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PRODUCER SERVICES AND PRODUCTIVITY: A GLOBAL VALUE CHAIN PERSPECTIVE

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Services have long been blamed for their stagnant productivity and cost disease. This study demonstrates that producer services defy the cost disease. We explore, in the context of global value chains (GVCs), how the growth of producer services helps improve the productivity of final goods and services and how the effects differ for local and foreign sources of producer services. The GVC revolution, along with technological progress, expands the market and deepens division of labor across the world, which, in turn, magnifies the available varieties of producer services as intermediate inputs. The proliferation of producer services, along with their productivity enhancement induced by the GVC competition, helps boost the overall productivity and reduces the cost of supplying producer services. We develop a simple model to justify this mechanism and employ the World Input-Output Database to quantify producer services and the GVC division of labor. The empirical results are consistent with theoretical predictions.

JEL Codes: F15, F20, O19, O53

Keywords: final goods and services, global value chain, producer services, productivity

1. INTRODUCTION

Modern industrial production started with the invention of machines. With the development of ever more powerful and smarter machines, manufacturing productivity increased significantly, and complete automation of production has become a cause of worry for economists today (Acemoglu and Restrepo, 2018). By contrast, services have long been blamed for their "cost disease,"[1] presumably due

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[1]The cost disease, also known as Baumol's disease, is the hypothesis that productivity improvements are less likely in service industries than in goods-producing industries of the economy because of the inherent nature of services (Baumol, 1967). See also Hartwig (2011), Atanda *et al*. (2018), Nishi (2019), Atanda and Reed (2020), and the subsequent discussions.

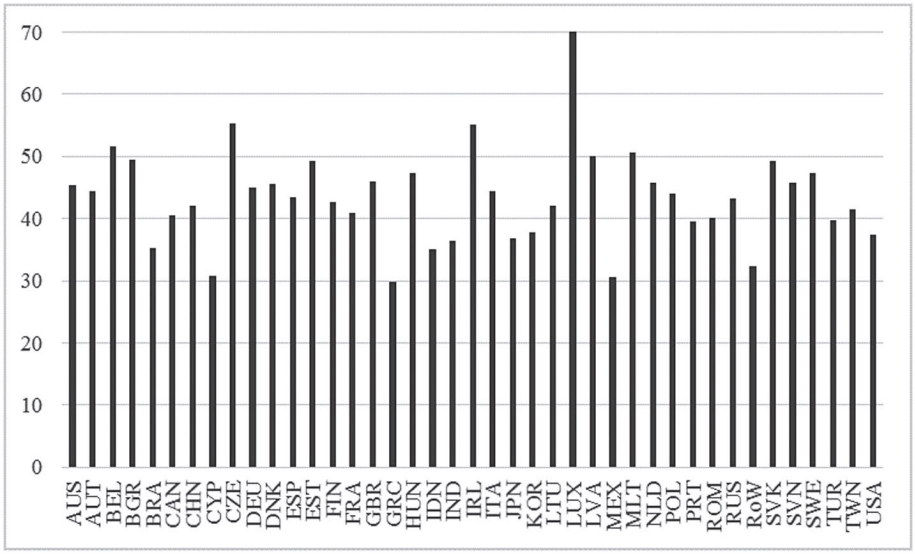


Figure 1. Share of Service Output Used as Intermediates (%) in the Sample Economies in 2009
Source: Authors' calculation based on the WIOD database.

to their stagnant productivity. This perception regarding the productivity of services is understandable because several final services entail manual intervention with negligible application of machines. This might lead to sluggish technological progress, especially as the cost of cultivating an equally able human being has not declined substantially, a stark contrast with the manufacturing sector, where the costs of making equally functional machines have been declining continuously. However, services, when used as intermediate inputs of production, dubbed as "producer services," might enjoy a productivity boost and improve the overall efficiency. Therefore, they can circumvent the cost disease by engaging in and integrating into the modern machine-based global production systems.

Research on the service industry can be traced at least as far back as Adam Smith. The service industry has undergone a profound transformation, especially after the information and communication technology revolution, which has major ramifications. Services are becoming increasingly important, with striking sectoral heterogeneity, in the modern economy (Buera and Kaboski, 2012). Francois and Hoekman (2010) point out that it is meaningful to categorize services into consumer services and producer services. Consumer services are used for final consumption, while producer services enter the production process of manufacturing or other services as intermediate inputs. Overall, services for intermediate use (i.e., producer services) account for more than 30 percent of the total service industry output across the world (see Figure 1).[2] However, one has to be careful when drawing inferences from the numbers because many service sectors listed in the national account statistics perform dual functions—of both producer and consumer services—even though they may emphasize the provision of services to one group

[2]The data source and processing in Figures 1 and 2 are presented in Section 3.

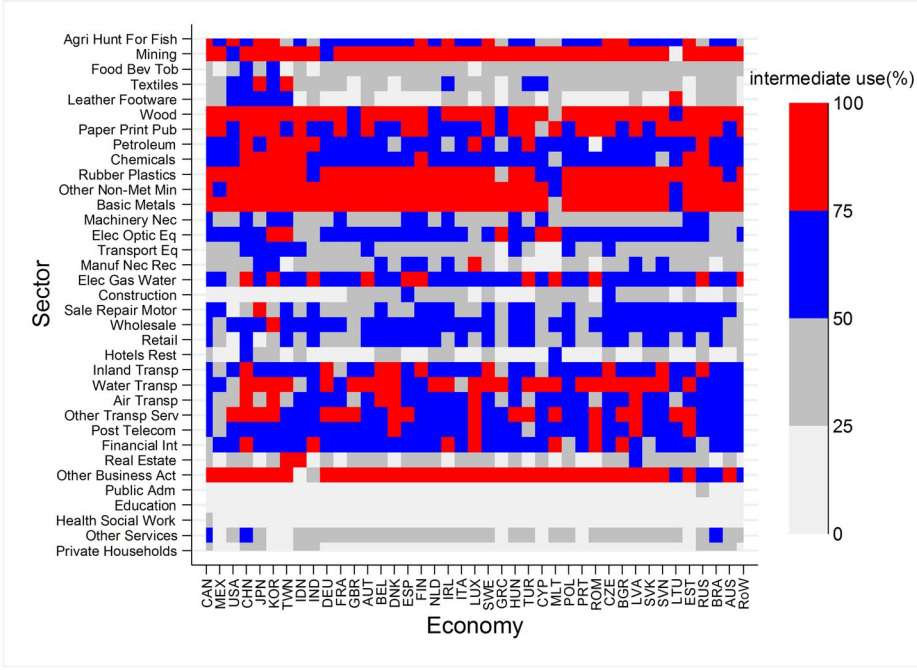


Figure 2. Share of Each Sector's Output Used as Intermediates (%) in the Sample Economies in 2009
Source: Authors' calculation based on the WIOD database. [Colour figure can be viewed at wileyonlinelibrary.com]

or the other. In the service industry, wholesaling, transport, post and telecommunications, financial intermediation, and other business activities are more likely to be producer services as more than 50 percent of their total output is used as intermediates (see Figure 2).

According to the United Nations Conference on Trade and Development (UNCTAD, 2013), about 60 percent of global trade occurs in intermediates, including goods and services, which are embodied in the production process of products and services for final consumption at different stages. Although services contribute to only about 20 percent of the global exports of goods and services reported in the balance of payments, they account for nearly half (46 percent) of the export value-added, as most of the exports need to apply services (i.e., producer services) into the production process. In addition, more than 60% of the global foreign direct investment flows into the service sectors, of which over 60 percent is directed to those mainly performing the function of producer services (UNCTAD, 2004).

In this study, we explore how the growth of producer services improves the productivity of final goods and services in the context of global value chains (GVCs). We propose a mechanism through which the growth of producer services is channeled to final goods and services. Specifically, the GVC revolution, along with technological progress, has expanded the market and catalyzed the deepening of the division of labor across the world. This, in turn, has magnified the available varieties of producer services as intermediate inputs. The proliferation of producer services, along with their productivity increase induced by GVC competition,

has boosted the overall productivity and reduced the cost of supplying producer services.

We develop a simple model to characterize such mechanisms and use the 1996–2009 transnational input-output (IO) data set of the World Input-Output Database (WIOD) to identify producer services and quantify the GVC division of labor. The results show that the expansion in output tends to deepen the value chain division of labor and increase the employment share of producer services. Meanwhile, with the rising employment in producer service activities, the productivity of final products or sectors tends to increase, albeit differing with the sources of labor embodied in the producer service activities in the context of the GVCs.

This study is related to the literature on the economic effects of services growth. William Baumol's argument of the "cost disease of services" is the first to capture such effect (e.g., Baumol, 1967; Baumol *et al*., 1985). The argument maintains that productivity growth is inherently more difficult to achieve in the services than in the goods-producing sectors. Further, if demand for services is price inelastic and income elastic, then services garner an increasing share of nominal output, leading to a decline in aggregate productivity growth, which equals the nominal output share weighted average of sectoral productivity growths. Triplett and Bosworth (2003) believed that Baumol's disease had been cured, as they found a broad acceleration of labor productivity growth in the services industries after 1995, due to a great expansion in services industry's total factor productivity (TFP), information and communication technology investment, and purchased intermediate inputs. Young (2014) argues that if workers self-select into industries based on their relative productivity in different tasks, the average efficacy of a sector's workforce will be negatively correlated with its employment share. This might explain the difference in the reported productivity growth of contracting goods and expanding services. The view that goods and services have similar productivity growth rates is a plausible alternative characterization of growth in developed economies. In this study, we highlight the roles of producer services that are highly tradable in shaping the productivity, and thereby, in curing the cost disease in the open economy.[3]

This study also joins the research efforts that use the IO method to evaluate the effect of producer services growth and liberalization, which can be categorized into two: prospective and retrospective studies. The former studies rely on using the computable general equilibrium models to simulate the impact of producer services-related events, such as the opening-up in the field of producer services (e.g., Walmsley and Winters, 2005; Konan and Maskus, 2006; Christen *et al*., 2012). The latter studies use the historical information during the actual course of producer services opening-up, and compare what actually happened and what is likely to happen. The related studies focus on the impact of privatization and deregulation in telecommunication and relevant infrastructure (e.g., Fink *et al*., 2003), the impact of information infrastructure quality and pricing behavior on commodity trade (e.g., Francois and Woerz, 2008), the impact of producer services opening-up and liberalization on the economic performances of the producer services sectors

[3]There are two implicit notions in Baumol's argument. One is that the services are confined to consumer services (i.e., for final use), and the other is that the service output is relatively non-tradable.

themselves and other sectors (e.g., Cummins and Rubio-Misas, 2006; Arnold *et al*., 2008; Arnold *et al*., 2011; Fernandes and Paunov, 2012; Beverelli *et al*., 2017), and the role of services input intensity in upgrading manufacturing productivity and exports (Hoekman and Shepherd, 2017) and mitigating the negative effect of the China shock on the United States manufacturing employment (Bamieh *et al*., 2017). In particular, new evidence shows that services in GVCs not merely function as inputs but also involve more value-creating activities (Miroudot and Cadestin, 2017a) and that there are gains from specialization in services across countries (Miroudot and Cadestin, 2017b). Based on the same idea highlighted by Miroudot and Cadestin (2017a, b), our study, however, undertakes a more formal analysis and determines whether the findings and conclusions in the empirical and policy studies hold. Our additional evidence also lends support to the purely theoretical research in this field (e.g., Markusen, 1989; Francois, 1990; Jones Kierzkowski, 1990).[4]

The theoretical analysis of this paper draws inspiration from Francois's (1990) model of increasing return to scale and monopolistic competition, and Romer's (1990) endogenous growth model with expanding varieties of products. On the one hand, we assume the productivity of labor undertaking producer service activities in the production process of every variety (corresponding to every firm) to be heterogeneous. On the other hand, we extend one country's domestic specialized division of labor to the international context (i.e., GVCs) and identify different sources of labor content embodied in producer services. Similar to Young (2014), we focus on supply relations only, leaving the general equilibrium closure of the model with preferences and demand unspecified.

Instead of resorting to the conventional sector-level employment statistics in the system of national accounts, we adopt the GVC and value-added measurement method (e.g., Leontief, 1936; Miller and Blair, 2009; Koopman *et al*., 2014; Wang *et al*., 2014) to quantify the factor input content in the relevant production activities (including producer service activities) to obtain the actual employment that carries out related production activities (including producer service activities). By doing so, we are more consistent with the broad context of the GVC division of labor. Furthermore, we break down the sources of labor content in producer services into domestic and foreign, to investigate the differences in the impacts of output expansion on the various sources of producer services employment growth. We also examine the variations in the impacts of different sources of producer services growth on the productivity of final goods and services. This part of our work adds to such empirical analyses with presumably important policy implications, especially regarding producer services sector liberalization (e.g., Hoekman and Shepherd, 2017; Miroudot and Cadestin, 2017b).

[4]In the context of GVC division of labor and specialization, producer services like logistics, finance, information, distribution, and professional services are crucial in coordinating and connecting highly disaggregated production activities and borderless complicated production networks. Economic efficiency relies on the interconnections among different production activities, not merely on the productivity level of each production activity. These services not only play a "glue-like" role in the GVC but are in themselves integral parts of global trade in value-added. Refer also to Miroudot and Cadestin (2017a) for such insightful analyses.

The rest of the paper is arranged as follows. Section 2 presents a simple model illustrating the growth mechanism and productivity effect of producer services in the GVC context and derives three testable hypotheses. Section 3 sets up econometric models and presents the processing of relevant data and indices. Section 4 reports detailed empirical analysis results, and Section 5 concludes and draws out some implications.

2. Theoretical Model and Hypotheses

This section first offers an illustrative model of specialization and division of labor along the lines outlined in the studies by Edwards and Starr (1987), Francois (1990), and Jones and Kierzkowski (1990). The aim is to portray the growth of producer services, their role in joint production, and especially their impact on productivity in the GVC context. Following Young (2014), we focus on the supply relations only, leaving the general equilibrium closure of the model with preferences and demand unspecified. The model implications are then summarized with three hypotheses to guide the empirical analysis.

2.1. *Basic Setup*

Consider a one-sector economy where all firms produce a differentiated final good Y by employing labor L. There are N possible varieties of the final good indexed by $j = 1, \ldots, N$. For producing any variety j, there are n possible technologies available, indexed by $v = 1, \ldots, n$. In this setup, v is the index of the degree of value chain specialization of labor and can be thought of as the total number of (domestic and international) stages/segments of the production process. We assume that n is very large.

The activities of a firm producing a final good variety Y_j consist of direct production activities (D_{ij}) and producer services (i.e., indirect production activities [S_j]).[5] All the activities require labor inputs. Like Francois (1990), we define the first tier of the nested production function of Y_j as:

$$Y_j = \min \{ Y_j(D), Y_j(S) \} \tag{1}$$

where $Y_j(.)$ is the contribution of different production activities (D and S) to the final output. The Leontief-type relationship between Y_j and $Y_j(.)$ means that all activities are necessary for producing final output.[6]

We also follow Edwards and Starr (1987) and Francois (1990) to assume that the direct production activities exhibit increasing returns to scale due to the specialized division of labor.

The production cost of each differentiated product will be the lowest for the case where there is only one firm for one variety. Therefore, each variety will not allow more than one firm in the market. All firms are free to enter and exit, and set

[5]The Online Appendix Figure A1 shows how these activities are organized.

[6]Like Antràs (2003), we assume that, given a level of specialization and division of labor, the activities (inputs) must be of high quality, and therefore, production of the final good requires no further costs.

prices at average costs. Specifically, the production function for the direct production activities (D) in equation (1) is:

$$Y_j(D) = v^{\delta} \prod_{i=1}^{n} L_{D_{ij}}^{\frac{1}{v}} \tag{2}$$

where $L_{D_{ij}}$ denotes direct labor used in the direct production activity i for producing differentiated product j. δ (>1) is an index for the benefit from specialization and division of labor. The literature (e.g., Spence, 1976; Dixit and Stiglitz, 1977; Borland and Yang, 1992; Yang and Ng, 1993; Rodríguez-Clare, 1996) on specialization and division of labor ever since Adam Smith maintains that deepening specialization and division of labor leads to gains in economic efficiency and productivity; however, it also levitates the transaction costs that arise from overcoming the holdup problem. When the productivity gains outweigh the transaction costs, the evolution of specialization and division of labor will proceed smoothly; otherwise, it would come to a stop. To describe such a mechanism, we define

$$P = \left(\frac{v}{\tau}\right)^{\alpha} \tag{3}$$

where P denotes economic efficiency and productivity, τ is transaction costs, and $\alpha \geq 0$ is a parameter.

Under the assumption of symmetries, as illustrated in equation (1), direct labor is equally allocated across all production activities for a given level of specialization. Thus, the demand of firm (corresponding to a specific product variety) j for direct labor is:

$$L_{D_j} = \sum_{i=1}^{n} L_{D_{ij}} = v^{1-\delta} Y_j \tag{4}$$

This is because $Y_j = v^{\delta}(L_{D_{1j}}^{1/v} L_{D_{2j}}^{1/v} L_{D_{3j}}^{1/v} \ldots L_{D_{nj}}^{1/v}) = v^{\delta} L_{D_{ij}}$.

The demand for labor undertaking indirect production activities or producer service activities (S) in equation (1) is:

$$L_{S_j} = \kappa v^{\beta} + q_j^{\gamma} Y_j \tag{5}$$

where L_{S_j} represents indirect labor employed by firm j in its producer service activities, q_j denotes productivity of labor undertaking producer service activities,[7] and γ is an elasticity parameter that is expected to be negative. κ is a parameter for overhead costs related to the specialized division of labor (e.g., firms employ management personnel, engineers, and other technical personnel to manage and coordinate every specialized direct production activity). Because firms use services to coordinate and control the production process, service input cost is an increasing

[7]Slightly different from Francois (1990), here we do not assume the labor productivities of producer service activities are homogeneous.

function of both the complexity degree (measured by v) of the production process and the output scale (Y_j). $\beta \geq 0$ is a nonnegative parameter. Note that the producer services can be supplied in-house and/or bought from the market.[8] No matter how the producer services are acquired, firms always need to incur costs (or to employ labor).

Assuming that the wage rate is w for direct labor and ϕw for indirect labor, the total cost function (i.e., the sum of direct and indirect labor cost) related to the production function in equation (1) is:

$$C(Y_j, q_j) = \left(v^{1-\delta} Y_j + \kappa v^{\beta} + \phi q_j^{\gamma} Y_j \right) w \tag{6}$$

Given the output scale and the labor productivity of producer service activity, firm j chooses v, the specialization degree index, to minimize its total cost. Solving the first-order condition of the optimization problem with cost function (6), we have:

$$v = \left(\frac{\delta - 1}{\beta \kappa} Y_j \right)^{1/(\delta+\beta-1)} \tag{7}$$

This shows that specialization degree v is an increasing function of output scale Y_j. Plugging equation (7) into equation (6), we can obtain the minimizing cost function C^*:

$$C^*(Y_j, q_j) = \left[\left(\frac{\delta - 1}{\beta \kappa} \right)^{\beta/(\delta+\beta-1)} \frac{\kappa(\delta+\beta-1)}{\delta-1} Y_j^{\beta/(\delta+\beta-1)} + \phi q_j^{\gamma} Y_j \right] w = f(Y_j, q_j) w \tag{8}$$

where $f(Y_j, q_j) = \left[\left(\frac{\delta-1}{\beta\kappa} \right)^{\beta/(\delta+\beta-1)} \frac{\kappa(\delta+\beta-1)}{\delta-1} Y_j^{\beta/(\delta+\beta-1)} + \phi q_j^{\gamma} Y_j \right]$. The function $f(Y_j, q_j)$ can be used to measure labor amount employed by firm j. Plugging equation (7) back into equation (4) and solving for the firm's demand for direct labor as a function of Y_j results in:

[8]This differentiation is not crucial for the results of the model but very important for service accounting and industrial development in the real economy. The producer services provided in-house reflect the specialized division of labor across production activities or stages within a producer's or a firm's boundaries. If firms buy producer services from the market, this reflects the specialization and division of labor among different firms (including producer services provider and user) in the market (outside the firm). The evolution from the within-firm specialized division of labor to within-market is itself an evolution of specialized division of labor. However, such analysis needs to specify a multi-sector model to fully depict this evolution process and its impact. If the analysis focuses on the production of a specific product (rather than a firm) from the perspective of GVCs, such differentiation is unnecessary. That is, a specific product's production process involves different production activities or stages that can be completed by a single firm within a single country (i.e., a within-firm specialized division of labor) or cooperatively by different firms in different countries (i.e., an outside-firm specialized division of labor, both locally and globally). Generally, the more are the production activities or stages involved in a production process, the higher are the levels of specialized division of labor, and the more is the likelihood for the outside-firm specialized division of labor. In this sense, relevant theoretical and empirical studies can be conducted from both sector/product-level (which is the focus of this study) and firm-level perspectives.

$$L_{D_j} = \left(\frac{\delta-1}{\beta\kappa}\right)^{(1-\delta)/(\delta+\beta-1)} Y_j^{\beta/(\delta+\beta-1)} \tag{9}$$

It is evident that with the expansion in production, the demand for direct labor tends to increase but its growth rate reduces (since $\delta > 1$). Substituting equation (7) into equation (5), we can solve for the demand for indirect labor:

$$L_{S_j} = \left[\kappa\left(\frac{\delta-1}{\beta\kappa}\right)^{\beta/(\delta+\beta-1)} + q_j^{\gamma} Y_j^{(\delta-1)/(\delta+\beta-1)}\right] Y_j^{\beta/(\delta+\beta-1)} \tag{10}$$

The ratio (s_j) of indirect labor input (i.e., producer services employment) to direct labor input is:

$$s_j = \frac{L_{S_j}}{L_{D_j}} = \frac{\delta-1}{\beta} + \left(\frac{\delta-1}{\beta\kappa}\right)^{(\delta-1)/(\delta+\beta-1)} q_j^{\gamma} Y_j^{(\delta-1)/(\delta+\beta-1)} = g(Y_j, q_j) \tag{11}$$

The relative proportion of producer service employment is the function of production scale and labor productivity of producer service activity. In the following empirical analysis, we consider the relative share not only of labor factor of global source contained in producer service activity (which is relative to the labor factor input in the direct production activity) but also of domestic and foreign sources of labor contained in producer service activity, respectively. [9]

Finally, from equations (3), (7), and (11), we get the following equation describing the relationship between the economic efficiency or productivity (P) and the share of producer services (s), the labor productivity of producer services (q_j), and the transaction costs (τ):

$$P_j = \tau^{-\alpha}\left(\frac{\delta-1}{\beta\kappa}\right)^{[\alpha^2-(\delta-1)^2]/[\alpha(\delta+\beta-1)]} q_j^{\gamma(\delta-1)/\alpha}\left(s_j - \frac{\delta-1}{\beta}\right)^{\delta-1/\alpha} \tag{12}$$

Figure 3 illustrates the above conditions. In the first quadrant of Figure 3, the vertical axis shows the output (Y), while the horizontal axis denotes the specialization index (v) and the share of labor undertaking producer service activities (s). In the second quadrant, the horizontal axis represents the economic efficiency or productivity of the final product or sector (P). Equation (8) presents another side of the relationship between employment and output: $f(Y_j, q_j)$ is for labor input that is a function of output, whose inverse function is $Y(L)$, which is for the output level and viewed as the function of labor input. $Y(L)$ is depicted by a straight line perpendicular to the vertical axis in Figure 3. Equation (7), which determines the specialization degree, is demonstrated by a positive slope curve starting from the

[9]The study by Francois (1990) does not focus on externalization and rules out joint production, while we incorporate these features into the GVC division of labor. Besides, we push it further to derive the impact of producer services growth on the productivity of final goods in equation (12).

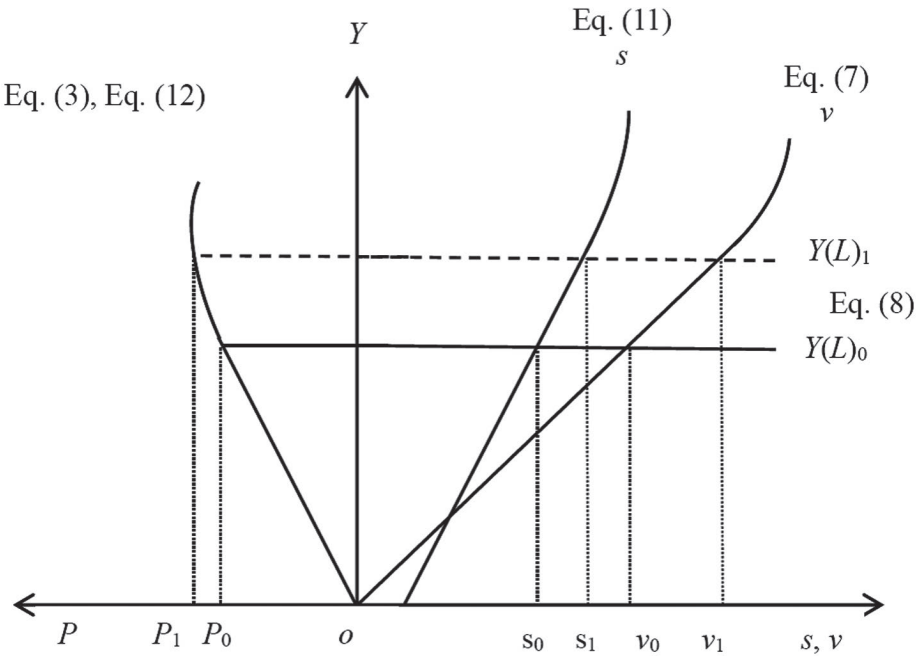


Figure 3. Growth Mechanism and Productivity Effect of the Producer Services

origin in the first quadrant, as $\delta > 1$, $\kappa > 0$ and there is no intercept. The curve for equation (11) also has a positive slope but does not pass through the origin (the horizontal intercept is positive). The intersection of the curve Y and curve s determines the relative proportions of producer service labor and direct labor, and the intersection of curves Y and v determines the level of specialization. The curve for equation (3) starts from the origin, which reveals that with the division of labor (v) deepening and the producer services (s) increasing, the economic efficiency or productivity of final products or sectors (P) tends to rise.

2.2. *Participation in the GVCs*

The GVC revolution has drastically changed the landscape of the world economy since the 1990s. By participating in GVCs, an economy's division of labor will likely deepen, typically leading to reduced costs and enhanced productivity.[10] The intensification of the division of labor will, in turn, lead to market expansion (Smith, 1776; Krugman 1979, and 1980). With the expansion of market L, the output grows from $Y(L)_0$ to $Y(L)_1$ in the first quadrant of Figure 3, and the level of specialization and the labor share for producer service activity tend to rise accordingly. The escalation in specialization degree means that production activity has decomposed into more production stages or segments. To coordinate these stages

[10]Recent research develops a multi-country, multi-sector model to explore tariff determination and distortions under GVCs (Blanchard *et al*., 2016; Caliendo *et al*., 2017). Our model, however, highlights how the GVCs reshape mechanisms of producer services growth and its productivity effect.

or segments, one needs to employ more labor to assume producer service activities.

Participation in the GVC division of labor will catalyze the specialization of labor in the economy concerned and will also compel it to open up its producer service market. With increasing producer service inputs from within and abroad, the productivity of final product or sector tends to rise (from P_0 to P_1).[11]

To sum up, the preceding theoretical analysis reveals that a system of equations formed by equations (7), (8) (11), and (12) determine an individual firm's (variety) output scale (Y), division of labor (v), the share of labor undertaking producer service activity (s), the labor productivity of producer services (q_j), and the productivity (P) of final products or sectors.

Thus, we propose three basic hypotheses to be tested with empirical data:

Hypothesis 1: *The value chain division of labor deepens as the total output scale expands.*

Hypothesis 2: *The employment share of producer services rises with the total output scale and falls with the labor productivity of producer services.*

Hypothesis 3: *The productivity of the final product or sector increases with the rise in labor input share of producer service activities.*

3. Econometric Model and Data

3.1. *The Regression Model*

We use a panel data regression model with multilevel fixed effects to test the empirical relevance of our theoretical implications.

First, we take logarithm of the two sides of equation (7) and make a linear transformation to test Hypothesis 1:

$$\ln v_{ijt} = \alpha_1 \ln Y_{ijt} + \mu_i^v + \eta_j^v + \lambda_t^v + \varepsilon_{ijt}^v \tag{13}$$

where the key parameter of interest $\alpha_1 = \frac{1}{\delta+\beta-1}$, i, j, and t are indices for country, sector, and year, respectively, μ_i^v, η_j^v, and λ_t^v denote the country-, sector-, and year-fixed effects, respectively, and ε_{ijt}^v represents the random error item. To allow for possible nonlinear relationship, we also include the squared $\ln Y_{ijt}$ as an additional explanatory variable.

Second, we consider the testing of Hypothesis 2. Equation (11), the theoretical statement behind Hypothesis 2, cannot be simply linearized by taking logarithm of both sides, as the right-hand side is additive instead of multiplicative.

[11]The productivity change described in the model is consistent with the stylized relationship between output growth and productivity demonstrated by Verdoorn's Law (Verdoorn, 1949), while the difference is that our model also relates producer service growth to productivity changes. The subsequent empirical analysis will check the impact of producer service growth on productivity.

Thus, we consider the following form of econometric model as an approximation of equation (11):

$$\ln s_{ijt} = \beta_1 \ln Y_{ijt} + \beta_2 \ln q_{ijt} + \mu_i^s + \eta_j^s + \lambda_t^s + \varepsilon_{ijt}^s \tag{14}$$

where μ_i^s, η_j^s, and λ_t^s denote the country-, sector-, and year-fixed effects, respectively, and ε_{ijt}^s represents the random error item. We also include the squared $\ln Y_{ijt}$ as an additional explanatory variable to allow for possible nonlinear relationship.

Third, to test Hypothesis 3, we rely on equation (12), and regress the following equation:

$$\ln P_{ijt} = \gamma_1 \ln s_{ijt} + \gamma_2 \ln q_{ijt} + \mu_i^p + \eta_j^p + \lambda_t^p + \varepsilon_{ijt}^p \tag{15}$$

where P_{ijt} is the productivity of variety j (final good and service) at year t for country i, and μ_i^p, η_j^p, λ_t^p, and ε_{ijt}^p are defined similarly as above.

3.2. *Data*

The core variables for regression models (13), (14), and (15) include: (1) total sectoral output (Y); (2) index of value chain division of labor (v); (3) labor conducting producer service activities (L_S); (4) productivity of producer services labor (q); (5) labor assuming direct production activities (L_D); and (6) sectoral productivity of final product and service (P).[12] We create these variables using the constant-price (i.e., at previous year price) WIOD data set, which covers 40 economies and the rest of the world as a whole, 35 sectors, and 14 years (1996–2009) of transnational IO information (Dietzenbacher *et al*., 2013; see Online Appendix Table A1).

In the following subsection, we discuss in detail the measurements and construction of the index of value chain division of labor, the labor share of producer service activity, and the productivity of final product and service. The statistical description of all core variables is presented in Table A2 of the Online Appendix.

Measuring the Division of Labor Under GVC (v)

We construct the index of value chain division of labor (v) by using the measures of downstreamness or upstreamness proposed by Fally (2011), Antràs *et al*. (2012), Antràs and Chor (2013), and Miller and Temurshoev (2017). Miller and Temurshoev (2017) refer to the upstreamness indicator of Antràs *et al*. (2012) as "output upstreamness" (OU) measure of sectors, and propose an "input downstreamness" (ID) index that is equivalent to Fally's (2011) definition. For OU, "output" is added to signify the intermediate output supply links with other sectors, while for ID, "input" is added to signify the intermediate input demand links with other sectors. Both indices can be used to gauge the integration of an economy or a sector into the GVCs, which is consistent with the GVC division of labor measure in this study.

[12]We use labor productivity in our benchmark regressions and use TFP as a robustness test.

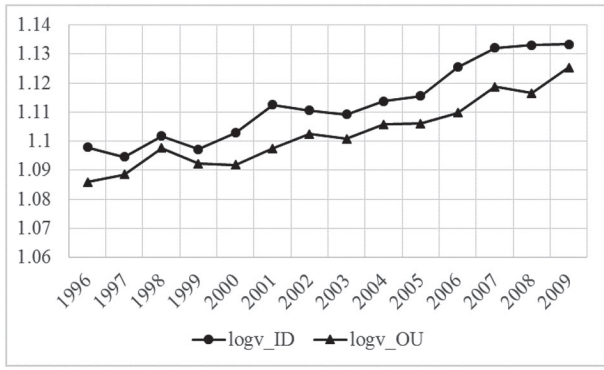


Figure 4. Evolution of the GVC Division of Labor (in terms of Annual Average of $logv_{ID}$ and $logv_{OU}$): 1996–2009

First, we rely on the transnational IO table to establish the basic equations regarding total output and total input. Then, we obtain a downstreamness-based measure of v (v_{ID}) and upstreamness-based measure of v (v_{OU}), respectively.[13] Figure 4 reveals that v_{ID} and v_{OU} (mean values in logarithm) increase steadily from 1.098 and 1.086 in 1996 to 1.134 and 1.125 in 2009, respectively. This indicates that, on average, the worldwide division of labor deepened in the sample period.[14]

Measuring the Employment of Production Activities

Instead of following the traditional statistical approach of measuring employment, we will follow the IO method to extract the factor content of different production activities.

First, we calculate the direct factor input per unit of output, which is the ratio of the direct factor input and total output. The WIOD data have information on two basic factors: capital and labor, where labor is measured in terms of the employment number (in thousand persons) and working hours (in million hours) and consists of three types, the high-skill, medium-skill, and low-skill (all in terms of working hours).[15]

Second, we calculate the total (direct and indirect) factor content per unit of output for different factors. This is achieved by multiplying a matrix of direct factor input per unit of output, obtained from the first step, by the global Leontief inverse matrix (**L**).

[13]Refer to Part A in the Online Appendix for the detailed computation procedure. In our sample, several observations (1.29%) present values of total output equal to zero, which could mean either a missing value or that nothing is produced in that sector and economy. In such cases, the computation of the model would become difficult. To avoid this, we input a value of 0.0000001 dollar in these cases. This has a very negligible effect as it corresponds to a trivial share (i.e., about one in five trillion) of the average total output across sectors and economies. This data processing approach was also adopted by Caliendo and Parro (2015).

[14]Figure A2 in the Online Appendix shows that the two indices (in logarithm) have a strong positive correlation.

[15]The skill types are defined according to the International Standard Classification of Education (ISCED) of the United Nations Educational, Scientific and Cultural Organization (UNESCO).

Third, we differentiate the types and sources of intermediate products used by every economy in the data sample. Intermediate products include goods and services, among which services are included as producer services in question, and all other intermediates are viewed as direct production activities.[16] Besides, the sources of intermediates include domestic and foreign sources. Such differentiation conforms to the inherent meaning of the GVC division of labor.

Finally, we calculate the total (direct and indirect) factor content of intermediate production activity (output) of different types and sources for different factors. We also calculate the proportion of factor content of producer service activity relative to direct production activity.

Figure 5 displays the average trend in the relative importance of the labor content of producer service activity with respect to direct production activity (s_j). It is clear that in the sample period, the average shares of labor content of producer service activity are on the rise for all different measures or kinds of labor, while the increases in the foreign-sourced labor content share are much more pronounced compared with the domestic-sourced.

Measuring Productivity

Following the previous model specification, we use the labor productivity (without consideration of capital input) as the benchmark measure of productivity for the final product or sector. We then use the TFP measure as a robustness check of results. To make the measurement of TFP internationally comparable in the context of the GVC division of labor, we follow Lai and Zhu (2007) to establish a multilateral value-added TFP index. The basic procedure is as follows.

Let V_{ijt}, K_{ijt}, L_{ijt}, and α_{ijt} be the real value-added, capital input, labor input, and the labor cost share of sector j in country i in year t, respectively. We define $\overline{\ln V_{jt}} \equiv \sum_i \ln V_{ijt}/C$, $\overline{\ln L_{jt}} \equiv \sum_i \ln L_{ijt}/C$, $\overline{\ln K_{jt}} \equiv \sum_i \ln K_{ijt}/C$, and $\overline{\alpha_{ijt}} \equiv (\alpha_{ijt} + \sum_i \alpha_{ijt}/C)/2$ (C is for the number of sample economies). Then, the TFP index of sector j in country i in year t is:

$$\ln TFP_{ijt} = (\ln V_{ijt} - \overline{\ln V_{jt}}) - \overline{\alpha_{ijt}}(\ln L_{ijt} - \overline{\ln L_{jt}}) - (1 - \overline{\alpha_{ijt}})(\ln K_{ijt} - \overline{\ln K_{jt}}), \quad \forall i, j, t \tag{16}$$

Figure 6 depicts the general trend of changes in labor productivity and TFP of the final goods/sectors. It is clear that no matter which measure is used or what type of labor is involved, on average, both indices of productivity are increasing in the sample period despite some fluctuations, especially, before 2003.

4. Results

4.1. *Main Results*

First, using equation (13), we test Hypothesis 1 to identify the impact of output scale on the division of labor from a global perspective. The modified Wald test

[16]The number of sample sectors is 35, and those with codes 1–17 are goods-producing sectors, and the other 18 sectors are services (see the classification in Online Appendix Table A1).

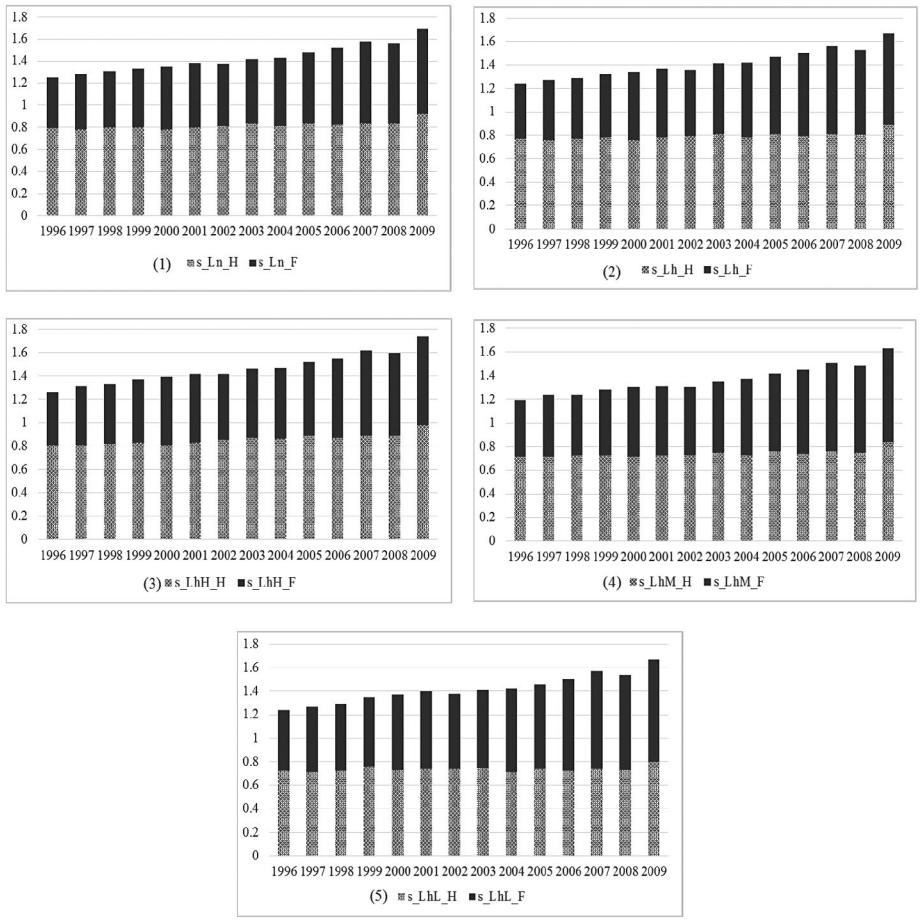
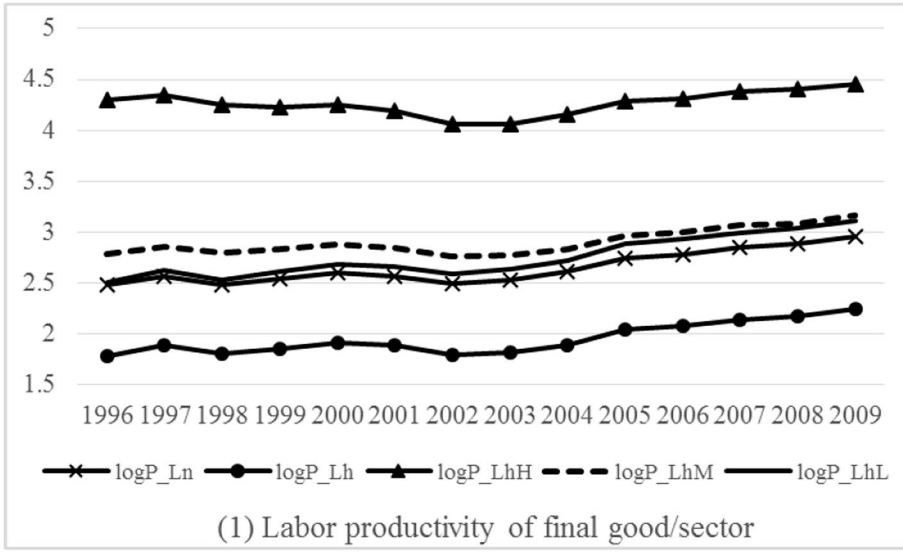


Figure 5. Changes in the Proportions of Labor Content of the Producer Service Activity Relative to the Direct Production Activity (Annual Average): 1996–2009

Note: For each subgraph, the black bars on the top represent parts of foreign source, while the gray bars below represent parts of domestic source. The sum of them equals the proportion of total labor content of the producer service activity with respect to the direct production activity. The units of labor in subgraphs (1) and (2) are in terms of the employment number (in thousand persons) and working hours (in million hours). Subgraphs (3), (4), and (5) are for the high-skill, medium-skill, and low-skill labor (all in terms of working hours), respectively.

indicates the existence of group-wise heteroscedasticity. Thus, we prefer the fixed effect regressions. Meanwhile, to account for the situation that the GVC division of labor tends to increase but exhibits a decreasing trend with the expansion in output scale, we add a square term of the output scale, whose coefficient is expected to be negative. That is, the relationship between the output scale and the level of GVC division of labor is probably hump-shaped. The regression results are presented in Table 1.

The coefficients on the output scale (log y) are significantly positive for both (linear and quadratic) model specifications, that is, 0.019 and 0.013 without a



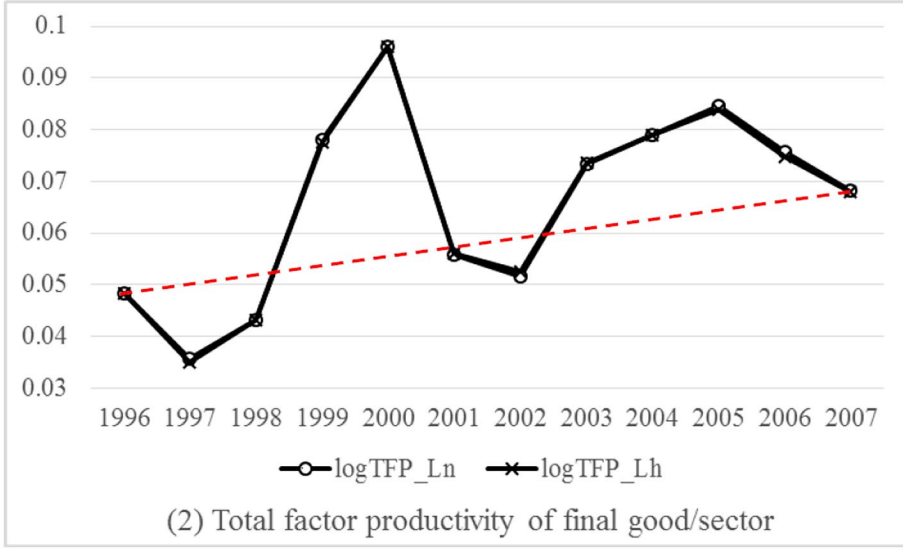


Figure 6. Changes in Productivity of the Final Good or Sector (in Logarithm, Annual Average)
Note: In subgraph (1), logP_Ln and logP_Lh are for aggregate labor productivity (in logarithm) measured in terms of the employment number and working hours, respectively, while logP_LhH, logP_LhM, and logP_LhL represent labor productivities (in logarithm) of the high-skill, medium-skill, and low-skill labor, respectively. In subgraph (2), logTFP_Ln and logTFP_Lh are for TFP (in logarithm) measured in terms of the employment number and working hours, respectively. The sample period in subgraph (2) shrinks due to missing observations in 2008 and 2009. [Colour figure can be viewed at wileyonlinelibrary.com]

square term, and 0.017 and 0.010 with a square term, respectively. As both the dependent and independent variables are in logarithms, these coefficients are the elasticities of the GVC division of labor to the output scale. The negative

TABLE 1
GVC Division of Labor and Output Scale: Test of Hypothesis 1

	Dependent var.: $\log v_{ID}$		Dependent var.: $\log v_{OU}$	
	(1)	(2)	(3)	(4)
$\log y$	0.019***	0.017***	0.013***	0.010***
	(0.001)	(0.001)	(0.003)	(0.002)
$\log y^2$		−0.0002**		−0.0003**
		(0.000)		(0.000)
R^2	0.216	0.217	0.058	0.060
N	20090	20090	20090	20090

Notes: All regressions with country-, sector-, and year-fixed effects, and standard errors in brackets are adjusted for clustering across country-sector pairs.
**Indicates significance at 5%;
***Indicates significance at 1%.

coefficients on the square term of output scale are consistent with theoretical expectation.[17] This implies that if the output scale expands by 10%, the level of GVC division of labor tends to increase by 0.1% − 0.2%, after controlling for the three-way (economy, sector, and year) fixed effects. Therefore, the regression results support Hypothesis 1; that is, the GVC division of labor tends to deepen with the expansion in output scale. Moreover, as $\alpha_1 = \frac{1}{\delta+\beta-1}$, when α_1 falls in the range of [0.01, 0.02], $\delta + \beta$ will fall within [51, 101]. Therefore, if β is not too large,[18] the benefit from specialization and division of labor, δ, will be far greater than 1.

Next, we test Hypothesis 2 to examine the impacts of the output scale and productivity of producer services on the labor share of producer services, in the context of the GVC division of labor. The labor content in producer services of a country or region comes either from within that country or region or from abroad. This distinction is very important because, on the one hand, the lower tradability of services would make output scale expansion contribute more to the growth of local producer service employment, and on the other hand, services can be embodied inside the tradable goods, thus becoming indirectly tradable.[19] This makes lower cross-border tradability of services unimportant, and consequently, the foreign-originated producer services would probably increase due to the expansion in domestic (sector's) output. The results are presented in Table 2.

Model specifications (1) and (2) in Table 2 consider the global source of labor factor contained in producer service activities. The total labor share contained in producer services is always positively correlated with the output scale. It is

[17]Based on the estimated coefficients in Table 1, we can determine the turning point of the relationship. Taking the derivative of the right-hand side of equation (13) and setting it equal to zero, we can obtain the value of the independent variable at the turning point. However, in this study, there are no cases where the samples reach the turning point. For example, according to the model specification (4) in Table 1, we can get $\log y = 16.67$ (=|0.011/(−0.0003×2)|) at the turning point but our sample's maximum value of $\log y$ is only 14.9137 (see Appendix Table A2). Therefore, the regression with a square term is used as a reference for the analysis.
[18]In Francois' (1990) specification, $\beta = 1$.
[19]This is similar to the concept of "embodied services" defined in Grubel and Walker (1989).

TABLE 2
Employment of Producer Services and Output Scale: Test of Hypothesis 2

	Sources of Labor Embodied in Producer Services					
	Global		Local		Foreign	
	(1)	(2)	(3)	(4)	(5)	(6)
log$y$	0.037	0.170***	0.080	0.245*	0.151***	0.160***
	(0.030)	(0.058)	(0.069)	(0.145)	(0.026)	(0.061)
logy^2		−0.009***		−0.011		−0.001
		(0.002)		(0.007)		(0.003)
log$q$	−0.077***	−0.082***	0.122	0.122*	−0.120***	−0.120***
	(0.021)	(0.022)	(0.074)	(0.074)	(0.014)	(0.014)
R^2	0.119	0.127	0.032	0.034	0.291	0.291
N	19528	19528	18979	18979	19105	19105

Notes: All regressions with country-, sector-, and year-fixed effects, and standard errors in brackets are adjusted for clustering across country-sector pairs.
*Indicates significance at 10%; ***Indicates significance at 1%.

insignificant for the linear specification (1) yet strongly significant for the quadratic specification (2). The quadratic specification results imply that at the average level, a 10 percent increase in the output scale will bring about 1.43 percent increase in the labor share contained in producer services.[20] The labor share of producer services is significantly negatively correlated with the labor productivity of producer services: a 10 percent increase in the labor productivity of producer services will bring about 0.82 percent decrease in the labor share of producer services. The signs of the coefficients of the two independent variables are both consistent with theoretical expectations. Furthermore, comparing the standardized coefficients of the two independent variables,[21] we can find that the magnitude of the standardized coefficient β (0.89 = 0.17*[4.229/0.808]) of the output scale is larger than that (−0.346 = −0.082*[3.409/0.808]) of the labor productivity (in the second specification), suggesting a dominating effect of the output scale over productivity.

If the sources of labor factor embodied in producer services are disaggregated into local and foreign sources (e.g., specifications [4] and [6] in Table 2), the results are broadly consistent with theoretical expectation. To be specific, if an economy's (or a sector's) output scale expands by 10 percent, the share of locally sourced labor factor contained in producer services will increase by 2.45 percent, while the share of foreign-sourced labor factor will rise by 1.6 percent. This implies that the output scale expansion of an economy (or a sector) leads to an increase in the labor share of producer services as a whole but with a relatively larger rise in the share of locally sourced labor contained in producer service activities. In the meantime, with an

[20]The average output scale is 8.65 from Table A2. Thus, at the average level, the increase in the labor share of producer services caused by a 10% increase in the output scale is 0.017−2*0.009*8.65 = 0.0143.

[21]The standardized coefficient (β) can be obtained by multiplying the ratio of independent variable's standard deviation to dependent variable's standard deviation by the original coefficient (b). Therefore, standardized coefficients are scaled to units of standard deviation change in the dependent variable for a standard deviation change in the independent variable, and are used to identify the independent variables that have a greater effect on the dependent variable in a multiple regression analysis, when the variables are measured in different units.

TABLE 3
Final Product or Sector Productivity and Producer Services: Test of Hypothesis 3

	Sources of Labor Embodied in Producer Services					
	Global		Local		Foreign	
	(1)	(2)	(3)	(4)	(5)	(6)
LP						
log*s*	−0.087**	0.012	0.013	−0.036	0.182***	0.239***
	(0.043)	(0.043)	(0.021)	(0.026)	(0.025)	(0.026)
log*q*		0.512***		0.384***		0.100***
		(0.028)		(0.078)		(0.014)
R^2	0.161	0.346	0.169	0.285	0.176	0.209
N	19714	19405	18914	18863	19714	18994
TFP						
log*s*	0.119***	0.192***	−0.015	−0.067***	0.220***	0.270***
	(0.042)	(0.041)	(0.016)	(0.019)	(0.030)	(0.031)
log*q*		0.441***		0.390***		0.067***
		(0.034)		(0.081)		(0.015)
R^2	0.416	0.471	0.419	0.472	0.426	0.435
N	17901	17817	17817	17767	17901	17437

Notes: "LP" denotes labor productivity. All regressions with country-, sector-, and year-fixed effects, and standard errors in brackets are adjusted for clustering across country-sector pairs.
**Indicates significance at 5%; ***Indicates significance at 1%.

increase in labor productivity of producer service activity, the locally sourced labor contained in producer services will also increase. That is, if the labor productivity of producer service activity rises by 10 percent, the relative share of locally sourced labor factors contained in producer service activity will increase by about 1.0 percent. However, for the foreign-sourced labor, the productivity effect is different: an increase in labor productivity of producer service activity will be accompanied by a decline in the foreign-sourced labor contained in producer services.

The testing results of Hypothesis 3 are presented in Table 3. We consider the three different sources of labor factor contained in producer services separately to examine whether the impact of producer service growth on the productivity of final products or sectors is different across different sources of embodied labor. Results of column (2) of Table 3 show that there exists a positive correlation between growth in producer service and productivity (significant when TFP is used, and insignificant when labor productivity is used). Specifically, if the labor share of producer services rises by 10 percent, the TFP of final products or sectors increases by about 1.9 percent. Putting the sources of labor input into perspective, if the producer service growth is due to the growth of locally sourced labor input, the productivity of final products or sectors tends to drop, but it is insignificant at a conventional statistical level for the labor productivity and significant for the TFP. In other words, the rise in the share of locally sourced labor factors embodied in producer service activity does not improve the TFP of final products or sectors. However, if the producer service growth is a result of the growth in foreign-sourced labor input, the productivity of final products or sectors tends to increase (it is statistically significant for both productivity measures). To be specific, if the share of foreign-sourced labor factors contained in producer services increases by 10 percent, the labor productivity and TFP of final products or sectors will rise by about

2.4 percent and 2.7 percent, respectively. For all the specifications, the growths in labor productivity of producer services significantly improve the two measures of productivity of final products or sectors, and the magnitude of the impact is larger for the locally sourced producer services than those for the foreign-sourced.

Three observations emerge from the regressions of Tables 2 and 3. First, given the context of GVC division of labor, the sources of labor factor contained in producer services affect the impact of output expansion on the labor share of producer services and the impact of the rising labor share and labor productivity of producer services on the productivity of final products or sectors. Second, the expansion in output increases the share of locally sourced labor contained in producer service activity to a large extent, but the rising share of locally sourced employment does not improve the productivity of domestic final products or sectors. On the contrary, the rising share of foreign-sourced employment contained in the producer service activity significantly promotes the productivity growth of domestic final products or sectors. Third, the efficiencies of producer services significantly improve the productivity of final products or sectors, and that impact is larger for locally sourced producer services. The policy implication behind these findings is that in the context of the GVC division of labor, further opening-up and encouraging competition in the domestic services market, especially in the producer services market, is important for improving the efficiency of domestic final products or sectors.

4.2. *Endogeneity*

This study aims at exploring three sets of relationships, those between the output scale and the GVC division of labor, the output scale and the producer services growth, and producer services growth and productivity changes. In the aforementioned analysis, we have developed theoretical hypotheses using a partial equilibrium framework. We also aim to validate the hypotheses with empirical data. We now follow the common practice in empirical studies to address the potential endogeneity issue in our baseline regressions in Tables 1–3. Such an issue is likely to be present in these relationships. For example, the relation between the output scale and the value chain division of labor could be of a two-way nature; that is, the expansion of the former leads to the strengthening of the latter and vice versa. In such cases, regression coefficients might be biased estimates of the parameters that characterize the true relationship. To deal with the potential endogeneity, we introduce lagged terms of independent variables as instrumental variables (Cameron and Trivedi, 2005), and rely on two-stage least squares (2SLS) estimation. The results are broadly consistent with those of baseline regressions.[22]

[22]To save space, the results are displayed in Online Appendix Tables A3 and A4. All results are based on the user-written Stata command *xtivreg2* (Schaffer, 2010). We also employ a generalized method of moments (GMM) dynamic panel regression (Roodman, 2009) to conduct a test, but the results of baseline regressions remain unchallenged. We understand that these analyses serve mainly as a first step toward the treatment of endogeneity, and leave more in depth analyses with additional data to future studies.

TABLE 4
Different Labor Skills: Tests of Hypothesis 2

	Global	Home	Foreign
	(1)	(2)	(3)
High-skill			
log$y$	0.135**	0.289*	0.162**
	(0.064)	(0.149)	(0.070)
logy^2	−0.008***	−0.013*	−0.004
	(0.003)	(0.007)	(0.004)
log$q$	−0.073***	−0.007	−0.119***
	(0.022)	(0.087)	(0.014)
R^2	0.13	0.015	0.263
N	19528	18979	19105
Medium-skill			
log$y$	0.191***	0.374***	0.130**
	(0.058)	(0.141)	(0.059)
logy^2	−0.010***	−0.016**	0.0004
	(0.002)	(0.007)	(0.003)
log$q$	−0.088***	0.04	−0.118***
	(0.020)	(0.085)	(0.013)
R^2	0.138	0.025	0.274
N	19528	18979	19105
Low-skill			
log$y$	0.141***	0.254	0.148**
	(0.051)	(0.161)	(0.060)
logy^2	−0.007***	−0.001	0.001
	(0.002)	(0.008)	(0.003)
log$q$	−0.095***	−0.097	−0.137***
	(0.017)	(0.095)	(0.014)
R^2	0.099	0.085	0.299
N	19528	18979	19105

Notes: All regressions with country-, sector-, and year-fixed effects, and standard errors in brackets are adjusted for clustering across country-sector pairs.

*Indicates significance at 10%; **Indicates significance at 5%; ***Indicates significance at 1%.

4.3. *Heterogeneity in Labor Skill*

The aforementioned results are mainly based on aggregate variables without considering the heterogeneity in labor skills. In Tables 4 and 5, we distinguish different skills of labor to reexamine Hypotheses 2 and 3. The regression results show that no matter which type of skill of labor is considered, output expansion always significantly prompts the labor share of producer services. A subtle difference does exist, as output expansion contributes more to the rise in foreign-sourced high-skill labor input and locally sourced medium-skill labor input. For all skills of labor, the rising labor productivity always subdues the labor share of producer services. In aggregate, the producer service employment growth of three skills significantly boosts the TFP of final products or sectors. However, if considering the different sources of factor inputs, the rise in TFP of final products or sectors is mainly caused by the growth in foreign-sourced labor input contained in producer services. As expected, the efficiency of producer services always enhances the productivity of final products or sectors. These findings are not only consistent with the previous baseline regression results but also amplify the previous understanding.

TABLE 5
Different Labor Skills: Tests of Hypothesis 3

	LP			TFP		
	Global	Local	Foreign	Global	Local	Foreign
	(1)	(2)	(3)	(4)	(5)	(6)
High-skill						
log$s$	−0.031	−0.029	0.195***	0.185***	−0.019	0.209***
	(0.049)	(0.028)	(0.029)	(0.042)	(0.021)	(0.028)
log$q$	0.452***	0.310***	0.085***	0.406***	0.292***	0.069***
	(0.026)	(0.057)	(0.013)	(0.029)	(0.057)	(0.015)
R^2	0.311	0.262	0.197	0.465	0.456	0.43
N	19405	18863	18994	17817	17767	17437
Medium-skill						
log$s$	0.007	−0.028	0.223***	0.200***	−0.036*	0.242***
	(0.042)	(0.026)	(0.027)	(0.041)	(0.019)	(0.028)
log$q$	0.459***	0.354***	0.101***	0.382***	0.326***	0.071***
	(0.025)	(0.066)	(0.014)	(0.027)	(0.064)	(0.014)
R^2	0.326	0.28	0.206	0.463	0.461	0.432
N	19405	18863	18994	17817	17767	17437
Low-skill						
log$s$	0.021	0.017	0.211***	0.204***	−0.015	0.237***
	(0.039)	(0.024)	(0.024)	(0.040)	(0.018)	(0.030)
log$q$	0.429***	0.309***	0.097***	0.342***	0.306***	0.058***
	(0.022)	(0.058)	(0.013)	(0.026)	(0.060)	(0.014)
R^2	0.319	0.261	0.206	0.457	0.459	0.433
N	19405	18863	18994	17817	17767	17437

Notes: All regressions with country-, sector-, and year-fixed effects, and standard errors in brackets are adjusted for clustering across country-sector pairs.
*Indicates significance at 10%; ***Indicates significance at 1%.

4.4. *Heterogeneity in Country Type*

Hypotheses 1–3 are general propositions on the value chain division of labor and producer services for an arbitrary country. It is of interest to know how such general relations manifest themselves across different countries. Presumably, the relationships might be affected by the country's size and/or development level, as larger/more advanced countries tend to have more varieties domestically.[23]

To examine the effects of country size, we classify sample economies into four groups based on the quartiles of the real gross domestic product (GDP) in 2009. Groups 1–4 consist of the economies with real GDP in 2009 below the first quartile, between the first quartile and the median, between the median and the third quartile, and above the third quartile, respectively. By this classification, Group 1 represents the smallest economies, and Group 4 represents the largest economies. Similarly, to examine the effects of the country development level, we divide sample economies into four groups based on the quartiles of the real GDP per capita in 2009. Groups 1–4 consist of the economies with real GDP per capita in 2009 below the first quartile, between the first quartile and the median, between the median and the third quartile, and above the third quartile, respectively. By this

[23]We thank the reviewer for pointing out this issue.

classification, Group 1 represents the poorest economies, and Group 4 represents the richest economies.[24]

We then repeat the regression tests of Hypotheses 1–3 on the partitioned data. The results are presented in Online Appendix Tables A5–A7, respectively. It is shown that Hypotheses 1–3 are also empirically supported across various groups of economies characterized by size or income level. In most cases, both the magnitude and the sign of the coefficients of key regressors show no significant deviations from the aggregate regression results. The statistical significance also holds for the grouped economies. For the majority of the results, there is also no clear trend for the variation of the coefficients as we move from the smallest to the largest economies or from the poorest to the richest economies. Specifically, no evidence shows that a large country tends to involve less international sourcing.[25] All these indicate that the validity of Hypotheses 1–3 holds not only for the economies in the WIOD database altogether but also when the economies are grouped according to their size or per capita income level.[26] One particular result to note is that foreign-sourced labor inputs contained in producer services have a stronger association with downstream productivity: a finding we uncovered before still holds after allowing for the role of country size and income level.

Meanwhile, there are certain patterns of variation that might enrich the understanding of our propositions. First, in most of the scenarios, with the same percentage increase in the size of the economy, countries at the lowest quartile of ranking in terms of either size or income level achieve stronger value chains labor division than countries at upper quartiles.

Second, the effect of the producer service productivity on the share of foreign-sourced labor contained in producer services generally decreases in magnitude as country size/income level increases. In other words, smaller/poorer countries rely less on foreign-sourced labor as their labor productivity of producer services increases. Two facts might contribute to this phenomenon. On the one hand, smaller/poorer countries have less-developed producer service markets and, thus, have higher potential for improvement. On the other hand, the degree of liberalization in these countries is usually low.[27] Consequently, when the labor productivity of producer services increases, a larger share will accrue to the domestic providers.

Third, the promotion effects of the producer service productivity on final product productivity decreases as countries become richer and that this is true when the producer service growth is due to the growth of foreign-sourced labor input, or due to the growth of both local and foreign-sourced labor input. This result seems to connect with the convergence literature in economic growth, in

[24]The data on real GDP and per capita GDP (both in constant 2005 US dollar) are sourced from the World Bank.

[25]The "home market effect" theorem in the case of gross trade (Krugman, 1980) might also be valid in the scenario of value-added trade under the GVCs.

[26]In addition to the grouped regressions, we create interaction terms between core regressors and the real GDP or the real GDP per capita (all in logarithms) to check the relevance of country types. In most cases, the interaction terms are statistically insignificant, well in line with our grouped regressions. For brevity, the results are not reported and are available upon request.

[27]More evidence on services trade restrictions can be found in the 2019 World Trade Report of World Trade Organization (WTO, 2019).

which countries further away from the world technology frontier tend to exhibit higher growth. We understand that the grouped estimated results need to be interpreted with care, as the number of economies in each group is only 10, rendering the potential bias caused by outliers.[28]

5. Conclusion

It has long been believed that the service industry not only suffers from stagnant productivity but also causes cost disease and hampers the overall economic growth. The metamorphosis of the modern services industry, partly triggered by the reconfiguration of the division of labor under the GVC revolution, has provided researchers with new perspectives for understanding the functions of this growingly important ingredient of the modern economy.

By focusing on producer services, a crucial component of the service industry, this study sheds light on how the growth of producer services affects the productivity of final goods and services. We derived an analytical relationship between specialization, output scale, labor input share of producer services, and aggregate productivity, employing a partial equilibrium framework. We postulate three related conjectures: (1) the degree of specialization intensifies as the economy expands; (2) the employment share of producer services increases as the economy expands, and decreases as the labor productivity of producer services increases; and (3) the final productivity increases as the labor input share of producer services increases.

Working with a multi-country multi-industry panel data constructed from the inter-country IO table, we find that a 10 percent increase in output scale leads to 0.1–0.2 percent rise in the degree of value chain division of labor, verifying our first conjecture. The empirical evidence is also consistent with our second conjecture. For example, considering from a globally sourced labor perspective, a 10 percent increase in the output scale at the average level will bring about 1.43 percent increase in the labor share contained in producer services, while a 10 percent increase in the labor productivity of producer services will engender 0.82 percent decrease in the labor share of producer services. The third conjecture is also supported by the regressions. For example, when the share of foreign-sourced labor factors contained in producer services increases by 10 percent, the labor productivity and TFP of final products or sectors will rise by about 2.4 percent and 2.7 percent, respectively.

This study identifies producer services as one of the potent drivers of productivity growth in the context of the GVC division of labor. Promoting the opening-up and competition of the service market, especially the producer services market, is a fundamental mechanism to expand the domestic and foreign market scale. The consequent expansion in output will generate the economies of scale effect, leading to higher demand for the intermediate producer services. Diversified and highly

[28]The coverage of WIOD database has its limitation as most developing countries are lumped together in a residual category. We would expect to find stronger results if the WIOD had more disaggregated coverage of developing countries. The current results, however, go in the direction of what we expect in terms of greater marginal effects for smaller/poorer countries.

efficient producer services help boost the productivity of producer service users (e.g., final product or sector). In other words, without liberalization in the field of producer services, liberalization only in the field of the users of producer services, such as the manufacturing and the agriculture sectors, can only deliver second-best economic performances.

Our empirical tests rest on country-sector-level longitudinal data constructed from inter-country IO tables, which provide detailed information on cross-country and cross-sector production linkages to identify the role of producer services in global production networks. The sector-level aggregation will probably lose some precision on firm heterogeneity. However, the rich structure of inter-sector linkage, which is generally hard to obtain at the firm level, might provide us reasonably reliable measurements for empirical validation. An interesting future research topic is to investigate whether the macro-level findings of this study remain binding with finer firm-level data that allow for the controlling of heterogeneities.

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Supporting Information

Additional supporting information may be found in the online version of this article at the publisher's web site:

Appendix: Measuring the division of labor under GVCs (*v*)
Table A1: Sample economies and sectors
Table A2: Statistical description of core variables (1996–2009)
Table A3: Endogeneity: 2SLS regression for Hypotheses 1 and 2
Table A4: Endogeneity: 2SLS regression for Hypothesis 3
Table A5: Different country scale and income levels: Test of Hypothesis 1
Table A6: Different country scale and income levels: Test of Hypothesis 2
Table A7: Different country scale and income levels: Test of Hypothesis 3
Figure A1: Combination of direct production activity (D) and indirect production activity (i.e., producer service activities [S])
Figure A2: Correlation between two measures of v based on input downstreamness (ID) and output upstreamness (OU): 1996–2009