_c + \theta_t + \varepsilon_{ict}$$

(26)

where the explained variable $PRO_{ict}$was the logarithm for the profit gained from industry *i* in country *c* in year *t*, $forwardindex_{ict}$ is the domestic value added embodied in foreign exports as share of gross export which describes the forward position in global value chain. $backwardindex_{ict}$ is the ratio of foreign value added to gross exports which measures the backward position in global value chain. θ_c and θ_t indicated the country and time fixed effects, and ε_{ict} was the error term. The OLS method with robust standard errors was used for the regression.

Table 11. Evidence of the smile curve

VARIABLES	(1) *PRO*	(2) *PRO*
$forwardindex$	-0.910***	
	(0.159)	
$forwardindex^2$	0.307***	
	(0.0599)	
$backwardindex$		-0.155***
		(0.0105)
$backwardindex^2$		0.000424**
		(0.000193)
Constant	4.989***	7.520***
	(0.140)	(0.168)
Observations	19,131	19,131
R-squared	0.003	0.090
Country FE	YES	YES
Year FE	YES	YES

Notes: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 11 gives the evidence of profitability-driven "smile curve". Both$forwardindex^2$ and $backwardindex^2$ get significant positive coefficients. That is, profits are higher for backward and forward sectors than the middle ones. There is a U-shaped relationship between profit and GVC position.

4.3.2 Testing the inter-supply chain upgrading mechanism

In this section, we test if there is moderating effect through which the increase in production complexity and capital intensity could enable all the firms to experience the inter-supply chain upgrading, which is a upward lift of a whole profitability-driven smile curve (Equations (27) and (28)). In the model, $postionindex$ includes $forwardindex$ and $backwardindex$.

$$PRO_{ict} = \alpha + \beta 1 postionindex_{ict} + \beta 2 positionindex_{ict}^2 + \beta 3 TFP_{ict} + \beta 4 TFP_{ict} * positionindex_{ict} + \beta 5 TFP_{ict} * positionindex_{ict}^2 + +\theta_c + \theta_t + \varepsilon_{ict}$$

(27)

$$PRO_{ict} = \alpha + \beta 1 positionindex_{ict} + \beta 2 postitionindex_{ict}^2 + \beta 3 CI_{ict} + \beta 4 CI_{ict} * positionindex_{ict} + \beta 5 CI_{ict} * positionindex_{ict}^2 + \theta_c + \theta_t + \varepsilon_{ict}$$

(28)

where TFP_{ict} was the total factor productivity for each industry country pair in year *t*, CI_{ict} was the ratio of capital stock to employees for each industry country pair in year *t* proxy for capital intensity. θ_c and θ_t indicated the country and time fixed effects, and ε_{ict} was the error term. The OLS method with robust standard errors was used for the regression.

Table 12. Inter-Supply Chain Upgrading mechanism through TFP and Capital intensity

VARIABLES	(1) *PRO*	(2) *PRO*	(3) *PRO*	(4) *PRO*
TFP	0.116***	0.000408		
	(0.00202)	(0.00572)		
$forwardindex$	-0.0744		1.978***	
	(0.164)		(0.330)	
$forwardindex^2$	0.0190		-0.653***	
	(0.0608)		(0.114)	
$backwardindex$		-0.0724***		0.0226
		(0.0102)		(0.0197)
$backwardindex^2$		-0.000298*		-0.000285
		(0.000180)		(0.000336)
$TFP * forwardindex$	-0.0211***			
	(0.00405)			
$TFP * forwardindex^2$	0.00287**			
	(0.00132)			
$TFP * backwardindex$		-0.000991***		
		(0.000217)		
$TFP * backwardindex^2$		0.00973***		
		(0.00179)		
CI			0.103***	0.153***
			(0.0282)	(0.0350)
$CI * forwardindex$			-0.0592	
			(0.0395)	
$CI * forwardindex^2$			0.0536***	
			(0.0145)	
$CI * backwardindex$				-0.00330
				(0.00264)
$CI * backwardindex^2$				1.51e-05
				(4.89e-05)
Constant	2.989***	5.595***	8.207***	8.273***
	(0.0728)	(0.225)	(0.298)	(0.337)
Observations	18,830	18,721	18,963	18,963
R-squared	0.290	0.489	0.618	0.616
Country FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Notes: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 12 offers evidence of the inter-supply chain upgrading effect on profit through production complexity and capital intensity. The regression coefficients for $TFP *$

$forwardindex^2$ and $TFP * backwardindex^2$ in columns (1) and (2) are all significantly positive, meaning there is strengthening effect to lift up the U-shaped curve through an increase in TFP. In column (3), $CI * forwardindex^2$ shows significant positive coefficient. It also demonstrates that capital intensity can be part of the reasons to raise the profitability-driven “smile curve”. Propositions 2 and 3 are therefore proved.

5. Conclusions

This paper constructed a simple theoretical framework to illustrate the relevance of the smile curve hypothesis, which has been relatively unexplored in previous studies. A hierarchy assignment model that was developed shows that given a constant source of gains in labor costs across stages in the chain, the dynamics of the average profitability in each firm in each stage in the supply chain was determined by the average product of labor (necessary conditions) and the relative ratio of output elasticity of capital to output elasticity of labor (sufficient conditions) at each production stage in the chains. To further explore the industrial upgrading mechanism of firms producing along the chains, a new concept called the ‘*inter-supply chain upgrading mechanism*’ was tested to prove that increases in both production complexity and factor intensity led to higher average profitability for all firms in the chain, thus making industrial upgrading along the supply chains become feasible. Static and dynamic panel estimation empirical analyses were then conducted to corroborate the theories proposed in this paper. The conclusions drawn from this paper have far-reaching implications for the current debate on the division of the gains in the different countries participating in global supply chain-driven trade.

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