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The Evolution of the Global Value Chain: Theory and Evidence

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Abstract

This paper develops a theory of the evolution of global production and the aggregate welfare effects it has. In my task-based growth model, a learning-by-doing mechanism enables firms to improve their production efficiency, giving rise to task upgrading in firms and countries that are engaged in global production. In a North-South framework, both the technologically advanced North and the lagging South move up the global value chain through this self-reinforcing process. I characterize the evolution of welfare in the steady state and during the transitional period. While non-monotonic welfare effects may exist in the short run, both countries gain from openness to offshoring in the long run, provided that they both undertake manufacturing activities. The model yields testable predictions for the share of industry value added in each country over time. When I confront the model with data on multinational subsidiaries in China, there is strong support for the key predictions of my model.

JEL codes: F23, F43, F63, O14, O33.
Keywords: value chain, offshoring, learning, trade of tasks, production dynamics

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1 Introduction

Currently, global economic activities feature a complex network of multinational production with a prominent role played by international task trade. Production processes become increasingly fragmented geographically and the performance of production tasks is spread across the globe. It is not unusual for a final good sold in a high-income country to have components or technology produced in that country, which are then exported to a lower-income country for final assembly and packaging, with the final product exported back to the originating high-income country.

Over time, an intriguing phenomenon arises which is widely referred to as countries and firms "moving up along the value chain of global production." This phrase is used, for instance, (1) in describing the fact that the Brazilian automotive industry, which began with an assembly line built by General Motors, now develops new car models and has become among the world's largest vehicle producers; (2) as the reason why Asian-Tiger economies experienced rapid industrialization and maintained high growth rates for decades after World War II; and (3) as the recipe for OECD countries to stay competitive in the global environment. While many people may have an informal understanding of what "moving up the value chain" means, testable definitions and mechanisms of the dynamics are lacking. In particular, what is the chain variable? Who is on the chain? Why do countries and firms claim they move up the chain altogether, even if they are at quite different development stages? And how do countries and firms move along the chain?

This paper provides a unified framework to address the meaning of global production and value chain and its dynamics that arise from learning-by-doing and experience accumulation over time. I develop a unified dynamic task-based model with technology for producing a final good modeled as a spectrum of production "tasks" that are ranked according to their degree of technological sophistication. The global value chain of an industry is then described as a sequence of tasks that may be fragmented and spread across countries, with each task adding value to the final industrial product.[1] Moving up the value chain is then given a specific definition as an upgrading in the set of tasks that a country, an industry, or a firm conducts. For different countries and firms, the task-upgrading pattern may vary.

A growing literature on multinational production views global integration as increasingly marked by task trade, and the global chain of production is thus modeled as a collection of offshorable tasks or a continuum of stages of production. Early examples include Dixit and Grossman (1982) and Feenstra and Hanson (1996, 1997).[2] More recent works explore further issues such as the effects of heterogeneous offshoring costs (e.g. Grossman and Rossi-Hansberg, 2008, 2012),

[1] Grossman and Rossi-Hansberg (2012) had a similar definition for tasks, while in their model, tasks differ in offshoring cost, and they looked at the static task specialization pattern and related it to relative wages and outputs.

[2] Other early related works such as Dornbusch, Fischer and Samuelson (1977, 1980) have studied trade theories based on a continuum of goods.

the optimal allocation of ownership rights along the value chain (e.g. Antràs and Chor, 2012), and the influence of technological change on the interdependence of countries participating in the global supply chain (e.g. Costinot et al., 2013).[3] Sharing with this body of literature that global production is considered and analyzed in a task-based framework, I formulate a dynamic theory of global value chain, in which the location of value added and task trade are endogenously determined. There are various configurations of production processes, such as the "spider" and "snake" described in Baldwin and Venables (2013). Thus, it is desirable that "moving up the global value chain" be understood and interpreted in a generalized way, without depending on any particular pattern of production processes. To capture this idea, my model sets no specific requirement for the sequence of task- or stage-completion, with tasks being ranked by their degree of technological sophistication in the framework.[4] Thus, the specific organization pattern of a production process is less a concern when using this model to examine and explain value-chain issues.

My theory features the critical role of learning-by-doing in the dynamic production process, providing rich descriptions on how global production may evolve and analyzing the dynamic effects on various economic aspects. At the start, firms allocate the relatively sophisticated tasks to the technologically advanced country (the North) and the relatively simple tasks to the country that lags behind (the South). The subsidiaries in the South acquire certain tasks that are moderately beyond their technical capability in the sense that the subsidiaries in the North are more efficient at these tasks. The technological gap between the two countries on these "beyond" tasks provides the subsidiaries in the South with opportunities to improve their production efficiency, through conducting those activities and accumulating technological experience. Over time, this learning-by-doing effect enables the subsidiaries in the South to conduct the relatively complex tasks more efficiently, leading to more sophisticated tasks being offshored. This self-reinforcing process continues until the tasks offshored to the South match its technological capability – the long-run steady state. Gradually, the scope of tasks undertaken by the subsidiaries in the South expands and increasingly covers sophisticated activities, while the Northern coverage of the task spectrum, although narrower over time, concentrates on the most highly sophisticated activities. In terms of the industrial value chain, the South moves up along the chain by carrying out additional and more difficult tasks, and the North moves up by conducting fewer but more complex activities.

Learning-by-doing has long been viewed as a central driver for growth and upgrading at various economic levels. Since Arrow (1962) incorporated learning-by-doing into the endogenous growth theory, it has been examined and tested in various economic studies. Theoretically, it is

[3] Other important task- or stage-based works include Carluccio and Fally (2012), Yi (2003), Baldwin and Venables (2013), and Baldwin and Robert-Nicoud (2010).

[4] Studies on value-chain issues often assumes that tasks and/or stages of production are sequential in nature; see, for example, Costinot, Vogel and Wang (2013), and Antràs and Chor (2012). Similar rankings/categorization of tasks as presented in my model are discussed in Costinot, Oldenski and Rauch (2011), Oldenski (2012), and Keller and Yeaple (2013), but their studies focus on different issues than those examined in this paper.

examined in frameworks of the mechanics of economic growth and development in many fields, including international trade.[5] Empirical studies have also found support for it as an important driver of growth.[6] This paper contributes to this body of literature by incorporating learning-by-doing into the task-based framework, examining the effects of learning on the dynamics of global production. Particularly, it addresses what countries and firms can do in order to learn and thus climb up along the global value chain. Understanding these essential factors and the mechanism involved is important since they are critical in explaining why some developing countries experience rapid growth and industrialization within the global production network, while some other ex-ante similar countries do not. In the model, it is by conducting those tasks where there is a marked technological gap between countries where the technologically less advanced country can learn and improve its production efficiency. This reflects the common observation that a developing country may be as efficient as a developed country in conducting the simplest production tasks (e.g. assembly and packaging), but its technology lags behind with regard to more sophisticated activities. By carrying out those tasks moderately beyond its technological capability, the South engages in contact with the advanced technologies for those activities, and further exploration and actualization of those technologies empower its progress.[7] Thus, the theory fundamentally examines the dynamics of global production through the endogenous exploration of technologies.

This stylized model featuring learning-by-doing addresses the question of whether trade in tasks is beneficial for countries dynamically, particularly for developing countries. In terms of factor income, while the gap between the North and South exists initially in the short run, it diminishes over time as tasks are increasingly offshored. In the long run, the factor income converges, and it is equalized at the steady state if both countries engage in manufacturing – the homogeneous factor of production receives the same reward rate. What is noteworthy here is that the factor price equalization could be achieved here without requiring both countries to be equally efficient in conducting every task. Specifically, developing countries do not need to acquire the most advanced technologies for every task to enjoy the same factor reward rate as their developed partners.

This paper further examines the dynamic welfare effects of participating in the global production network. There is a long list of studies that have explored the effects of production fragmentation and offshoring on welfare issues. The arguments and results are mixed.[8] Production fragmentation has different effects on welfare, probably working in opposite directions.[9] In this

[5]See, for example, Krugman (1987), Lucas Jr (1988, 1993), Stokey (1988), Young (1991), Matsuyama (1992) and Jovanovic and Nyarko (1996).

[6]See, for example, Bahk and Gort (1993), Irwin and Klenow (1994), and Levitt, List and Syverson (2012).

[7]As mentioned in Young (1991), learning-by-doing could probably be conceived of as the exploration and actualization of advanced technologies, which may be new to a country.

[8]See, for example, Burstein and Monge-Naranjo (2009), Arkolakis, Ramondo, Rodríguez-Clare and Yeaple (2013), Arkolakis, Costinot and Rodríguez-Clare (2012), Markusen (1984), Markusen and Venables (1998), Ramondo and Rodrıguez-Clare (2013), Rodriguez-Clare (2010), Garetto (2013).

[9]For example, in Grossman and Rossi-Hansberg (2008), fragmentation has three main effects on low-skill wages,

paper, I focus primarily on the *dynamics* of welfare effects. As global production converges to the steady state, the South experiences welfare gains constantly along the way, while the North may see a "hump-shaped" path, with the Northern welfare in the long run possibly lower than some intermediate level of task offshoring. In the long run, the Northern steady-state welfare may be higher or lower than its initial state with offshoring – the technologically advanced country may gain or lose as global production evolves, depending upon the country's relative factor endowment, the initial technological gap between countries, and certain industrial characteristics.

Although the North may experience a "hump-shaped" welfare path while global production evolves, it does gain from engaging in offshoring. Compared with autarky, the North earns positive gains from the initial time when offshoring starts, and is better off in the long run, if the optimal offshoring threshold is within the range of offshorable tasks. The effect of offshoring turns out to be different for the country with technological disadvantages. Engaging in offshoring could have a negative effect for the South initially, wherein the short-term involves pains, but the effect dissipates gradually while offshoring continues bringing welfare benefits to the country over time. In the long run, the effect is always positive – the South is always better off at the steady state than it was under autarky. Therefore, both countries could benefit from joining in global production, but the paths are different.[10]

Different effects contribute to the welfare dynamics. The South and North experience a factor reward increase and decrease, respectively, when global production evolves. At the same time, consumers in both countries enjoy an increasing number of consumption options in the market – the number of varieties available keeps growing along the way. The output dynamics of each variety also contributes to the welfare changes over time. These effects are analyzed and discussed in the paper.

A central prediction of the theory is that global production converges to a steady state where no further offshoring happens. During this process, the national contribution of value-added as well as the national share of world income is dynamically redistributed – the Southern part increases while the Northern part decreases, and the speed of redistribution declines gradually. In fact, the convergence of the Southern value-added portion essentially and exactly maps the convergence pattern of task-offshoring. Therefore, the theory offers a convenient prediction as to how the South's share of value added in an industry should behave over time: "moving up the value chain" translates into an increasing share of value added in total value of industrial output over time, while

including the productivity effect, the relative-price effect, and the labor-supply effect. In Rodriguez-Clare (2010), another set of effects – a productivity effect, a terms-of-trade effect, and a world-efficiency effect – is discussed. Depending upon the interactions among separate effects, countries may see different aggregate welfare effects of offshoring.

[10] Classic trade theories such as the Ricardian and Heckscher-Ohlin models have argued that there is static positive gain from trade. Later studies looking at dynamic situations find negative effects over time. For example, see Matsuyama (1992), Redding (1999), and Stokey (1991).

the speed of moving up declines gradually. A micro-founded approach is then applied to test the dynamics of the value-added ratio (VR) of global production contributed by the South (i.e. the South's share of value added). By using a dataset on China's multinational operation spanning 10 years, the evolution pattern of industry-level VR is examined.[11] The VR change of multinational operation is analyzed at the industrial level, and the aggregate VR change is further decomposed into a within-subsidiary margin and a cross-subsidiary margin, with convergence testing pursued for these two margins respectively. The results show that convergence evidences are present, and the industrial VR dynamics are mainly driven by changes within subsidiaries.

The rest of the paper is organized as follows. In Section 2, I introduce the main framework of the dynamic theory. Section 3 studies the instantaneous equilibrium of the model and the steady state situation in the long run. In Section 4, I examine the evolution dynamics of global production under different circumstances. This section includes discussions of the dynamics of other important economic aspects, such as factor income and national welfare. Section 5 discusses the gains from fragmentation and offshoring by comparing national welfare in the state of global production to the state under autarky. In Section 6, the empirical approach, data, and results are presented. Section 7 offers concluding remarks.

2 Set-up of the Model

Consider a world comprised of two countries: North (N) and South (S). There is an industry supplying a differentiated final consumer product, in which there is a continuum of firms, each producing a single and distinct brand indexed by j and selling it in both countries. Firms are symmetric – the final varieties are only different in the sense that they are under different brand names. Labor is the sole factor of production, and it is inelastically supplied and immobile across countries. The labor endowment of country i is denoted by L_i, which is constant over time. Time is continuous and is indexed by t.

[11] China is appropriate as the subject of testing here since it is active in the global production network in the past few decades, attracting large volumes of foreign direct investment (FDI) into the country. With its abundance of production factors, particularly labor, China's current position in global production is far from its steady state and thus it learns and converges relatively quickly. Therefore, the pattern should be easily detected. This could be partially seen from the findings that the sophistication of China's exports has been rising (e.g. Schott (2008); Xu and Lu (2009); Wang and Wei (2010); Jarreau and Poncet (2012)) and that the domestic content in China's exports has been increasing (e.g. Koopman, Wang and Wei (2012); Kee and Tang (2011)).

2.1 Preference

Consumer preferences are assumed to be identical in the two countries, and the instantaneous preference of a representative consumer at any time t is given by a C.E.S. utility function:

$$U(t) = \left[\int_0^{J(t)} q(j,t)^\rho dj \right]^{\frac{1}{\rho}} , \tag{1}$$

where $J(t)$ denotes the number of product varieties available and thus also the number of firms at time t; $q(j,t)$ is the consumption of good j at time t; and $0 < \rho < 1$.

This instantaneous utility function implies that the elasticity of substitution between any two varieties within this industry is constant and equals $\sigma = \frac{1}{1-\rho} > 1$. As in Dixit and Stiglitz (1977), the demand for brand j at time t is given by

$$q(j,t) = \frac{E(t)p(j,t)^{-\sigma}}{P(t)^{1-\sigma}} , \tag{2}$$

where $E(t)$ stands for the aggregate consumer expenditure at time t; $p(j,t)$ denotes the price of brand j at time t; and $P(t)$ is a price index such that

$$P(t) = \left[\int_0^{J(t)} p(j,t)^{1-\sigma} dj \right]^{\frac{1}{1-\sigma}} . \tag{3}$$

2.2 Product Market

Facing the constant elasticity demand function derived above, firms choose the same profit maximization markup equal to $\frac{1}{\rho}$. Given the symmetry of firms, the pricing rule is thus given by

$$p(j,t) = p(t) = \frac{c(j,t)}{\rho} = \frac{c(t)}{\rho} , \tag{4}$$

where $c(t)$ is the marginal cost of producing any variety j at time t. Assuming no trade or transportation cost, the price of any product is the same across countries.

Firms need to pay a fixed cost during each time period in order to maintain their brands. The fixed cost $f > 0$ is the amount of Northern labor used. It could be viewed as the non-production labor cost needed for keeping a brand visible on the market. The fixed cost is the same for all firms. This yields the firm profit:

$$\pi(j,t) = \pi(t) = \frac{E(t)}{\sigma} \left(\frac{c(t)}{\rho P(t)} \right)^{1-\sigma} - w_N(t) f , \tag{5}$$

where $w_N(t)$ is the wage level in the North at time t, and $E(t)$ could be expressed as

$$E(t) = \int_0^{J(t)} p(j,t)q(j,t)dj\,. \tag{6}$$

2.3 Production

The production of any variety requires an identical continuum of tasks, indexed by $z \in [0,1]$. The numeric value of z measures the technological sophistication of a task – the larger z is, the more sophisticated the task is. The production technology is identical across all brands. Given the symmetry of firms, at time t, the production function for any variety j is

$$\ln Y(j,t) = \ln Y(t) = \int_0^1 \ln x(j,z,t)dz\,, \tag{7}$$

where $x(j,z,t)$ is the amount of task z that is completed at time t for producing good j. Each task could be located and carried out in either country.

Consider the production technology. For any task z, there is a minimum unit labor requirement, given by

$$\bar{a}(z) = \bar{a}e^{-z}\,, \tag{8}$$

where $\bar{a}$ is a positive constant. It is time invariant and non-increasing in z.[12]

The North masters the most advanced technologies for all tasks. Thus the Northern plants can perform any task using the minimum amount of labor indicated by $\bar{a}(z)$. In contrast, the South lags behind technologically – it only possesses the most efficient technology for a range of low-sophistication tasks, and the situation is identical for all brands' production. Specifically, initially at time 0, the stock of technologies in the South is denoted by $T(0)$, with $0 < T(0) < 1$. For the relatively simple tasks with $z \leq T(0)$, the South is as efficient as the North in carrying out these tasks. For the tasks that are relatively difficult to carry out (with $z > T(0)$), the South does not have the best technology initially; and the more sophisticated a task is, the further the South lags behind the North in terms of production technology.[13] Specifically, the South's unit

[12] As in Young (1991), it implies that the ultimate productivity of labor is non-decreasing in the technical sophistication of task production.

[13] The idea of technological distance has appeared in other models of learning. See, for example, Auerswald et al. (2000), Jovanovic and Nyarko (1996), and Mitchell (2000).

labor requirement for conducting task z at $t = 0$ is given by[14]

$$a(z,0) = \begin{cases} \bar{a}(z) = \bar{a}e^{-z}\,, & \text{if } z \leq T(0), \\ \bar{a}e^{z-2T(0)}\,, & \text{if } z > T(0). \end{cases} \tag{9}$$

2.4 Learning-by-Doing

Tasks can be completed in the South or in the North. Firms are multinational enterprises in the sense that they have plants in both countries, performing different sets of tasks. For the South, it is probable that certain tasks beyond its technical capability are offshored to the country, which enables plants there to observe the technological gap between themselves and their Northern counterparts. By conducting those "beyond" tasks, the Southern plants can thus accumulate experience and improve their own technologies, thereby enhancing production efficiency. This is the effect of learning by doing in the South. Moreover, the learning-by-doing effect is assumed to be bounded and with spillovers across tasks, with the North serving as the technology frontier and learning boundary. Therefore, the Southern plants experience reduction in the unit labor requirement over time:[15]

$$\frac{\partial a(z,t)/\partial t}{a(z,t)} = -\int_0^1 2\beta \left\{ 1 \left| \frac{a(z,t)}{\bar{a}(z)} > 1 \right. \right\} L_S(j,z,t)\,dz\,, \tag{10}$$

where $\left\{ 1 \left| \frac{a(z,t)}{\bar{a}(z)} > 1 \right. \right\}$ is an indicator function that equals 1 if the learning room for task z in the South is not exhausted at time t; $L_S(j,z,t)$ denotes the amount of labor used for conducting task z in the Southern plant of any brand j at time t; and $\beta > 0$ is a parameter that measures the learning ability of the South.

On one hand, the function of learning-by-doing indicates that the Southern plants are not able to learn from the tasks that they do not conduct. On the other hand, for tasks on which learning space has been exhausted ($a(z,t) = \bar{a}(z)$), carrying them out does not contribute to further efficiency improvement. The learning effect is positive only if the Southern plants perform tasks for which they have not obtained the best techniques.

With the South's initial unit labor requirement function and the learning-by-doing effect, the

[14]Given the symmetry of firms, plants in the same country have the same technologies, and thus the unit labor requirement functions do not depend on the brand argument j.

[15]The environment here is built upon Young (1991), in which a general functional form of bounded learning-by-doing is provided.

unit labor requirement for completing a task z in the South at time t follows

$$a(z,t) = \begin{cases} \bar{a}(z) = \bar{a}e^{-z}\,, & \text{if } z \leq T(t)\ , \\ \bar{a}e^{z-2T(t)}\,, & \text{if } z > T(t)\ , \end{cases} \tag{11}$$

where $T(t)$ refers to the technology stock in the South at time t. $T(t)$ evolves according to

$$\frac{dT(t)}{dt} = \int_{T(t)}^{1} \beta L_S(j,z,t)dz\,. \tag{12}$$

Figure 1 shows the evolution of the unit labor requirement in the South.

A task could be conducted by plants in the North or in the South, using the corresponding technology indicated by function (8) or (11), depending on the offshoring pattern prevailing at the time. Each brand establishes only one plant in a country, which completes all tasks allocated to that country by its own brand. There is free entry in the market at all times. The new entrants bring in new distinct brands/varieties, which use the same set of tasks and the identical production function as all already-existing players do. Therefore, when a new firm enters the market, it will also use the same offshoring pattern as for the current firms. Free entry draws firms' profit to zero, which then determines the number of varieties present on the market.

3 Instantaneous Equilibrium and Steady State

3.1 Instantaneous Equilibrium

Let $w_i(t)$ denote the wage rate prevailing in country i at time t. Then given the symmetry of firms, the cost functions for conducting task z for any brand j in the two countries are, respectively,

$$C_S(w_S(t),j,z) = w_S(t)a(z,t)\,, \tag{13}$$

$$C_N(w_N(t),j,z) = w_N(t)\bar{a}(z)\,, \tag{14}$$

Under offshoring, certain tasks are allocated to the South. As described earlier, for the range of low-sophistication tasks with $z \leq T(t)$, the Southern plants are as competent in conducting them as their Northern counterparts. However, for the high-end tasks, the South increasingly lags behind. Thus, with consideration of production efficiency, the firms initially offshore relatively simple tasks, with their Southern plants conducting low-end tasks while the Northern plants focus on relatively sophisticated activities. Specifically, the cost functions (13) and (14) combine to form a no-arbitrage condition in trade of tasks, indicating the pattern of task allocation between the two countries.

There exists a threshold task $\bar{z}(t)$ at any time t such that $C_N(w_N(t), j, z) = C_S(w_S(t), j, z)$; or equivalently,

$$w_N(t)\,\bar{a}(\bar{z}(t)) = w_S(t)\,a(\bar{z}(t), t)\,, \tag{15}$$

with $\bar{z}(t)$ denoting the most sophisticated task that is conducted in the Southern plants.[16] Thus, for all firms within the industry, tasks with $z \in [0, \bar{z}(t)]$ are allocated to the South, and tasks with $z \in (\bar{z}(t), 1]$ are performed in the North. Given that the value chain of the industry is represented by the whole spectrum of tasks that could be disintegrated and spread over national borders, with each task adding value to the final industrial product, the pattern of task-allocation across countries implied by condition (15) indicates countries' position on the global value chain – the South is lower than the North. This condition also implies that all firms incur the same marginal cost of production and thus have the same pricing behavior at all times. Certainly, an essential condition that enables offshoring is $w_S(t) \leq w_N(t)$, so that the South has the unit cost advantages in performing those low-end activities. It will be shown later in the paper that this condition is always satisfied.

The labor market conditions for the two countries at time t are given by

$$\textit{South}: \int_0^{\bar{z}(t)} x_S(z,t)a(z,t)dz = L_S\,, \tag{16}$$

$$\textit{North}: \int_{\bar{z}(t)}^{1} x_N(z,t)\bar{a}(z)dz + J(t)f = L_N\,, \tag{17}$$

where the constant f is the fixed labor cost incurred by every firm in each time period; $J(t)$ is the number of varieties at time t; and $x_i(z,t)$ denotes the total amount of task z conducted by all plants in country i at time t.

As discussed earlier, $E(t)$ denotes the total world expenditure on final products at time t, and it is equal to the sum of factor payments in the two countries:

$$E(t) = w_S(t)L_S + w_N(t)L_N\,. \tag{18}$$

Given the pricing rule, the demand for a task z conducted in country i at time t is given by

$$x_i(z,t) = \frac{\rho E(t)}{C_i(w_i(t), z)}\,, \quad i \in \{N, S\}\,, \tag{19}$$

where $C_i(w_i(t), z)$ is the same across firms.

With the unit cost functions (13) and (14), along with (19), the labor market clearing condi-

[16] $\bar{z}(t)$ is the same across all plants because firms are symmetric.

tions become

$$South: \int_0^{\bar{z}(t)} \frac{\rho E(t)}{w_S(t)} dz = L_S \,, \tag{16'}$$

$$North: \int_{\bar{z}(t)}^1 \frac{\rho E(t)}{w_N(t)} dz + J(t) f = L_N \,. \tag{17'}$$

The free-entry condition drives the firms' profit to zero. Given the symmetry of firms, the zero-profit condition can be simplified to[17]

$$\frac{E(t)}{\sigma J(t)} = w_N(t) f \,. \tag{20}$$

Thus, the instantaneous aggregate equilibrium of the model at any time t is characterized by the offshoring threshold determination condition (15), the labor market clearing conditions (16′) and (17′), the world expenditure function (18), and the zero-profit condition (20). One equilibrium equation here can be dropped by Walras' law, so that one variable can be chosen as the numeraire. I thus normalize the world expenditure at unity, with $E(t) = 1$. Hence, all the wages are measured as shares of the world's total factor income.

3.2 Steady State

At the steady state, the task-allocation pattern of global production stays stable. No more tasks are reallocated from one country to the other. Other aspects of the two economies, such as wage rates and the South's technology stock, are also stabilized. By examining the labor market clearing conditions (16′) and (17′), along with the zero-profit condition (20), it is found that there exists a threshold task z^* such that if all tasks with $z \in [0, z^*]$ are allocated to the South and tasks with $z \in (z^*, 1]$ are retained in the North, the wage rates of the two countries are equalized. Specifically, the time-invariant z^* is solved to be

$$z^* = \frac{L_S}{\rho\,(L_S + L_N)} \,. \tag{21}$$

z^* serves as the threshold task of offshoring at the steady state if it is within the range of offshorable manufacturing tasks ($\frac{L_S}{\rho\,(L_S+L_N)} \leq 1$).[18] If z^* exceeds the task range, then offshoring will stop when all offshorable manufacturing tasks are allocated to the South with the North focusing

[17] It is straightforward to obtain (20) from examining the profit function (5), with considering the aggregate price index expression (3) and the pricing rule specified by (4).

[18] This condition is more likely to be satisfied if in consumers' eyes, the degree of substitutability between products is relatively high.

on brand creation and maintenance. Namely, in this circumstance, the threshold task of offshoring will be $z^{*\prime} = 1$. Certainly, with learning being the main driving force of technical improvement, if both countries are involved in manufacturing in the long run, the South will be as capable as the North is on the tasks it conducts when the steady state is achieved. The unit completion cost of the threshold task of offshoring at the steady state is thus the same in the two countries. The steady state of global production is then featured with equalized wage rates and all tasks being carried out using the best technologies.[19]

4 Transition Dynamics

Countries' initial stocks of technology and their factor endowments determine their initial positions on the global value chain, which further indicates their learning opportunities in the global environment. As discussed earlier in the paper, if a firm conducts tasks at which it is not particularly competent, the learning effect will be positive in the sense that the production efficiency on these tasks will be improved, through exploring advanced technologies while carrying out the tasks. In contrast, by conducting tasks for which the best technologies have already been in use, plants cannot obtain further learning opportunities. Therefore, a country's initial position on the global value chain is important for understanding its transitional dynamics. In this section, I examine the transition dynamics of the model – the movement from an initial situation of task-allocation to the steady state of global production.

Depending upon how far the South lags behind the North in terms of technology (essentially, where $T(0)$ is) and where the steady state is, there are four possible cases as to how global production may evolve over time:

Case I. *Normal Evolution* This is the situation where the steady state stays within the range of offshorable tasks ($0 < z^* \leq 1$) and the initial stock of technology in the South is not adequate for efficiently performing all tasks that could be offshored to the country at the steady state ($T(0) < z^*$). Under this circumstance, the Southern plants acquire certain tasks that are moderately beyond their technical capabilities. This will provide the South with opportunities to learn and improve on the production technology. The positive learning effect will drive the equilibrium of global production to the steady state, in which both countries participate in producing final products.[20]

Case II. *Extreme-end Evolution* In this case, the steady state of global production is $z^{*\prime} = 1$. Namely, at the steady state, all manufacturing tasks will be allocated to the South, with the North

[19]From here on, all notations with the superscript "$*$" stand for corresponding variables in the long-run steady state.

[20]This case indicates that the South has adequate labor but without enough of an initial stock of technologies, which is the case for most developing countries that currently participate in global production.

solely focusing on non-manufacturing activities such as brand maintenance. With initial technology stock being $0 < T(0) < 1$, the learning effect is positive here as in Case I – the global task allocation evolves to the steady state as the Southern technology improves over time. What is different from Case I is that the evolution path here is not smooth – the actual steady state ($z^{*\prime}$) lies in between the initial equilibrium and the potential steady state ($z^* > 1$), which thus leads to an interruption in the potential evolution path. Once the global production pattern hits the extreme end of offshoring while it evolves to the potential steady state, it will stop progressing further.

Case III. *Static Normal Offshoring* If the South's initial technology stock is sufficiently high ($T(0) > z^*$), then global production arrives at the steady state at the initial time $t = 0$. Possessing the best technologies for all tasks conducted in the country, the South will not have opportunities for further learning, which thus leads to a static equilibrium.

Case IV. *Static Complete Offshoring* This situation happens when the South is technologically identical with the North ($T(0) = 1$) and the relative labor supply of the South is so large that all manufacturing tasks are offshored to the country since the initial time period. Since the variables hit the extreme end from the very beginning, they will not change further during the following time periods. Certainly, in this case, there is no positive learning effect present in the South.

Among the cases described above, I will mainly focus on Case I, the normal evolution, in this paper. This case could well illustrate the essential transitional dynamics of global production described by the model. The other three cases could then be naturally and easily understood. For instance, Case II is essentially a variation of Case I, and it will be discussed briefly later in the section.

4.1 Task Dynamics

Given $T(0) < z^* \leq 1$, $\bar{z}(0) \in (T(0), z^*)$ follows. The reasons are that an offshoring threshold at $T(0)$ is not cost-minimizing for any firm, and that without the best technologies for tasks beyond $T(0)$, it is costly for the South to conduct all tasks $[0, z^*]$ compared to the North. By examining (15), (16′) , (17′) and (20), together with conditions (8) and (9), the equilibrium at the initial time of offshoring ($t = 0$) is characterized by

$$e^{2\bar{z}(0)-2T(0)} = \frac{1-\rho\bar{z}(0)}{\rho\bar{z}(0)}\frac{L_S}{L_N}, \tag{22}$$

$$w_S(0) = \frac{\rho\bar{z}(0)}{L_S}, \tag{23}$$

$$w_N(0) = \frac{1-\rho\bar{z}(0)}{L_N}, \tag{24}$$

$$J(0) = \frac{L_N}{\sigma f\,(1-\rho\bar{z}(0))}. \tag{25}$$

At equilibrium, with $\bar{z}(0) \in (T(0), z^*)$, the South receives not only all tasks that it could conduct as efficiently as the North does, but also certain activities beyond its initial technical capability because of its abundance of labor. This initial equilibrium is illustrated in Figure 2. Furthermore, given $\bar{z}(0) < z^*$, it is the case $w_S(0) < \frac{1}{L_S+L_N} < w_N(0)$. The relatively low wage rate in the South ensures that the low-end activities for which the South has the best technologies could be allocated to the South.

The situation which involves the South conducting certain tasks that are moderately beyond its capability will turn on the learning-by-doing effect and the production efficiency will improve gradually. This effect will further attract more tasks to be offshored. At time t, the instantaneous equilibrium is characterized by

$$e^{2\bar{z}(t)-2T(t)} = \frac{1-\rho\bar{z}(t)}{\rho\bar{z}(t)}\frac{L_S}{L_N}, \tag{22$'$}$$

$$w_S(t) = \frac{\rho\bar{z}(t)}{L_S}, \tag{23$'$}$$

$$w_N(t) = \frac{1-\rho\bar{z}(t)}{L_N}, \tag{24$'$}$$

$$J(t) = \frac{L_N}{\sigma f\,(1-\rho\bar{z}(t))}. \tag{25$'$}$$

Following the same logic as discussed for the initial equilibrium, as long as $T(t) < z^*$, it is always the case that the offshoring threshold lies between the South's technology stock and the steady state (i.e., $\bar{z}(t) \in (T(t), z^*)$), which enables the South to learn. The wage rate in the South is at the same time always lower than the Northern wage level (i.e., $w_S(t) < \frac{1}{L_S+L_N} < w_N(t)$).

The positive learning effect in the South is reflected by the accumulation of technology in the country. The technology-stock indicator $T(t)$ evolves over time according to the technology accumulation path:[21]

$$\frac{dT(t)}{dt} = \frac{\beta L_S}{J(t)} \frac{\bar{z}(t) - T(t)}{\bar{z}(t)} = \beta\sigma f\left(1 - \rho\bar{z}(t)\right) \frac{L_S}{L_N} \frac{\bar{z}(t) - T(t)}{\bar{z}(t)} \,. \tag{26}$$

The learning effect implies that as long as the South performs certain tasks beyond its technical capability ($\bar{z}(t) > T(t)$), the country can always learn from what it conducts (i.e., $\frac{dT(t)}{dt} > 0$).

This positive learning-by-doing effect pushes the offshoring threshold further, with the Southern coverage of tasks expanding to include more sophisticated activities. Namely, if the set of tasks undertaken in a plant is viewed as the scope of the plant, then the learning effect will lead to scope expansion in the Southern plants. This can be seen by examining ($22'$):

$$\frac{d\bar{z}(t)}{dt} = \frac{2\bar{z}(t)\left(1 - \rho\bar{z}(t)\right)}{1 + 2\bar{z}(t)\left(1 - \rho\bar{z}(t)\right)} \times \frac{dT(t)}{dt} \,, \tag{27}$$

which implies

$$0 < \frac{d\bar{z}(t)}{dt} < \frac{dT(t)}{dt} \,, \tag{28}$$

as long as the learning room is not exhausted. With learning, the South is capable of conducting tasks increasingly efficiently for those tasks at which it was not competent before; together with a relatively low wage rate, the South attracts more and harder tasks to be undertaken there. Certainly, while a wider range of low-sophistication tasks are being offshored to the South, the North increasingly focuses on the most difficult activities ($(\bar{z}(t), 1]$). Therefore, both low-income and high-income countries move up the global value chain over time – they both experience upgrading in the sets of tasks that their firms conduct.

As indicated by (26), how strong the learning effect is depends upon the relative learning opportunities for the South – for which tasks there is still room for technology improvement, relative to all tasks that are actually performed in the country (i.e., the distance between $T(t)$ and $\bar{z}(t)$). As time passes, with $\frac{dT(t)}{dt} > \frac{d\bar{z}(t)}{dt}$, the initial learning opportunites are gradually exhausted, which will in turn slow down the pace of learning over time.[22] This further translates into a concave-shaped time path of task-scope of offshoring. As global production evolves, $\frac{d^2T(t)}{dt^2} < 0$ and $\frac{d^2\bar{z}(t)}{dt^2} < 0$.[23] Furthermore, by examining (27), it is found that[24]

$$\frac{d\dot{\bar{z}}(t)}{d\bar{z}(t)} < 0 \,,$$

[21] See Appendix A1 for the derivation of (26).

[22] This pattern is not hard to tell from (26). The increase in $\bar{z}(t)$ with decrease in $(\bar{z}(t) - T(t))$ leads $\frac{dT(t)}{dt}$ to decline over time.

[23] See Appendix A2 for proof.

[24] See Appendix A3 for proof.

where $\dot{\bar{z}}(t) \equiv \frac{d\bar{z}(t)}{dt}$. The first-order Taylor series approximation shows that

$$\dot{\bar{z}}(t) \approx \left(\frac{d\dot{\bar{z}}(t)}{d\bar{z}(t)} \right)_{\bar{z}(t)=z^*} \times (\bar{z}(t) - z^*) ,$$

which implies that the offshoring threshold always converges to the steady state at a speed proportional to its distance from the steady state.

In the long run, both the technology stock in the South and the offshoring threshold converges to the same steady state, z^*.[25] When they arrives at the steady state, they will not grow further beyond it. With equalized wage rates and both countries possessing the same best technologies for tasks conducted domestically, the pattern of global production is stabilized.

In sum, the dynamics of both the technology stock in the South ($T(t)$) and the task-scope of offshoring ($\bar{z}(t)$) display concave-shaped growth paths, both converging to the same steady state, which serves as the upper bound. The convergence process is demonstrated in Figure 3.

Certainly, factors such as the learning ability of the South (indicated by β), brand maintenance cost (f), variety substitutability in the industry (σ, and thus ρ), and the countries' labor endowments (L_S and L_N) all have influence on the convergence paths. Numerical simulations are performed here to examine how different variables may affect the evolution dynamics of global production. Figure 4 demonstrates the results of the numerical simulations. Panel A shows that the size of a country could compensate for its production inefficiency – a larger although technically inefficient country gets a wider range of tasks to carry out, and it enjoys higher technology advancement along the way. Panel B shows the results from variation in the learning ability of the South. It is obvious that a Southern country with strong abilities to explore and actualize advanced technologies converges to its steady state relatively quickly. For Panel C, variety substitutability is the main focus. It is shown that first, an industry with a higher variety substitutability tends to have less tasks conducted in the South in the long run. This is because with high substitutability among varieties, the demand for new ones is low. Therefore, the North will not experience much pressure on creating new brands, which thus allows for more labor in the North to be involved in manufacturing activities. This leads to a relatively low offshoring threshold. Second, the higher the variety substitutability is, the faster global production converges. Panel D demonstrates how the fixed cost for branding affects the dynamics of offshoring – a higher fixed cost leads to faster convergence. While more efforts are required to create or maintain a brand, labor in the North will be transferred from the manufacturing to the branding sector more quickly, which accelerates the whole offshoring process.

[25]This can be seen by examining (22′) at z^*.

4.2 Variety Dynamics

Under monopolistic competition, consumers' love for variety provides the market with the incentive to create and maintain different brands. With more and more manufacturing tasks allocated to the South, the labor in the North that was previously devoted to production lines can now switch to the branding sector. The evolution of offshoring thus brings a change in industrial structure in the country. With more efforts reallocated from manufacturing to branding, more varieties are brought into the market. This process can be seen by examining the dynamics of variety along the evolution progress.

From (25′), it is found that[26]

$$\frac{dJ(t)}{dt} > 0\,, \text{ and } \frac{d^2J(t)}{dt^2} < 0 \tag{29}$$

along the way while global production evolves to its steady state, and this indicates a concave-shaped time path for the number of varieties present in the market. In the long run, the number of varieties converges to

$$J^* = \frac{L_S + L_N}{\sigma f}\,. \tag{30}$$

Figure 5 shows the results from numerical simulations. A higher substitutability among varieties leads to a smaller number of brands on the market and faster convergence to its steady state.

Therefore, the productivity improvement in the South does not only expand the scope of tasks performed in the country which thus causes the country to move up the value chain, it also benefits consumers across the globe by relieving Northern workers of their manufacturing duties, which thus enables the creation of more varieties.

4.3 Dynamics of Factor Income

As mentioned in Section 4.1, with offshoring, the wage rate in the South continues to be lower than that in the North while the multinational operation evolves. How do the wage levels change over time? By examining (23′) and (24′), it is found that the wage rates in the two countries are closely related to the offshoring threshold in global production. With a constant labor size, the number of tasks conducted within a country determines the reward the workers there can obtain. With technology improvements, even with the same amount of labor, the South can carry out more activities, which is then reflected in the increasing factor price in this country. In contrast, the North experiences a decline in factor price. In the long run, while global production reaches the

[26] See Appendix A4 for proof.

steady state z^*, the two countries' wage rates are equalized at:

$$w^* = \frac{1}{L_S + L_N}\,, \tag{31}$$

which indicates that in the long run, no matter what task a worker performs and which country and/or sector he or she is in, the wage rate is the same for all. Certainly, this factor-price-equalization condition holds here when both countries engage in manufacturing activities at the steady state ($z^* \leq 1$) and labor flows freely between sectors in the North. In the other cases where the potential steady state z^* exceeds the range of production-task ($z^* > 1$) so that the actual steady state is at $z^{*\prime} = 1$, the situation may be different and will be discussed in later sections.

The wage rate dynamics in the South shows a concave-shaped path, while in the North it displays a convex one, both converging to the steady-state wage rate w^*.[27] Figure 6 demonstrates the wage dynamics of the two countries.[28]

It is clear that although the wage gap between the two countries exists initially in the short run, it diminishes over time as tasks are increasingly offshored. In the long run, if both countries are involved in manufacturing activities, the wage gap could be closed with factor prices equalized. In the steady state, workers in the South enjoy the same income level as their Northern counterparts, even though they do not have all the most advanced technologies. Therefore, what matters most for workers is the actualization of technologies, rather than the potential productivities that are not embodied in real productions.

4.4 Dynamics of National Welfare

Evolution in the pattern of offshoring naturally translates into evolution in the national welfare of the two countries. Given the utility function (1), national welfare depends on both the number of varieties on the market and the consumption or output volume of each variety. From Section 4.2, it is found that the number of varieties keeps growing over time. Consider the output of each brand. Given the production function (7), it is found that the per-brand output at time t is[29]

$$Y(t) = \frac{\rho\sigma f}{\bar{a}} e^{\frac{1}{2}} \times e^{\bar{z}(t)^2 - T(t)^2}\,. \tag{32}$$

Further examination of (32) shows that the dynamics of per-brand output may not display a monotonic growth pattern over time. There exists a threshold task $\tilde{z}_y$ that if less than $\tilde{z}_y$ is

[27] From (23′) and (24′), $\frac{dw_S(t)}{dt} = \frac{\rho}{L_S}\frac{d\bar{z}(t)}{dt} \geq 0$, $\frac{d^2 w_S(t)}{dt^2} = \frac{\rho}{L_S}\frac{d^2\bar{z}(t)}{dt^2} \leq 0$; $\frac{dw_S(t)}{dt} = -\frac{\rho}{L_N}\frac{d\bar{z}(t)}{dt} \leq 0$, $\frac{d^2 w_S(t)}{dt^2} = -\frac{\rho}{L_N}\frac{d^2\bar{z}(t)}{dt^2} \geq 0$.

[28] Wage rates here are expressed as a share of the world expenditure, since $E(t)$ has been normalized to 1.

[29] See Appendix A5 for the derivation of (32).

offshored to the South (i.e., the offshoring threshold $\bar{z}(t) < \tilde{z}_y$), the per-brand output increases ($\frac{dY(t)}{dt} > 0$); and if more than $\tilde{z}_y$ is offshored (i.e., the offshoring threshold $\bar{z}(t) > \tilde{z}_y$), the per-brand output experiences a decline over time. Moreover, the threshold $\tilde{z}_y$ is below the offshoring steady state z^*, which implies that when global production gets close to its steady state, the output of each individual brand will see a decreasing pattern.[30] Results from numerical simulations are presented in Figure 7. It is obvious from the results that the further the South lags behind the North initially in terms of technology, the more likely that the per-brand output will experience an increase in the short run.

In the long run, the per-brand output always converges to its steady state:

$$Y^* = \frac{\rho\sigma f}{\bar{a}} e^{\frac{1}{2}}\,, \tag{33}$$

which implies that a higher substitutability among varieties will lead to a higher steady state of per-brand output. It is interesting to find that as global production evolves, $Y(t) \geq Y^*$. This indicates an effect of crowding-out with technology improvement and free-entry: the number of variety grows continuously, but at the same time, each individual variety's output may decline. This reflects the interaction between consumers' love for variety and the utility gains they enjoy from enhancements in manufacturing efficiency. Firms could produce more outputs because of the internal technology improvement, but they also face mounting external competition pressure stemming from new entrants that come into the market continuously. The interaction among those forces determines the evolution path of the per-brand production.

The instantaneous utility function given by (1) indicates that the welfare of a representative consumer in a country can be expressed as

$$U_i(t) = \left[\int_0^{J(t)} q_i(j,t)^{\rho}\right]^{\frac{1}{\rho}} = L_i w_i(t) Y(t) J(t)^{\frac{1}{\rho}}\,,\ i \in \{N,\, S\}\,, \tag{34}$$

where $U_i(t)$ represents the welfare level of the representative consumer in country i at time t, and $q_i(j,t)$ denotes the consumption amount of variety j in country i at time t. The national welfare of a country thus is determined by three effects: (1) the income effect, which is indicated by the aggregate national income indicator, $L_i w_i(t)$; (2) the per-variety output effect, represented by $Y(t)$; and (3) the variety effect, which is given by the last term, $J(t)^{\frac{1}{\rho}}$.

With conditions (23′), (24′), (25′), and (32), the two countries' consumer welfares are, respectively,

$$U_S(t) = \rho \times \left(\frac{L_N}{\sigma f}\right)^{\frac{1}{\rho}} \times \frac{\rho\sigma f}{\bar{a}} \times e^{\frac{1}{2}} \times \left[\bar{z}(t)\left(1-\rho\bar{z}(t)\right)^{-\frac{1}{\rho}} e^{\bar{z}(t)^2 - T(t)^2}\right]\,, \tag{35}$$

[30] See Appendix A5 for proof.

and

$$U_N(t) = \left(\frac{L_N}{\sigma f}\right)^{\frac{1}{\rho}} \times \frac{\rho\sigma f}{\bar{a}} \times e^{\frac{1}{2}} \times \left[(1-\rho\bar{z}(t))^{1-\frac{1}{\rho}}\, e^{\bar{z}(t)^2 - T(t)^2}\right]. \tag{36}$$

Dynamics of welfare in the South Examining the South's consumer welfare indicated by (35), it is found that the utility level enjoyed by Southern consumers keeps increasing since the initial time $t = 0$ (i.e., $\frac{dU_S(t)}{dt} > 0$), until global production reaches the steady state.[31] Therefore, for the South, although the world output of each brand may experience a decline over time, the other two effects, i.e., the income effect and the variety effect, are positive and dominate the evolution.[32] With increasing income and a growing number of varieties, the South keeps enjoying welfare improvements while taking more and more production tasks. In the long run, the national welfare of the South reaches its steady state:

$$U_S^* = \frac{L_S}{L_S + L_N} \times \left(\frac{L_S + L_N}{\sigma f}\right)^{\frac{1}{\rho}} \times \frac{\rho\sigma f}{\bar{a}} \times e^{\frac{1}{2}}. \tag{37}$$

Dynamics of welfare in the North For the North, the situation is different. Among the three effects, the national income decreases in the North, which can be explained by (24′). The per-variety output also decreases when global production gets close to the steady state. The only effect that keeps seeing positive growth is the number of varieties. By examining (36), it is found that the national welfare of the North may not be monotonic over time. There is a threshold $\tilde{z}_{UN}$ that serves as a stationary point. If the offshoring threshold ($\bar{z}(t)$) is right at $\tilde{z}_{UN}$, it is the case that $\frac{dU_N(t)}{dt} = 0$. When less than $\tilde{z}_{UN}$ tasks are allocated to the Southern plants for completion ($\bar{z}(t) < \tilde{z}_{UN}$), the consumers in the North experience growth in their consumption utility ($\frac{dU_N(t)}{dt} > 0$). In contrast, when more than $\tilde{z}_{UN}$ tasks are offshored ($\bar{z}(t) > \tilde{z}_{UN}$), the Northern welfare declines over time ($\frac{dU_N(t)}{dt} < 0$). This stationary point is further found to be higher than $\tilde{z}_y$.[33] Therefore, after the per-brand output reaches the peak amount and when it starts to decline, the consumers in the North can still enjoy an increasing utility for an extended period of time, during which the variety effect dominates the other two, while both the national income and the production of each variety decrease. Consequently, Northern consumers' utility has two possible different time paths. In the first case, the South initially receives relatively few tasks, with $\bar{z}(0) < \tilde{z}_{UN}$. The variety effect, and possibly with a positive output effect, is significant so that the Northern consumers get better off in the short run. This trend is reversed after more than $\tilde{z}_{UN}$ tasks are offshored. The other possible path happens when the Southern plants obtain a relatively large range of activities initially beyond $\tilde{z}_{UN}$, which will lead the North to experience persistent declines in welfare until the steady state is

[31] See Appendix A6 for proof.
[32] This could be seen from conditions (23′), (28) and (29).
[33] See Appendix A6 for proof.

reached. No matter which path is realized, the steady-state level of Northern welfare is

$$U_N^* = \frac{L_N}{L_S + L_N} \times \left(\frac{L_S + L_N}{\sigma f}\right)^{\frac{1}{\rho}} \times \frac{\rho\sigma f}{\bar{a}} \times e^{\frac{1}{2}} \tag{38}$$

in the long run. Compared with the initial level $U_N(0)$, the long-run steady-state welfare U_N^* is not necessarily higher or lower. The interaction among the three effects, as well as the initial situation, determines where the final case is.

Figure 8 displays results from simulations with different parameter values. Panel A displays how the variety substitutability may affect the two countries' welfare dynamics. For both countries, the lower the substitutability is, the higher the long-run welfares are at the steady state. This implies that consumers' love for variety is important in the sense that it can strengthen and enlarge the variety effect on national welfare, which is always positive for both countries among the three. Panel B shows the situations with different relative Southern labor endowments. The results show that a large South engaging in offshoring could bring both countries higher welfares, compared to the situation with a small South. Thus, for technologically advanced countries, it is to their benefit to cooperate with developing countries with relatively large factor supplies. Compared with small ones, a large South would have more opportunities for learning in global production,[34] which empowers a wider improvement in technologies. This will lead to more products and varieties being produced and thus to higher national welfare.

4.5 Extreme-End Evolution

In the case of extreme-end evolution, the potential steady state z^* is beyond the range of offshorable tasks ($z^* > 1$), which thus leads the actual steady state of global production to be $z^{*\prime} = 1$ in the long run. The most sophisticated manufacturing task serves as the upper bound of offshoring, where global production saturates. Therefore, all manufacturing tasks will be offshored to the South in the long run under this circumstance – theoretically, a situation that may happen if the South is very large in production factors relative to the North. The North will then focus solely on brand maintenance.

The dynamics of variables are essentially variations of the normal-evolution situation. Instantaneous equilibrium conditions hold here. With both the South's initial technology stock $T(0)$ and the initial offshoring threshold $\bar{z}(0)$ within the task range $(0, 1)$, all aspects of the two economies behave as if the steady state is $z^{*\prime}$ at the beginning. Thus, the dynamics of all variables at first display patterns of convergence similar to the corresponding ones discussed in the normal-evolution case. For the task dynamics, once all task have been offshored to the South ($\bar{z}(t_z) = 1$), further

[34] Consider that the offshoring threshold at the steady state is relatively high.

offshoring will not happen. However, the South's technical capability will still improve for some time, until it matches the range of tasks offshored ($T(t^{*\prime}) = 1, \text{with } t^{*\prime} > t_z$). The evolution paths of tasks and technologies are shown in Figure 9. The left panel displays the potential dynamics if the task range could go beyond $z = 1$. The right panel shows the actual dynamics of the technology stock $T(t)$ and the offshoring threshold $\bar{z}(t)$ over time. Offshoring stops at the most sophisticated task once the threshold is reached. After that, the South's technological capability still improves, although the speed of learning is lower compared with the potential case.[35] The actual steady state will be arrived at when the technology stock in the South matches the offshoring pattern ($T^{*\prime} = z^{*\prime} = 1$).

Consider other variables characterizing the economies, such as the wage rates and the number of varieties. At first, before the South obtains all manufacturing activities to conduct ($\bar{z}(t) < 1$), they all follow the same corresponding paths of evolution as what they would experience if the task range could go beyond $z = 1$. Then when all tasks are offshored, the wage rates in the two countries stop changing. Thus, their evolution paths are not smooth – the time when offshoring hits its upper limit is a singular point when the wage rates reach their bounds and also their final steady states. Given that $z^{*\prime} = 1$, the factor prices in the long run are $w_S^{*\prime} = \frac{\rho}{L_S}$ and $w_N^{*\prime} = \frac{1-\rho}{L_N}$ respectively, with $w_S^{*\prime} < w_N^{*\prime}$.[36] Therefore, the factor-price-equalization condition is not achieved in this case. For the number of varieties, the situation is similar. It stops growing once all manufacturing tasks are allocated to the Southern plants. With all Northern efforts solely focused on branding, the total number of varieties on the market is given by $J^{*\prime} = \frac{L_N}{f}$ in the long run. Figure 10 presents the evolution paths for wage rates and the number of varieties. Essentially, they follow similar patterns as the offshoring threshold $\bar{z}(t)$.

For the per-brand output and welfares, their time paths of evolution are akin to that of the technology stock in the South, $T(t)$, rather than displaying a discontinuous feature. This is because the production efficiency is the key factor determining output and thus national welfare. After the offshoring threshold stops changing, the learning effect continues being positive in the South for some time, but is weaker than it would be if there was no compulsory limit on offshoring. This weaker-than-potential learning effect keeps driving production aspects of the economies to their long-run steady states. Convergence is thus present in these aspects. In Section 4.4, it has been shown that there is no deterministic growth pattern for per-brand output when it moves to its steady state over time. The situation is similar under the circumstance here. When both countries participate in manufacturing activities ($\bar{z}(t) < 1$), the growth path for the per-brand output is the same as if it is moving towards the potential steady state z^*, and it may or may not show positive growth in the short-run. When all manufacturing tasks have been offshored to the South ($\bar{z}(t) = 1$),

[35] This can be understood by examining equation (26).

[36] Consider that $z^* = \frac{L_S}{\rho(L_S+L_N)} > 1$ in this case.

the per-brand output starts to be described by[37]

$$Y(t)' = \frac{L_S f}{L_N \bar{a}} \times e^{-(T(t)-1)^2+\frac{1}{2}}\,, \tag{39}$$

which increases over time while the South improves its technology.[38] In the long run, it converges to its steady state

$$Y^{*\prime} = \frac{L_S f}{L_N \bar{a}} e^{\frac{1}{2}}\,, \tag{40}$$

when the South possesses the most advanced technologies for all tasks. Compared with the normal-evolution case, if the South takes all manufacturing responsibilities, there will be more brands competing on the market in the long run ($J^{*\prime} > J^*$), while less of each brand is supplied ($Y^{*\prime} < Y^*$).

With regard to national welfare, before the offshoring threshold $\bar{z}(t)$ reaches the most sophisticated task, like in the normal-evolution case, the South experiences positive growth since the very beginning of engaging in global production, while the North may see different possible patterns of growth over time. However, during the period of time when all tasks have been offshored and the South is still learning ($\bar{z}(t) = 1$ and $T(t) < 1$), both countries will experience welfare growth. Specifically, with the per-brand output expression derived above, the national welfares of the two countries are, respectively,

$$U_S(t)' = \rho \times \left(\frac{L_N}{f}\right)^{\frac{1}{\rho}-1} \times \frac{L_S}{\bar{a}} \times e^{-(T(t)-1)^2+\frac{1}{2}}\,, \tag{41}$$

and

$$U_N(t)' = (1-\rho) \times \left(\frac{L_N}{f}\right)^{\frac{1}{\rho}-1} \times \frac{L_S}{\bar{a}} \times e^{-(T(t)-1)^2+\frac{1}{2}}\,. \tag{42}$$

Both of them will be increasing monotonically while $T(t) < 1$ and $\frac{dT(t)}{dt} > 0$. When the South's technology stock covers the most sophisticated task, both welfares converge to their steady states:

$$U_S^{\star\prime} = \rho \left(\frac{L_N}{f}\right)^{\frac{1}{\rho}-1} \frac{L_S}{\bar{a}} e^{\frac{1}{2}}\,, \tag{43}$$

and

$$U_N^{\star\prime} = (1-\rho) \left(\frac{L_N}{f}\right)^{\frac{1}{\rho}-1} \frac{L_S}{\bar{a}} e^{\frac{1}{2}}\,. \tag{44}$$

With the discussion above and in Section 4.4, it is found that during the process of evolving, the South continues to see welfare improvement, although the speed of improvement may decrease over

[37]See Appendix A7 for derivation of (39).
[38]See Appendix A7 for proof.

time. For the North, the overall path of welfare development is not deterministic, with the long-run welfare level possibly being higher or lower than the initial situation when firms start to offshore. Numerical simulations are performed for per-brand output as well as national welfare. The results are shown in Figure 11. Panel A displays the simulation results for the per-brand output. After all manufacturing tasks are offshored to the South, the learning effect stimulates another round of output growth. For the national welfare results displayed in Panel B, the South sees positive increases in national utility during the whole evolution process. For the North, although the initial growth pattern is uncertain, after all manufacturing tasks are taken by the South, it will also experience positive growth – the learning effect will benefit both countries by increasing the output of each brand.

4.6 Static Equilibrium Cases

Except for the dynamic situations where countries see evolutions of their multinational operations, there are two other static equilibrium possibilities: Case III – static normal offshoring, in which the South's initial technology stock is sufficiently high so that global production reaches its normal steady state $z^* \in (0, 1)$ at the initial time $t = 0$; and Case IV – static complete offshoring, where since the very beginning, the South is essentially equal to the North in terms of technology ($T(0) = 1$), and the factor endowment of the South is abundant so that all tasks are offshored to the South since $t = 0$.

The static normal offshoring situation is likely to happen if the South is technically capable and relatively small, so that $T(0) \geq z^*$. When this situation prevails, there will be no room for the South to learn, as the country is not working on any activities at which it is not already skilled. Therefore, the world equilibrium stays at z^* since $t = 0$, with all aspects of the two economies at their steady states since the initial time.

The other static case is essentially an offshoring situation between two Northern countries. They have the same technology for every task, and one of them is relatively large such that $z^{*\prime} > 1$ and $\bar{z}(0) = 1$. If this is true, then the country with abundant factor endowments will be specializing in manufacturing, while the other one puts all its efforts into branding. Learning is not present here as both countries already possess the best technologies since the very beginning. Therefore, this pattern of specialization will be held as long as their factor supplies remain stable. The two economies are at the steady states characterized by $z^{*\prime} = 1$.

5 Gains from Offshoring

The discussion so far focuses on the time dynamics of the evolution processes of the two economies. It has been shown that compared with the initial time when the two countries start engaging in offshoring, the South continues to be better off over time and in the long run, while the North may or may not see higher utilities in the steady state. Then the question becomes whether the countries should participate in global production by offshoring or accepting offshored activities, or whether they should remain closed and supply all products domestically.

5.1 Equilibrium under Autarky

The consumer preferences are still identical in the two countries under autarky, described by the same C.E.S. function given by (1). The production of goods, as well as the two countries' production technologies, is also the same as defined in Section 2.3. Namely, the two economies start with the situations under autarky the same as under offshoring. Under autarky, countries do not have information about each other, and thus are not able to acknowledge their technological differences in production. Without seeing the gap, the South does not have incentives for learning from production, though it conducts all activities under this circumstance. Therefore, under autarky, there is no production efficiency improvement over time as what we have seen under offshoring. Since countries' behaviors do not change over time, the time index t could thus be omitted here.

In autarky, both countries have to conduct all activities on the task range $[0, 1]$ to produce the final goods, and both of them also need to pay the fixed branding costs, which are assumed to be the same (f), to make the products viewable on the market. Let E_i^A denote the national expenditure on final products in country i under autarky, defined as the sum of factor payments in that country:

$$E_i^A = w_i^A L_i \, , \, i \in \{N, \, S\} \, , \tag{45}$$

where w_i^A denotes the autarky wage rate of country i at time t.

Assume that the fixed cost of brand establishment is the same across countries: $f_S = f_N = f$. The labor market clearing conditions for the two economies under autarky are given by

$$\begin{aligned} South: & \int_0^1 x_S^A(z) a(z, 0) dz + J_S^A f = L_S \, , \\ North: & \int_0^1 x_N^A(z) \bar{a}(z) dz + J_N^A f = L_N \, , \end{aligned}$$

where $x_i^A(z)$ denotes the total amount of task z conducted in country i by all firms there, and J_i^A denotes the number of brands on the market in country i, both under autarky. The task demands could be expressed as:

$$x_S^A(z) = \frac{\rho E_S^A}{w_S^A a(z,0)} = \frac{\rho L_S}{a(z,0)}\,,$$
$$x_N^A(z) = \frac{\rho E_N^A}{w_N^A \bar{a}(z)} = \frac{\rho L_N}{\bar{a}(z)}\,.$$

With the task demands, the labor market clearing conditions become:

$$\textit{South}: \int_0^1 \rho L_S dz + J_S^A f = L_S\,, \tag{46}$$

$$\textit{North}: \int_0^1 \rho L_N dz + J_N^A f = L_N\,. \tag{47}$$

The numbers of varieties in the markets of the two countries thus are determined to be:

$$J_i^A = \frac{L_i}{\sigma f}\,,\ i \in \{N,\, S\}\,. \tag{48}$$

Given the production function (7), together with the task demand expressions, technology specifications (8) and (9), and condition (48), the per-brand outputs under autarky are found to be

$$Y_S^A = \frac{\rho\sigma f}{\bar{a}} \times e^{-(T(0)-1)^2+\frac{1}{2}}\,, \tag{49}$$

and

$$Y_N^A = \frac{\rho\sigma f}{\bar{a}} \times e^{\frac{1}{2}}\,. \tag{50}$$

Together with the number of varieties J_i^A, this implies that the national utility levels of the two countries are, respectively,

$$U_S^A = \left(\frac{L_S}{\sigma f}\right)^{\frac{1}{\rho}} \times \frac{\rho\sigma f}{\bar{a}} \times e^{-(T(0)-1)^2+\frac{1}{2}}\,, \tag{51}$$

and

$$U_N^A = \left(\frac{L_N}{\sigma f}\right)^{\frac{1}{\rho}} \times \frac{\rho\sigma f}{\bar{a}} \times e^{\frac{1}{2}}\,, \tag{52}$$

which remain constant over time.

5.2 Gains from Normal Offshoring

Under normal offshoring, global production is characterized by the participation of both countries in manufacturing. In the short-run and in the long-run, the production tasks are allocated to both the South and the North. During the process of evolution, the national welfares are given by (35) and (36). For the South, comparing the welfare under offshoring and the welfare under autarky, it is found that

$$\frac{U_S(t)}{U_S^A} = \left[\frac{L_N}{L_S} \times \frac{1}{1-\rho\bar{z}(t)}\right]^{\frac{1}{\rho}} \times \left[\rho\bar{z}(t) \times e^{\bar{z}(t)^2 - T(t)^2} \times e^{(T(0)-1)^2}\right] . \tag{53}$$

Countries' welfare levels essentially depend on the number of varieties available on the market and the consumption or output of each product. The first term of the equation above indicates the variety effect (the extensive margin), while the second implies the output (or consumption) effect (the intensive margin). When the South opens to offshoring, the Southern labor that was working in the branding sector is withdrawn and reallocated into manufacturing activities. Therefore, the number of goods available is no longer totally controlled within the country, while the North takes over branding responsibilities. This international shift of branding efforts adds uncertainty to how many varieties could be enjoyed by consumers initially when countries start to engage in global production. Therefore, initially the South may or may not be able to obtain the same number of varieties as they could under autarky. Then as time elapses, the situation improves. While more and more tasks are reallocated to the South which enables more Northern efforts to be put on branding, both countries' consumers could enjoy more variety options over time. In the long run, it is found that $\frac{J^*}{J_S^A} = \frac{L_S + L_N}{L_S} > 1$, which indicates that with offshoring and learning, the South could enjoy more varieties than they could under autarky. By participating in global production, the South not only obtains better technologies, but also enjoys more options for consumption. This variety effect contributes to the long-run welfare of the country.

Concerning the output effect, it is not definite that the South could enjoy more consumption on each brand at the initial time when it starts producing for the whole world. The output also depends on the North's conditions. In the long run, the output effect indicated by the second term of (53) turns out to be indefinite as well.[39] However, combining the two effects, both the variety and the output effects, it is found that

$$\frac{U_S^*}{U_S^A} = \left[\frac{L_S + L_N}{L_S}\right]^{\frac{1}{\rho}-1} \times e^{(T(0)-1)^2} > 1 . \tag{54}$$

Therefore, although the gain from engaging in global production is not definite for the South in the short run, it will certainly benefit the South in the long run. By accepting offshored activities and by learning in the process of conducting them, the South could end up enjoying more consumption choices, which dominates the other welfare effect.

[39]When the global economy reaches the steady state z^*, the second term becomes: $\rho z^* \times e^{(T(0)-1)^2} = \frac{L_S}{L_S + L_N} \times e^{(T(0)-1)^2}$, which is not necessarily greater or less than 1.

Consider the situation for the North. By comparing (36) and (52), it is the case that

$$\frac{U_N(t)}{U_N^A} = \left[\frac{1}{1-\rho\bar{z}(t)}\right]^{\frac{1}{\rho}} \times \left[(1-\rho\bar{z}(t)) \times e^{\bar{z}(t)^2 - T(t)^2}\right] > 1\,, \tag{55}$$

which is greater than 1 since the initial time of offshoring ($t = 0$). The first term in the equation is the variety effect for the North, while the second indicates the consumption or output effect. By allocating certain manufacturing tasks to the South, the North is able to focus more efforts on branding since the very beginning of offshoring. Thus, the variety effect is positive initially and will continue strengthening over time as more and more production tasks are offshored. The other one, the per-brand consumption effect, is not deterministic for the North, but it is dominated by the variety effect, which then leads to a situation in which the North overall is better off than under autarky, since the very start of engaging in global production as the source of offshoring. In the long run, the utility comparison shows that the North ultimately benefits from offshoring:

$$\frac{U_N^*}{U_N^A} = \left[\frac{L_S + L_N}{L_N}\right]^{\frac{1}{\rho}-1} > 1. \tag{56}$$

In sum, from the analyses above, participating in global production is beneficial for both countries. Even if they may experience short-term challenges when they initially join in the global production network and/or during the process in which they are evolving to the steady state, they both will ultimately see positive gains and rewards from offshoring. The results from simulations clearly demonstrate this pattern, and are shown in Figure 12. In the simulation, although both countries initially experience a cut in per-brand consumption when they join in global production, they do see welfare gains in the long run compared with autarky. This further confirms that for the static normal offshoring case, although learning is not present, both countries can still earn positive gains by forming a multinational production network.

5.3 Extreme-End Offshoring

In the case of extreme-end offshoring in the long run, all manufacturing tasks are ultimately offshored to the South. During the process of evolution, as discussed in the previous section, the paths of welfare gains may not be deterministic for the countries. Consider the long-run situation at the steady state. By comparing (43) and (51), as well as (44) and (52), it is the case that

$$\frac{U_S^{*\prime}}{U_S^A} = \left(\frac{L_N}{L_S} \times \frac{1}{1-\rho}\right)^{\frac{1}{\rho}-1} \times e^{(T(0)-1)^2}\,, \tag{57}$$

and

$$\frac{U_N^{*\prime}}{U_N^A} = \frac{L_S}{L_N} \times \frac{1}{\rho} \times (1-\rho)^{2-\frac{1}{\rho}} \,. \tag{58}$$

Close examinations show that on one side, there is no deterministic relationship between $U_S^{*\prime}$ and U_S^A, which implies that with extreme-end offshoring, although all tasks are ultimately offshored to the South, the country does not necessarily gain in the long run. The main reason is that the variety effect is found not to be necessarily significant in the long run in this case.[40] On the other side, the North does see positive gains from offshoring in the long run ($\frac{U_N^{*\prime}}{U_N^A} > 1$).[41] Thus, under extreme-end offshoring, the North does experience welfare gains compared with autarky. Figure 13 displays the result of the simulations, which clearly show the patterns discussed here.

6 Empirical Investigation

A unique and central prediction of the theory is that global production converges to the steady state where no further offshoring happens. This evolution process involves a shift of value added in the final industrial products from the North to the South. For the overall industry, the final output value in global production is given by

$$J(t)p(j,t)Y(j,t) = w_S(t)L_S + w_N(t)L_N \,, \tag{59}$$

with all manufacturing tasks contributing value to the final products. Within the final industrial output value, the shares of the two countries are, respectively,

$$\text{VR}_N(t) = \frac{w_N(t)L_N}{p(j,t)Y(j,t)J(t)} = 1 - \rho\bar{z}(t) \,, \tag{60}$$

and

$$\text{VR}_S(t) = \frac{w_S(t)L_S}{p(j,t)Y(j,t)J(t)} = \rho\bar{z}(t) \,, \tag{61}$$

which are defined as the value-added ratios (VRs) hereafter. The growth pattern of the Southern value-added portion VR_S thus exactly maps the convergence pattern of task-offshoring. For an arbitrary industry i, the change in its $\text{VR}_{S,i}(t)$ captures and reflects the change in its $\bar{z}_i(t)$. As analyzed in Section 4.1, the task offshoring threshold $\bar{z}(t)$ grows and converges to its steady state z^* over time. Even if in the case of extreme-end evolution, it goes through the convergence process until it hits the upper limit of offshorable activities. Therefore, the theory provides a central prediction on VR_S – it increases over time at a decreasing rate. "Moving up the value chain" thus could be translated into an increase in the South's share of value added in the total value

[40] $\frac{J^{*\prime}}{J_S^A} = \sigma \times \frac{L_N}{L_S}$, which is not necessarily greater than 1 here.

[41] See Appendix A8 for proof.

of industrial output (VR_S) over time, and the rate of this increase declines gradually. This is the theoretical prediction and a testable hypothesis as to how the VR_S should behave over time. By considering each industry as a random draw of the representative industry examined in the model, I can thus test the theory and its prediction by examining the dynamics of VR_S.

6.1 Approach

Multinational Data Data on multinational subsidiaries across industries in the South are employed here for investigation. For a given Southern country that hosts multinational operations, the rest of the world is treated as a whole as an aggregate North. The main reason for focusing on multinational subsidiaries is that multinational operations and subsidiaries are the closest approximations of global production in the theory. Although both vertical and horizontal offshoring patterns are present in reality, a common acknowledgment is that multinational subsidiaries in a host country generally only conduct some of the production tasks, rather than replicating the whole complete production processes. Therefore, multinational subsidiaries could provide a reasonable base for the empirical investigation. Certainly, domestic and local firms in a host country could be participating in the global production network, but distinguishing them from others is difficult, and their operations are in fact mixed in many circumstances. Multinational subsidiaries thus serve as a better representation than local firms for global production in the South.

By focusing on multinational subsidiaries, local firms in the host country could serve as a countercheck in the investigation. For those domestic firms that are not multinational subsidiaries, the value-added ratios constructed from their performance data are not expected to follow the convergence pattern of VR_S. Thus, examining local firms as a counter group could help to check whether the findings based on multinational subsidiaries represent a nation-wide trend or are specific to global production networks.

Multinational subsidiaries are aggregated at the industry level to form multinational industries (MIs), which closely approximate the concept of industry in the theory. Note here that it is not required that an MI in the South involves the very last task of producing the final consumer output. For example, an MI could be defined as a "tire" industry while the very final products are vehicles. Thus, by MI, I mean here an industry of multinational production constructed in a given host country. The VR_S of an MI is thus computed as

$$\text{VR}_{S,i}(t) = \frac{\sum_{j\in\Omega_i(t)} p_j(t)y_j(t) - \sum_{j\in\Omega_i(t)} M_j(t)}{\sum_{j\in\Omega_i(t)} p_j(t)y_j(t)}\,, \tag{62}$$

where i and j are industry and firm indicators, respectively; $\Omega_i(t)$ is the set of subsidiaries in industry i in the host country; $p_j(t)y_j(t)$ stands for the value of output; and $M_j(t)$ denotes the value of intermediate inputs. Here, $M_i(t) = \sum_{j \in \Omega_i(t)} M_j(t)$ could cover intermediate inputs from both domestic sources and foreign sources, since they are not different as non-value-added entities for the Southern MIs. The labor concept in the theory should be viewed as a composite factor of production in reality, which essentially contains all efforts that are used in production.

Convergence of $\mathbf{VR}_S$ Using panel data of MIs over time, the convergence dynamics of VR_S can be tested (VR for short hereafter). Specifically, given the theoretical discussions, the convergence pattern of VR can essentially be characterized by

$$\Delta \text{VR}_{i,\tau} = \psi_1 \text{VR}_{i,0} + \psi_2 \beta_i + \psi_3 \tau + \eta' X_{i,\tau} + \epsilon_{i,\tau}, \tag{63}$$

where τ is a time indicator starting from 1 for the first time period covered in the data, $X_{i,\tau}$ is a vector of control variables and $\epsilon_{i,\tau}$ is the error term. The theory predicts that $\psi_1 < 0$, $\psi_2 > 0$, and $\psi_3 < 0$. The specification (63) may be affected by the tendency of VR to mechanically revert to its mean. A negative shock at $\tau = 0$ may not have a persistent effect in following periods, which may lead to a spurious convergence captured by the regression. To address this concern, VR_i from different years are used for robustness checks.

Two Margins of Changes In the theory, the convergence of task offshoring essentially stems from the learning effect, which happens at the firm level and drives the progress of the whole industry. To investigate this idea, I decompose changes in ΔVR into two margins: (1) the within-subsidiary margin, which captures the change in subsidiary VR with constant relative subsidiary sizes; and (2) the cross-subsidiary margin, i.e., the change in relative subsidiary size with the VR constant. An empirical pattern consistent with the theory is that the VR convergence in MIs is driven by the first margin. The decomposition method is as follows:

$$\Delta \text{VR}_{i,\tau} = \sum_{j \in \Omega_i} \Delta \text{VR}_{j,\tau} \left(\frac{\lambda_{j,\tau} + \lambda_{j,\tau-1}}{2} \right) + \sum_{j \in \Omega_i} \Delta \lambda_{j,\tau} \left(\frac{\text{VR}_{j,\tau} + \text{VR}_{j,\tau-1}}{2} \right) , \tag{64}$$

where $\lambda_{j,\tau} = \frac{y_{j,\tau}}{y_{i,\tau}}$. The first term is the within-subsidiary margin, and the second is the cross-subsidiary margin. Both margins are investigated using the regression (63).

The empirical approach could be applied to data from a Southern country that meets the following requirements: (1) being a host country for multinational production operations in multiple industries for a reasonably long time span, (2) regularly and consistently reporting firm-level data that are representative of the multinational operations, and (3) reporting corresponding data that contain information on industrial classification, value-added, value of output and other industrial characteristics. It may be ideal to use data on the Southern countries that have abundant production factors and that host relatively large volumes of multinational operations – such countries are relatively far from their steady states in global production and thus the patterns can be easily detected. In the following sections, I provide an empirical investigation using this approach with data from China on multinational operations.

6.2 Data

The dataset used here covers the population of large- and medium-sized industrial enterprises in China with annual revenues of five million RMB or more, for a 10-year time period between 1998-2007.[42] It is drawn from the Annual Survey of Industrial Firms (ASIF) conducted by the National Bureau of Statistics of China. The ASIF is the main source of the industrial section of the China Statistical Yearbooks. Firms covered in the ASIF account for more than 90 percent of the total industrial output and more than 70 percent of the whole industrial workforce of China.[43] The ASIF reports different types of firms such as state, private, and foreign firms. The foreign classification is further categorized by the source of funding and the ownership. Firms categorized as wholly foreign-owned (non-HMT[44]) enterprises are extracted from ASIF and are defined as multinational subsidiaries here. Table 1 shows the summary statistics for multinational subsidiaries. During the 10 years covered, there were significant increases in multinational operations as indicated by the statistics. Their shares of output and export in the whole manufacturing sector of China almost quadrupled from 1998 to 2007. Concerning industrial VR values, the mean VR rose from 0.265 to 0.301, a 13.6% increase over the 10 years.

Figures 14-16 plot the trend of VR to the key explanatory variables in the specification (63). Figure 14 shows time trends of the VRs during the 10 years. Panel A presents the big picture with the VRs of all four-digit industries pooled together. Panel B classifies the four-digit industries into two-digit industries and plots the VR trends in eight of them that are relatively large in the constructed MIs. It is clear that industries experienced positive VR growth over time. The industry-wide pattern is not unique for the several industries presented here. Similar patterns show up in almost all industries in the dataset. Figure 15 demonstrates that industries with higher learning intensities experience a higher positive growth over time. Figure 16 plots the VR growth over the ten years against the initial value of VRs. It is obvious from the charts that subsidiaries with relatively high initial VRs grew relatively slowly over time.

Figure 17 demonstrates the decomposition results of the VR changes at the two-digit industry level over the 10 years.[45] The decomposition method (64) requires that subsidiaries included for

[42]It approximately equals $600,000 for the time period covered.

[43]Refer to Brandt, Van Biesebroeck and Zhang (2012) for a more detailed and comprehensive discussion.

[44]HMT stands for Hong Kong, Macau, and Taiwan.

[45]Table A1 shows the industrial classification codes and descriptions, as well as their corresponding training/learning intensities and capital-labor intensities.

computation need to be present in both periods. Therefore, entrants and exiters that show up in only one time period are excluded. The decomposition could be performed at any aggregate level of industry and for any time span. From Figure 17, the within-subsidiary margin appears to be the main source of VR changes over time. Most changes in VR are positive, but negative ones also exist, indicating the possibility that shocks affect multinational operations.

These observations shown above provide snapshots of the overall trends and characteristics of VR over time, which generally match the predictions of the theory. In the following section, further investigations are performed using regression analyses.

6.3 Results

The decomposition (64) is conducted at the four-digit industry level and with a two-year time span. Given industry i and year τ, the dependent variable in (63) could be the total change of in $\text{VR}_{i,\tau}$, the within-subsidiary margin $\sum_{j\in\Omega_i}\Delta\text{VR}_{j,\tau}\left(\frac{\lambda_{j,\tau}+\lambda_{j,\tau-1}}{2}\right)$, or the cross-subsidiary margin $\sum_{j\in\Omega_i}\Delta\lambda_{j,\tau}\left(\frac{\text{VR}_{j,\tau}+\text{VR}_{j,\tau-1}}{2}\right)$. Table 2 presents a snapshot of the average change in VR over time and the two margins obtained from the decomposition. The within-subsidiary margin dominates the cross-subsidiary margin in all years here.

Table 3 reports the regression results from (63) with the total two-year change in VR as the dependent variable. Column (1) shows the baseline results. They are in line with the theory predictions. VR change is higher if the initial VR is lower; it decreases over time; and higher employee training intensities do have a positive and significant influence on the VR change. In column (2), capital-labor intensity is included as a control variable, and the results are similar as in the baseline case. The result on capital intensity shows that industries with higher capital intensities tend to show higher growth, and the pattern is confirmed in columns (3) and (4), where the VR changes are divided into two groups with high and low capital-labor intensities, respectively.[46] The coefficient of τ is insignificant for the group of industries with low capital intensities. In the regressions, industry-dummies are included to address the issue that there may be industry-specific and non-time variant characteristics that affect the VR changes over time.[47]

Table 4 applies the regression specification (63) to the within-subsidiary margin obtained from decomposition of the two-year changes in VR. The results are consistent with the theory predictions as well as the results in Table 3. The within-subsidiary margin shows similar patterns of convergence as the total changes in VR. Table 5 then investigates the convergence pattern of the other margin, the cross-subsidiary margin, using the same regression. The results imply that the

[46]The groups are defined based on their capital intensities: industries in the high- (low-) intensity group are with capital-labor intensities above (below) the mean of the measure.

[47]As in the theory, there are time-invariant and industry-specific characteristics that affect the development of task-offshoring over time (i.e., $\frac{d\bar{z}(t)}{dt}$ depends also on parameters such as ρ).

cross-subsidiary margin does not display a significant convergence pattern as for the total ΔVR and the within-subsidiary margin. The coefficients are much less significant and their values are much smaller than for the other two margins. Comparing the results in Tables 4 and 5, it is found that the convergence of VR is mainly driven by the convergence of the within-subsidiary margin. The explanatory power of the independent variables for ΔVR primarily comes from their explanatory capabilities in addressing the within-subsidiary margin. This result is consistent with the theory in the sense that the growth in industrial VR mainly stems from the within-firm developments. Furthermore, in Tables 3-5, the constant terms are reported for those regressions. For ΔVR and the within-subsidiary margin, the constant terms are positive and significant when the regressions are run on the full sample. This indicates that there is a positive VR development which is primarily driven by the within-subsidiary changes. Again, the cross-subsidiary shows different patterns on the constant terms.

There may be concerns that the decreasing rate of VR growth over time might be caused by wage-rate changes. In the theory, wage levels in the South experience a gradual increase when global production evolves over time. To address the concerns here, a wage-rate index for China is constructed, and the regressions above are repeated with the wage-rate index added as a control variable. The results are shown in Table 6. The results suggest negative effects of wage rates on VR growth in China. The general pattern is the same as in the previous results. Independent variables exhibit strong explanatory powers for both the overall VR change and the within-subsidiary margin, but not for the cross-subsidiary margin. The time indicator τ is omitted here because the wage-rate index displays a strong time trend, which would create a problem of multicollinearity if both time and wage rates are included in the regressions.

As mentioned earlier, the specification (63) may be affect by the tendency of VR to mechanically revert to its mean, which may lead to spurious convergence patterns being captured by the results. To address this issue, regressions are re-conducted with different initial years, i.e., the time index τ starts from other initial years rather than 1998, which is the earliest year covered in the dataset and also the initial year used in the regressions above. The reason is that shocks may hit an industry and make its VR fluctuate in a short time, but it would not constantly and consistently hit it over the years. Table 7 presents the results, using 1999, 2001, 2003, and 2005 as the starting year, respectively. The results show that the convergence patterns are similar to those in the main regressions. This confirms that our results obtained above are not significantly affected by shocks.

Since the focus is mainly on multinational operations, domestic and local industrial operations can thus serve as groups for counterchecks. Table 8 replicates the primary regressions on the domestically-funded and the HMT-owned counterparts of MIs – the conceptual industries consisting of only domestically-funded or HMR-owned entities. The results turn out to be quite different from what has been shown for MIs. The local production does not show the convergence pattern that MIs do, either for the total change in VR or the within-subsidiary margin. Particularly, the coefficients on employee training intensity are negative, which is the opposite of the case with MIs. For HMT-owned operations, the situation is similar. Except for the initial VR, no other explanatory variable shows significant explanatory powers. Compared with domestic firms, the HMT-owned production displays patterns closer to the multinational operations, which may indicate that it is in character more similar to multinational subsidiaries.

7 Conclusion

This paper develops a unified framework for understanding movement along the value chain of global production. The global value chain of an industry is represented by a sequence of production tasks that may be fragmented and spread across countries, with each task adding value to the final industrial product. Tasks are ranked by their degree of technological sophistication, which enables "moving up the value chain" to be neatly defined as an upgrading in the set of tasks that a country, an industry, or a firm conducts. The pattern of upgrading may vary for different entities.

The dynamics of tasks stemming from learning is the central mechanism of this framework. By participating in global production and conducting tasks that are relatively simple but moderately beyond their technological capabilities, the Southern subsidiaries are able to learn and improve their production efficiencies over time, which then attracts multinational enterprises to allocate more activities to the country. Gradually, the scope of tasks undertaken by the South expands and covers increasingly sophisticated activities, while the Northern coverage of the task spectrum, although narrower over time, concentrates on the most complex activities. This self-reinforcing process of moving up the value chain continues until the South's technological capability catches up and matches the tasks offshored to the country.

The task dynamics that occur through learning also give rise to changes in other aspects of the global economy. The theory examines the dynamics of factor prices, number of varieties, outputs, and national welfare. By enjoying an increasing number of consumption choices in the market, both countries could benefit from the learning in the South. In the long run, global welfare is enhanced. Furthermore, I find that countries would be rewarded by participating in global production, compared with autarky. Although short-term challenges may be present in the process, in the long run the gains dominate and are shared by all countries. Therefore, it is beneficial for countries to participate in the global value chain and evolve together.

The model provides a unique prediction for how the less advanced country's share of value added in an industry should behave over time – "moving up the global value chain" naturally translates into an increasing share of value added in total output value over time, with its speed declining gradually. I apply a micro-founded empirical approach to test the dynamics of VR of global production contributed by the South. Evidence supporting the theoretical predictions is found by applying the approach to data from China on multinational operations.

In developing this task-based model of global production, several limitations are involved. These may be addressed in future research. First, I have not specifically considered innovation in this framework. In other words, the learning-by-doing effect could be understood as being conditional on innovation. I have not incorporated the possibility that innovations occur in the technologically-advanced country, which could create new gaps in production efficiency between the countries. This change may then lead to different dynamics in global production, such as the "reshoring" phenomenon that has recently begun to arise. To capture such ideas in the future, I will need to enrich the framework to allow for further innovation possibilities.

The second limitation relates to firm identification. Symmetric firms have been defined in the model, performing the same sets of tasks. This offers convenience to the theoretical analyses here, but it may sacrifice flexibility in discussing firm dynamics. Another possible avenue for future research is to consider firms as collections of tasks that are not necessarily symmetric, with each conducting a certain range of tasks along the spectrum. This will provide opportunities to study the firm dynamics over time and will also create further possibilities for empirical investigation.

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Mathematical Appendices

A.1 Derivation of Equation (26)

By equation (13) and (19),

$$L_S(z,t) = \frac{\rho}{w_S(t)} \,.$$

Recall that $L_S(z,t) = 0$ for all $z > \bar{z}(t)$ at any time t and that all Southern plants are symmetric. Together with (23′) and (25′), the technology accumulation function (12) turns to

$$\frac{dT(t)}{dt} = \int_{T(t)}^{\bar{z}(t)} \frac{\beta L_S(z,t)}{J(t)} = \int_{T(t)}^{\bar{z}(t)} \frac{\beta}{J(t)} \frac{\rho}{w_S(t)} dz = \int_{T(t)}^{\bar{z}(t)} \frac{\beta}{J(t)} \frac{L_S}{\bar{z}(t)} dz$$

$$= \frac{\beta L_S}{J(t)} \frac{\bar{z}(t) - T(t)}{\bar{z}(t)} = \beta\sigma f \left(1 - \rho\bar{z}(t)\right) \frac{L_S}{L_N} \frac{\bar{z}(t) - T(t)}{\bar{z}(t)} \,.$$

A.2 Derivation of $\frac{d^2T(t)}{dt^2}$ and $\frac{d^2\bar{z}(t)}{dt^2}$

(i). Derivation of $\frac{d^2T(t)}{dt^2}$

By examining (26), it is obtained that

$$\frac{d^2T(t)}{dt^2} = -\frac{\beta L_S}{J(t)} \times \frac{1}{\bar{z}(t)^2} \times \left(\bar{z}(t)\frac{dT(t)}{dt} - T(t)\frac{d\bar{z}(t)}{dt}\right) - \beta\sigma\rho f \times \frac{L_S}{L_N} \times \frac{\bar{z}(t) - T(t)}{\bar{z}(t)} \times \frac{d\bar{z}(t)}{dt} \,.$$

It is easy to tell that $\frac{d^2T(t)}{dt^2} < 0$ before it reaches the steady state.

(ii). Derivation of $\frac{d^2\bar{z}(t)}{dt^2}$

From examining (26) and (27), $\frac{d^2\bar{z}(t)}{dt^2}$ can be derived as:

$$\frac{d^2\bar{z}(t)}{dt^2} = \left\{ -\frac{\beta L_S}{J(t)\bar{z}(t)} \times \frac{1}{1 + 2\bar{z}(t)\left(1 - \rho\bar{z}(t)\right)} - \frac{\beta L_S}{J(t)} \times 2\left(\bar{z}(t) - T(t)\right) \times \frac{2\left[1 - \rho\bar{z}(t)\right]^2 + \rho}{\left[1 + 2\bar{z}(t)\left(1 - \rho\bar{z}(t)\right)\right]^2} \right\} \times \frac{d\bar{z}(t)}{dt} -$$
$$\beta\sigma\rho f \times \frac{L_S}{L_N} \times \frac{\bar{z}(t) - T(t)}{\bar{z}(t)} \times \frac{2\bar{z}(t)\left(1 - \rho\bar{z}(t)\right)}{1 + 2\bar{z}(t)\left(1 - \rho\bar{z}(t)\right)} \times \frac{d\bar{z}(t)}{dt} \,.$$

It is not hard to tell from the result that $\frac{d^2\bar{z}(t)}{dt^2} < 0$.

A.3 Derivation of $\frac{d\dot{\bar{z}}(t)}{d\bar{z}(t)}$

Examining (27), together with (22′) and (26), it is found that

$$\frac{d\dot{\bar{z}}(t)}{d\bar{z}(t)} = -\beta\sigma f \times \frac{L_S}{L_N} \times \frac{1}{\bar{z}(t)} \times \frac{1-\rho\bar{z}(t)}{1+2\bar{z}(t)\left(1-\rho\bar{z}(t)\right)} - \beta\sigma f \times \frac{L_S}{L_N} \times \ln\left(\frac{L_S}{L_N} \times \frac{1-\rho\bar{z}(t)}{\rho\bar{z}(t)}\right) \times \frac{\left(1-\rho\bar{z}(t)\right)\left[2\rho+2\left(1-\rho\bar{z}(t)\right)\right]}{\left[1+2\bar{z}(t)\left(1-\rho\bar{z}(t)\right)\right]^2},$$

which is negative before $\bar{z}(t)$ reaches the steady state.

A.4 Derivation of Condition (29)

By condition (25′),

$$\frac{dJ(t)}{dt} = \frac{L_N\rho}{\sigma f} \times \frac{1}{\left[1-\rho\bar{z}(t)\right]^2} \times \frac{d\bar{z}(t)}{dt},$$

which is positive before $\bar{z}(t)$ arrives at its steady state. Further examination of the condition, together with (26), (27) and the conditions derived in Appendix A.2, shows that

$$\frac{d^2J(t)}{dt^2} = \frac{\beta\rho L_S}{1-\rho\bar{z}(t)} \times \frac{d\bar{z}(t)}{dt} \times \frac{1}{\bar{z}(t)\left[1+2\bar{z}(t)\left(1-\rho\bar{z}(t)\right)\right]^2} \times \left\{2\bar{z}(t)\left(1-\rho\bar{z}(t)\right)\left[2\left(\bar{z}(t)-T(t)\right)\left(2\rho\bar{z}(t)-1\right)-1\right]-1\right\},$$

which is negative when $\bar{z}(t)$ moves to its steady state.

A.5 Dynamics of Per-brand Output

(i). Derivation of Per-brand Output – (32)

Given the production function (7) and the symmetry of firms, together with conditions (8), (11), (13), (14), (19), and equilibrium conditions (22′), (23′), (24′), and (25′), it is the case that

$$\begin{aligned}\ln Y(t) &= \int_0^1 \ln x(z,j,t)dz \\ &= \int_0^{T(t)} \ln\left(\frac{1}{J(t)}\frac{\rho}{w_S(t)\bar{a}e^{-z}}\right)dz + \int_{T(t)}^{\bar{z}(t)} \ln\left(\frac{1}{J(t)}\frac{\rho}{w_S(t)\bar{a}e^{z-2T(t)}}\right)dz + \\ &\quad \int_{\bar{z}(t)}^1 \ln\left(\frac{1}{J(t)}\frac{\rho}{w_N(t)\bar{a}e^{-z}}\right)dz \\ &= \bar{z}(t)^2 - T(t)^2 + \frac{1}{2} + \ln\left(\frac{\rho\sigma f}{\bar{a}}\right).\end{aligned}$$

This implies that the per-brand output $Y(t)$ is

$$Y(t) = \frac{\rho\sigma f}{\bar{a}} e^{\frac{1}{2}} \times e^{\bar{z}(t)^2 - T(t)^2}.$$

(ii). Time Dynamics of Per-brand Output

Given the per-brand output expressed by (32),

$$\frac{dY(t)}{dt} = Y(t) \times 2\left[\bar{z}(t)\frac{\bar{z}(t)}{dt} - T(t)\frac{dT(t)}{dt}\right].$$

There is no deterministic relationship between $\bar{z}(t)\frac{\bar{z}(t)}{dt}$ and $T(t)\frac{dT(t)}{dt}$, thus the path of $Y(t)$ may not be monotonic. With ($22'$) and (27), it is found that there exists a stationary point $\tilde{z}_y$, which is determined by the following equation:

$$\frac{z}{1 + 2z(1 - \rho z)} = \frac{1}{2}\ln\left[\frac{L_S}{L_N}\frac{1 - \rho z}{\rho z}\right],$$

that at $\tilde{z}_y$, $\frac{dY(t)}{dt} = 0$. The solution is unique, as the left-hand side of the equation above monotonically increases in z, while the right-hand side of the equation monotonically decreases in z. By examining the values of the left-hand-side as well as the right-hand-side of the equation above at z^*, it is found that it must be the case: $\tilde{z}_y < z^*$. Similarly, the values examined at $z = 0$ indicate that $\tilde{z}_y > 0$.

A.6 Dynamics of National Welfares

(i). Derivation of $\frac{dU_S(t)}{dt}$

Given (35), together with condition (27),

$$\begin{aligned}\frac{dU_S(t)}{dt} =& \rho \times \left(\frac{L_N}{\sigma f}\right)^{\frac{1}{\rho}} \times \frac{\rho\sigma f}{\bar{a}} \times e^{\frac{1}{2}} \times (1 - \rho\bar{z}(t))^{-\frac{1}{\rho}} \times e^{\bar{z}(t)^2 - T(t)^2} \times \frac{d\bar{z}(t)}{dt} \times \\ & \left\{\frac{(1 - \rho\bar{z}(t)) + (\bar{z}(t) - T(t)) \times [1 + 2\bar{z}(t)(1 - \rho\bar{z}(t))]}{1 - \rho\bar{z}(t)}\right\},\end{aligned}$$

which is non-negative, and is positive before $\bar{z}(t)$ reaches the steady state.

(ii). Dynamics of Northern welfare $U_N(t)$

Given (36), together with condition (27),

$$\frac{dU_N(t)}{dt} = \left(\frac{L_N}{\sigma f}\right)^{\frac{1}{\rho}} \times \frac{\rho\sigma f}{\bar{a}} \times e^{\frac{1}{2}} \times (1-\rho\bar{z}(t))^{-\frac{1}{\rho}} \times e^{\bar{z}(t)^2 - T(t)^2} \times \frac{d\bar{z}(t)}{dt} \times$$
$$\left\{1-\rho+2\bar{z}(t)\left(1-\rho\bar{z}(t)\right) - \frac{T(t)}{\bar{z}(t)} - 2T(t)\left(1-\rho\bar{z}(t)\right)\right\} .$$

With condition (27), it is found that there exists a stationary point $\tilde{z}_{UN}$ determined by

$$\frac{\rho z}{1+2z\left(1-\rho z\right)} = \frac{1}{2}\ln\left[\frac{L_S}{L_N}\frac{1-\rho z}{\rho z}\right] .$$

At $\tilde{z}_{UN}$, $\frac{dU_N(t)}{dt} = 0$. The left-hand side of the equation above monotonically increases in z, while the right-hand side monotonically decreases in z, and therefore the solution is unique. Moreover, by comparing the values of the two sides of the equation at different points of z, it is found that

$$\tilde{z}_{UN} > \tilde{z}_y ,$$

and

$$\tilde{z}_{UN} \in (0, z^*) .$$

A.7 Extreme-end Evolution

(i). Derivation of (39)

Given the production function (7) and the symmetry of firms, together with conditions (8), (11), (13), (14), (19), (23′), (24′), (25′), and the condition that $\bar{z}(t) = 1$, it is the case that

$$\begin{aligned}
\ln Y(t)' &= \int_0^1 \ln x(z,j,t)dz \\
&= \int_0^{T(t)} \ln\left(\frac{1}{J(t)}\frac{\rho}{w_S(t)\bar{a}e^{-z}}\right)dz + \int_{T(t)}^1 \ln\left(\frac{1}{J(t)}\frac{\rho}{w_S(t)\bar{a}e^{z-2T(t)}}\right)dz \\
&= \ln\frac{L_S f}{L_N\bar{a}} - T(t)^2 + 2T(t) - \frac{1}{2} .
\end{aligned}$$

This implies that the per-brand output $Y(t)'$ is

$$Y(t)' = \frac{L_S f}{L_N \bar{a}} \times e^{-(T(t)-1)^2 + \frac{1}{2}} .$$

(ii). Derivation of $\frac{dY(t)'}{dt}$

Given (39),

$$\frac{dY(t)'}{dt} = \frac{L_S f}{L_N \bar{a}} \times e^{-(T(t)-1)^2+\frac{1}{2}} \times [2\,(1-T(t))] \times \frac{dT(t)}{dt}\,,$$

which is positive when $T(t) < 1$ and $\frac{dT(t)}{dt} > 0$.

A.8 Proof of $\frac{U_N^{*\prime}}{U_N^A} > 1$

From (58),

$$\frac{U_N^{*\prime}}{U_N^A} = \frac{L_S}{L_N} \times \frac{1}{\rho} \times (1-\rho)^{2-\frac{1}{\rho}}\,.$$

The function $\frac{1}{\rho} \times (1-\rho)^{2-\frac{1}{\rho}}$ is monotonically decreasing in ρ. Thus, with $\rho < \frac{L_S}{L_S+L_N}$ in the extreme offshoring case,

$$\frac{U_N^{*\prime}}{U_N^A} > \frac{U_N^{*\prime}}{U_N^A}\bigg|(\rho = \frac{L_S}{L_S+L_N}) = \left(\frac{L_S+L_N}{L_N}\right)^{\frac{L_N}{L_S}} > 1.$$

Therefore, the North's national welfare is higher with offshoring in the long run than under autarky.

Figure 1. Unit Labor Requirement in the South with Learning-by-Doing

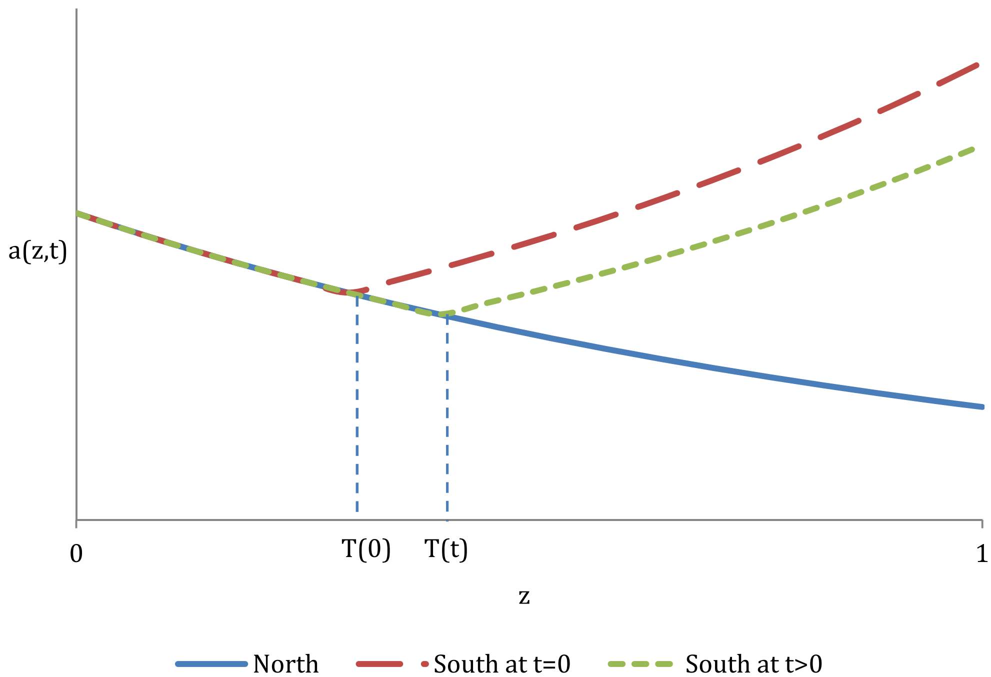


Figure 2. Initial Equilibrium of Global Production, *T*(0) < *z**

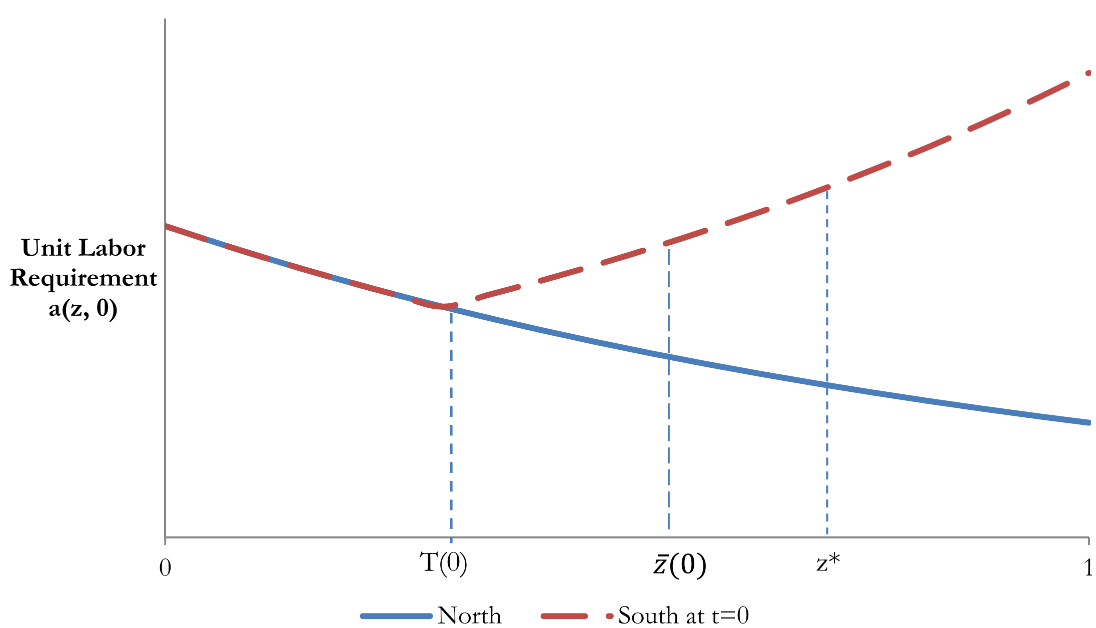


Figure 3. Task Dynamics, *T*(0) < *z**

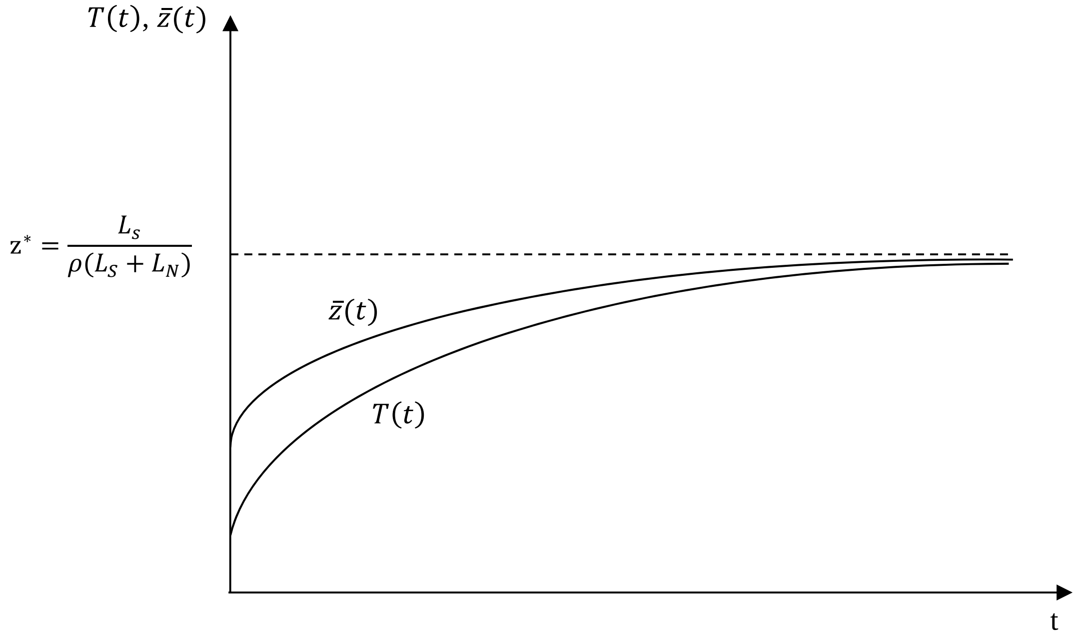
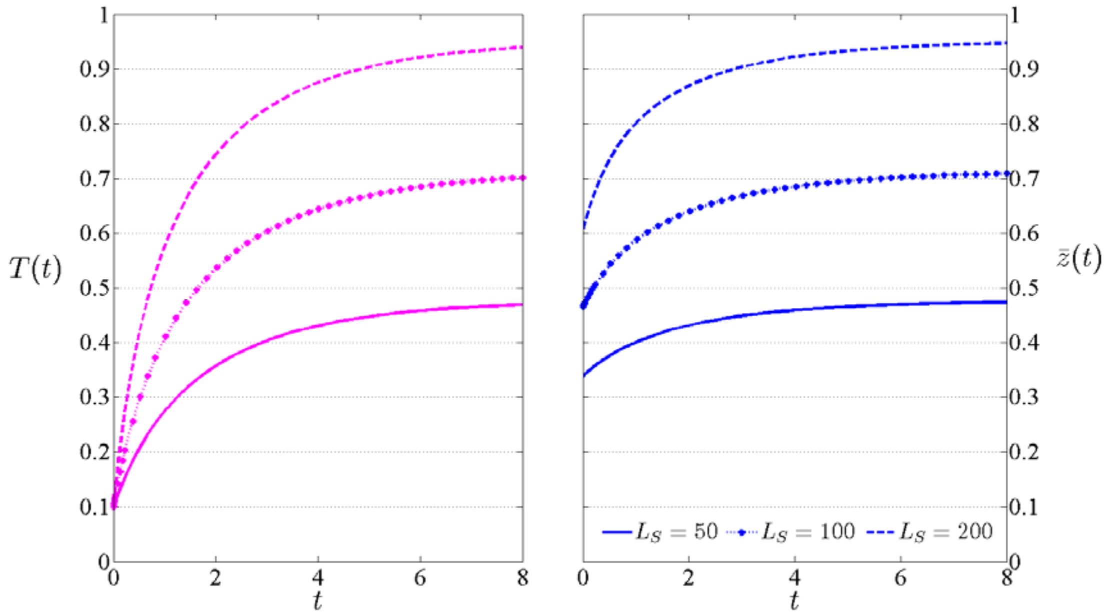


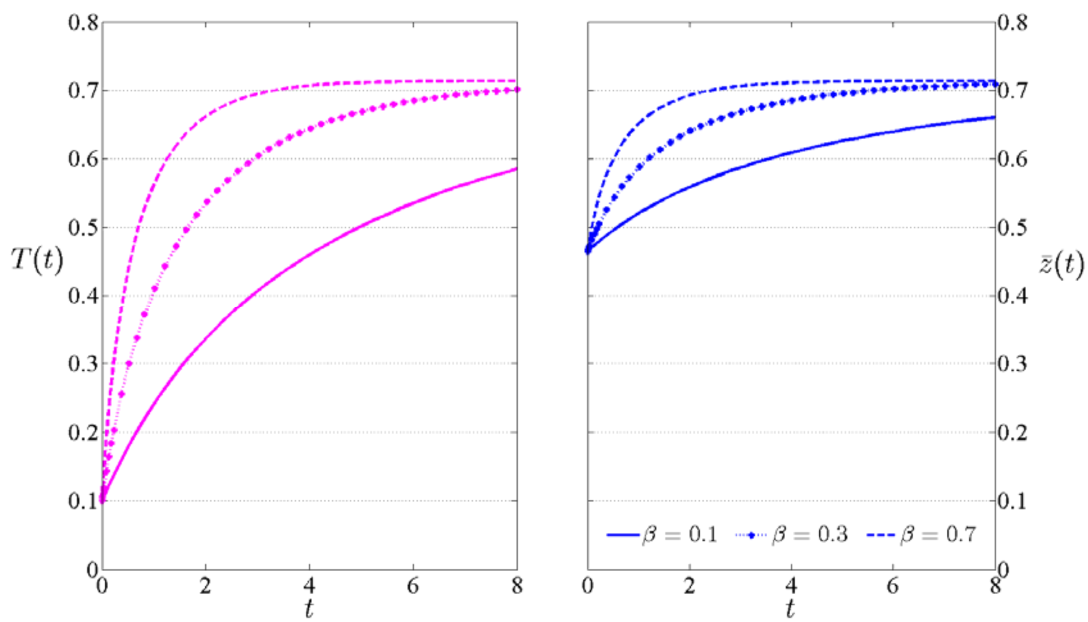
Figure 4. Task Dynamics – Simulations

Panel A. Labor Endowment in the South



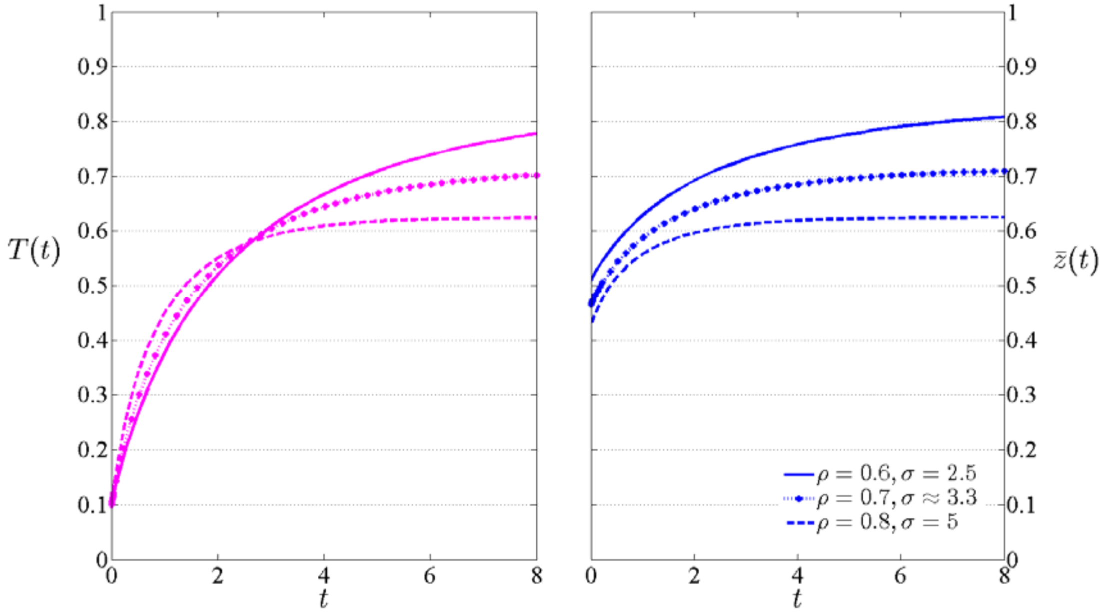
Note: $L_N = 100$; $\beta = 0.3$; $\rho = 0.7$; $f = 1$; $T(0) = 0.1$.

Panel B. Learning Ability



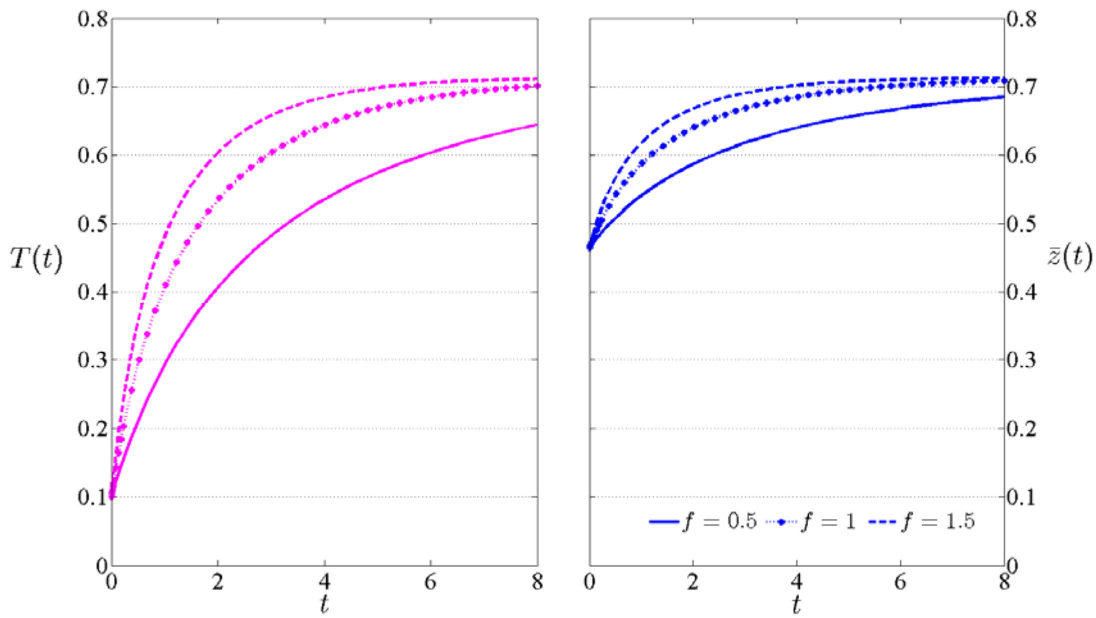
Note: $L_S = 100$; $L_N = 100$; $\rho = 0.7$; $f = 1$; $T(0) = 0.1$.

Panel C. Variety Substitutability



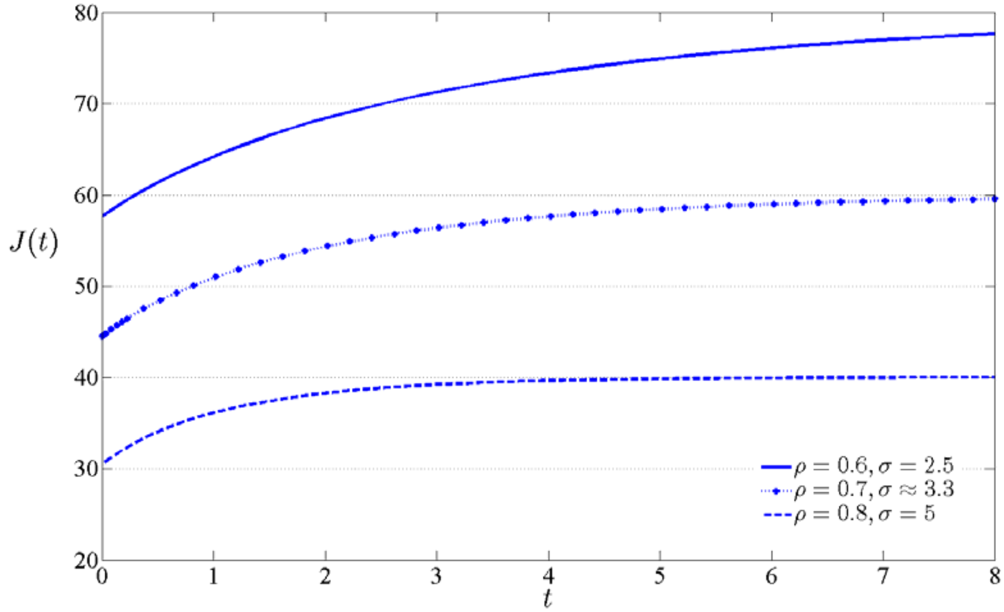
Note: $L_S = 100$; $L_N = 100$; $\beta = 0.3$; $f = 1$; $T(0) = 0.1$.

Panel D. Fixed Cost for Branding



Note: $L_S = 100$; $L_N = 100$; $\beta = 0.3$; $\rho = 0.7$; $T(0) = 0.1$.

Figure 5. Dynamics of Variety



Note: $L_S = 100$; $L_N = 100$; $\beta = 0.3$; $f = 1$; $T(0) = 0.1$.

Figure 6. Dynamics of Wage Rates

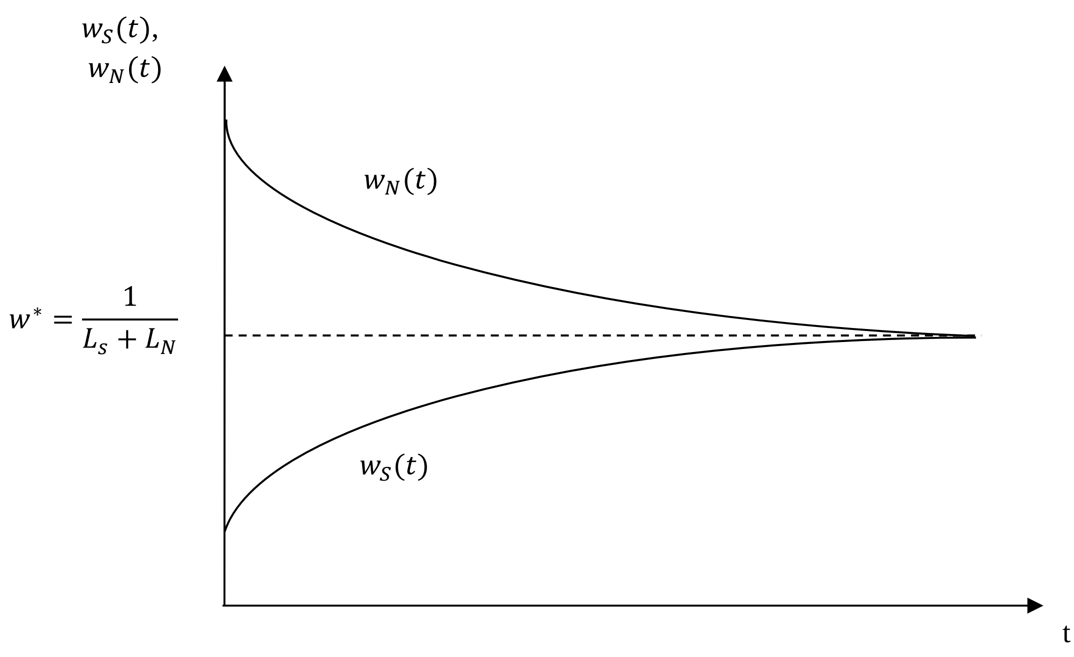
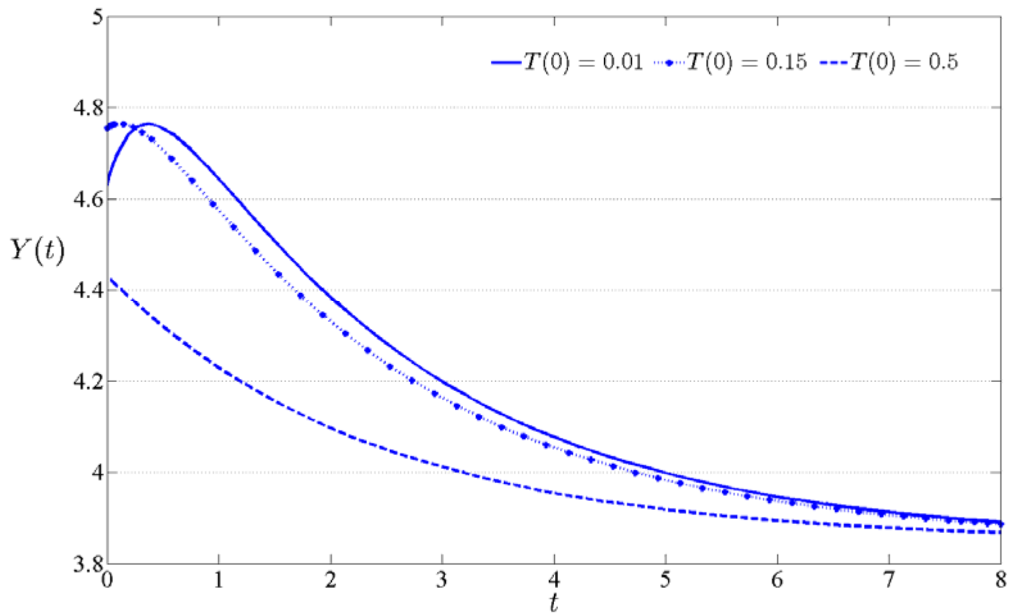


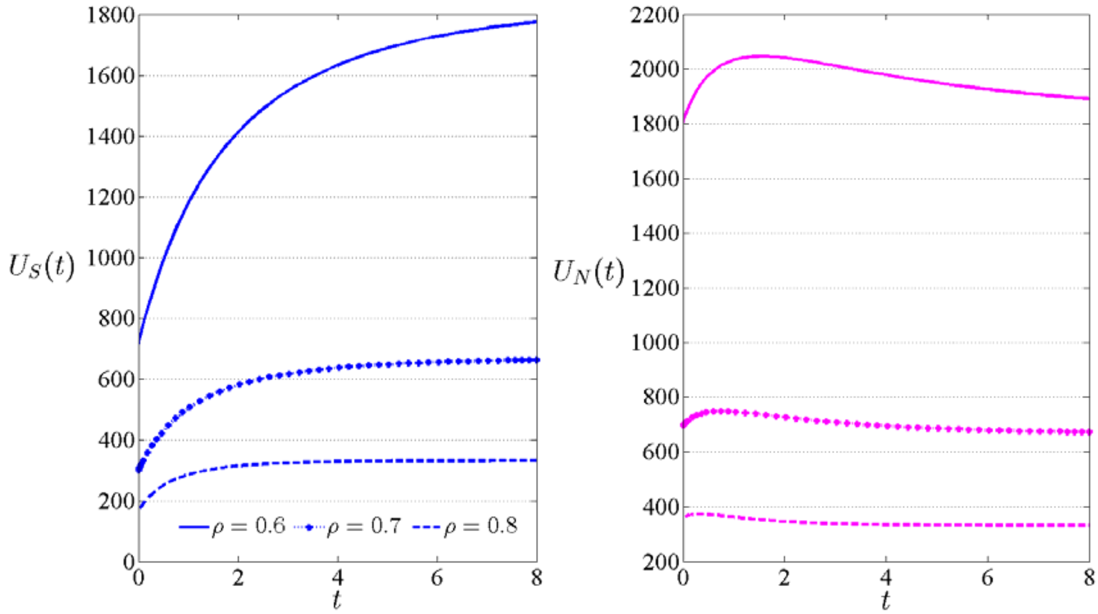
Figure 7. Dynamics of Per-brand Output



Note: $L_S = 100$; $L_N = 100$; $\beta = 0.3$; $\rho = 0.7$; $f = 1$; $\bar{a} = 1$.

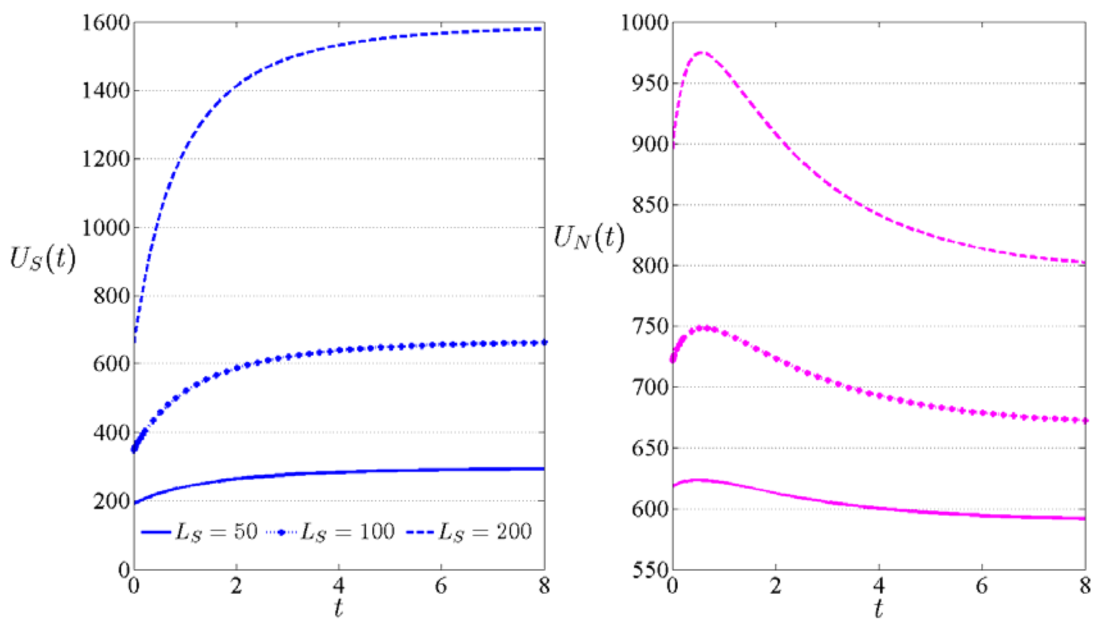
Figure 8. Dynamics of National Welfares

Panel A. Variety Substitutability



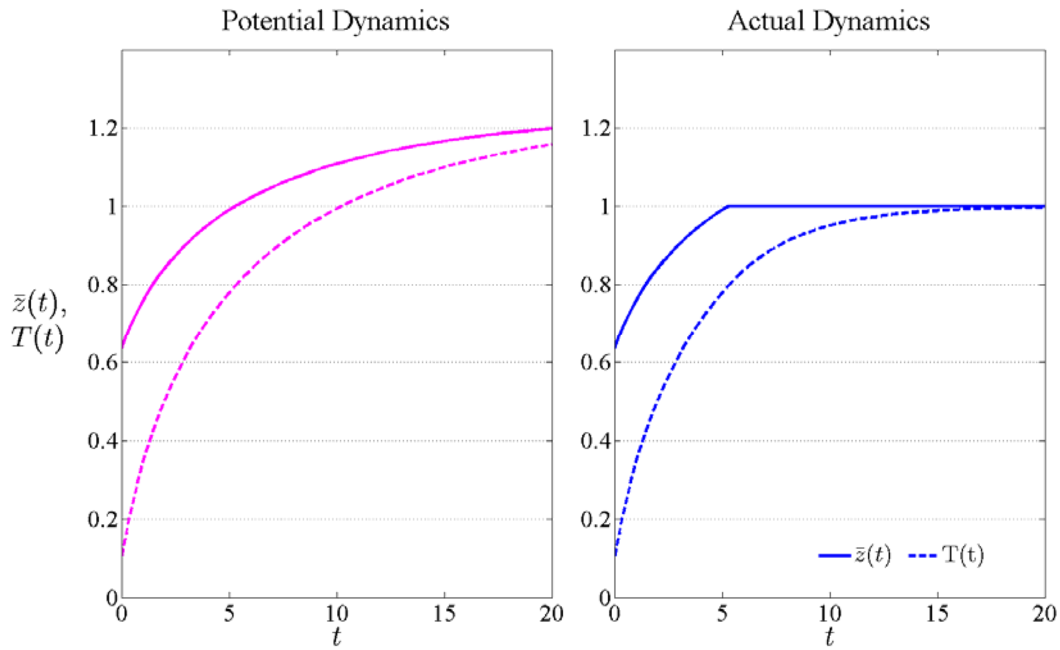
Note: $L_S = 100$; $L_N = 100$; $\beta = 0.3$; $f = 1$; $T(0) = 0.01$; $\bar{a} = 1$.

Panel B. Size of the South



Note: $L_N = 100$; $\beta = 0.3$; $\rho = 0.7$; $f = 1$; $T(0) = 0.1$; $\bar{a} = 1$.

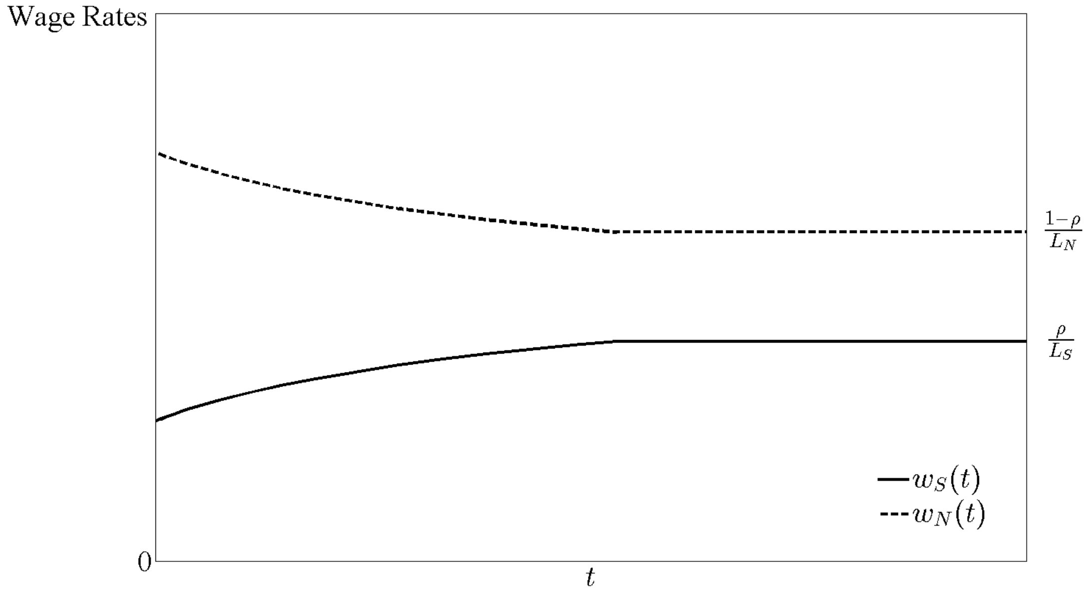
Figure 9. Task Dynamics under Extreme-end Evolution



Note: $L_N = 100$; $L_S = 100$; $\beta = 0.3$; $\rho = 0.4$; $f = 1$; $T(0) = 0.1$.

Figure 10. Dynamics of Wages and Number of Varieties under Extreme-end Evolution

Panel A. Dynamics of Wage Rates



Panel B. Dynamics of Variety

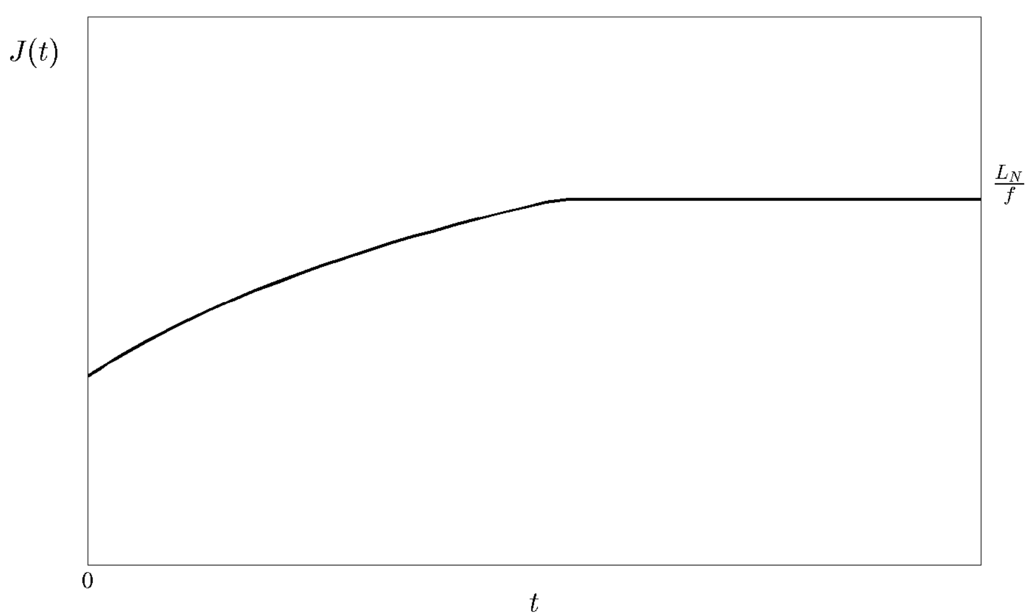
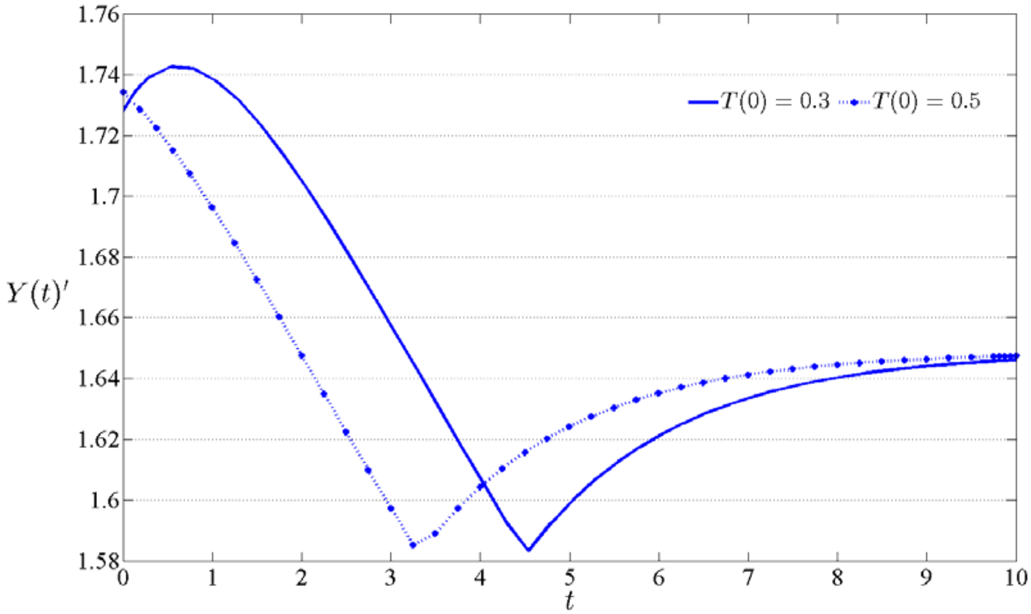


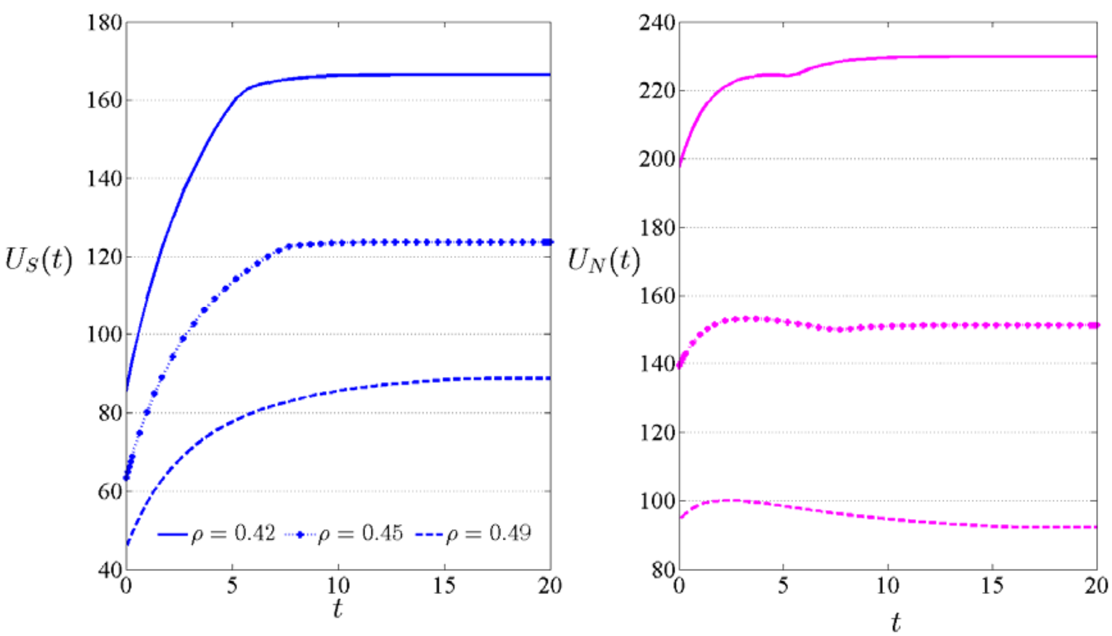
Figure 11. Dynamics of Output and Welfares under Extreme-end Evolution

Panel A. Dynamics of Per-brand Output



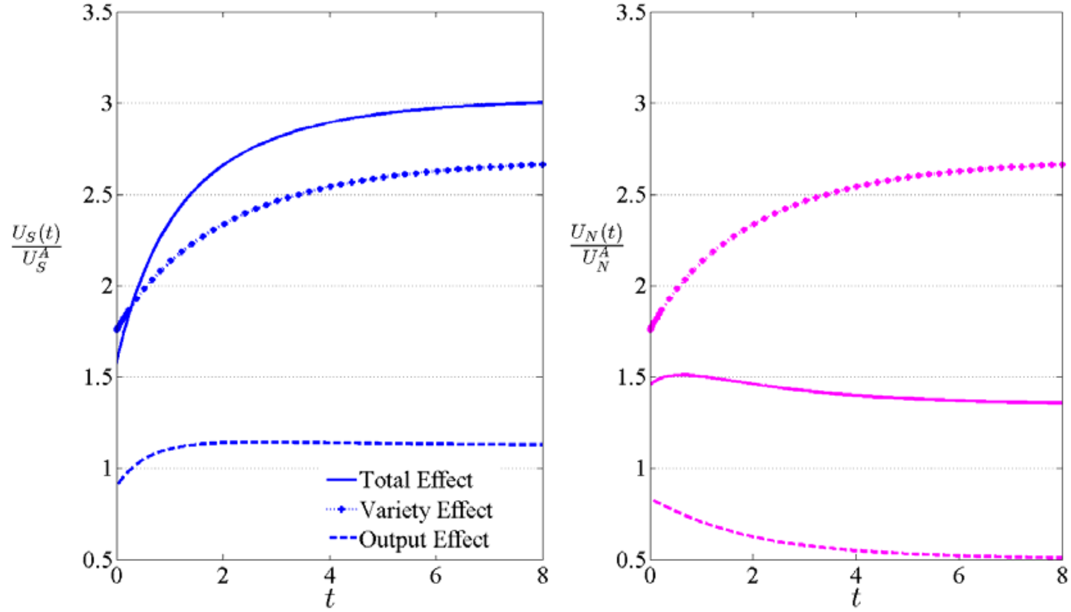
Note: $L_S = 100;\ L_N = 100;\ \beta = 0.3;\ \rho = 0.4;\ f = 1;\ \bar{a} = 1.$

Panel B. Dynamics of National Welfares



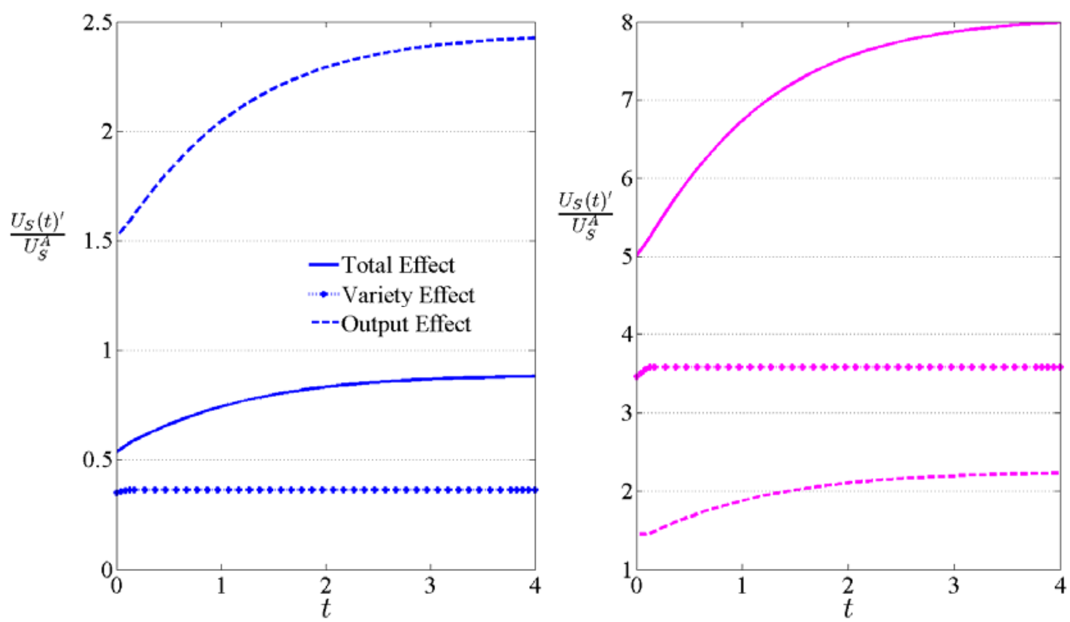
Note: $L_S = 10;\ L_N = 10;\ \beta = 0.3;\ f = 1;\ T(0) = 0.3;\ \bar{a} = 1.$

Figure 12. Welfare Gains from Offshoring – Normal Case



Note: $L_S = 100$; $L_N = 100$; $\beta = 0.3$; $\rho = 0.7$; $f = 1$; $T(0) = 0.1$; $\bar{a} = 1$.

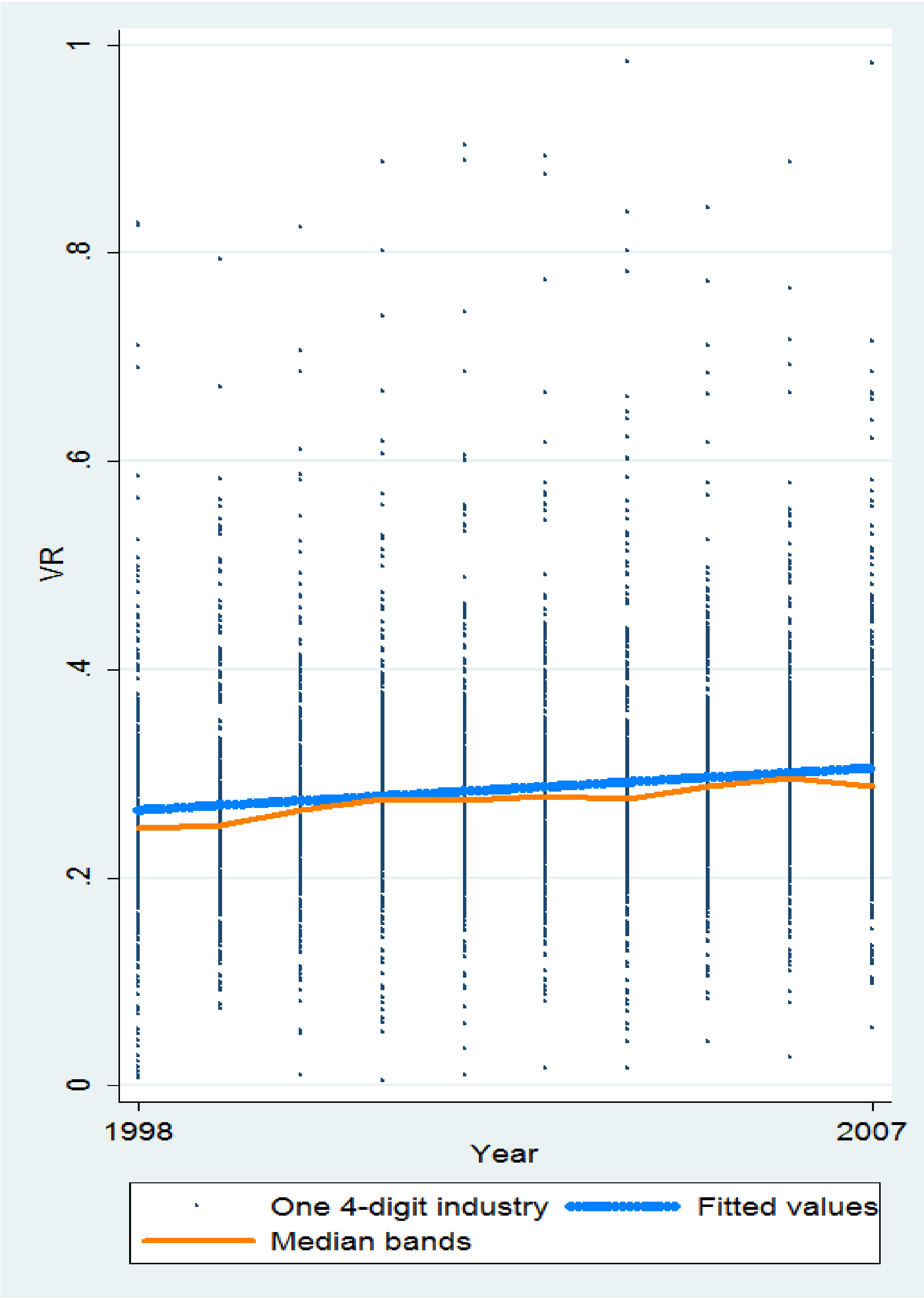
Figure 13. Welfare Gains from Offshoring – Complete Offshoring



Note: $L_S = 10$; $L_N = 4$; $\beta = 0.2$; $\rho = 0.4$; $f = 1$; $T(0) = 0.3$; $\bar{a} = 1$.

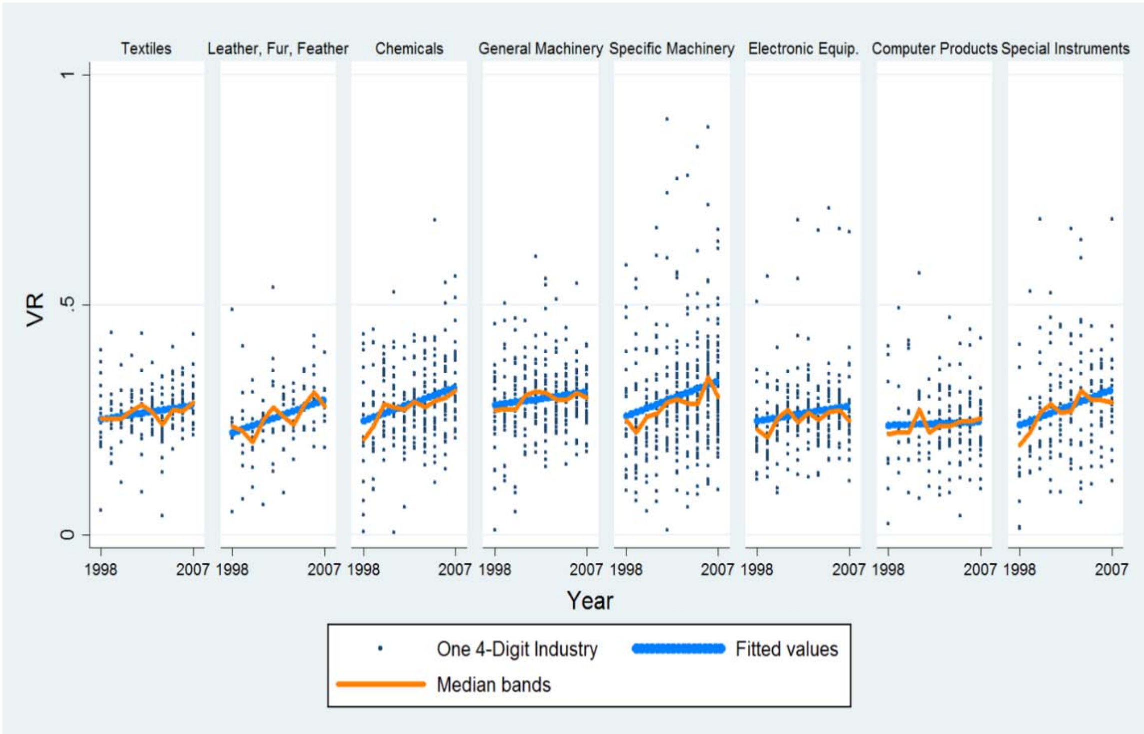
Figure 14. VR Growth

Panel A. VR Growth, Overall



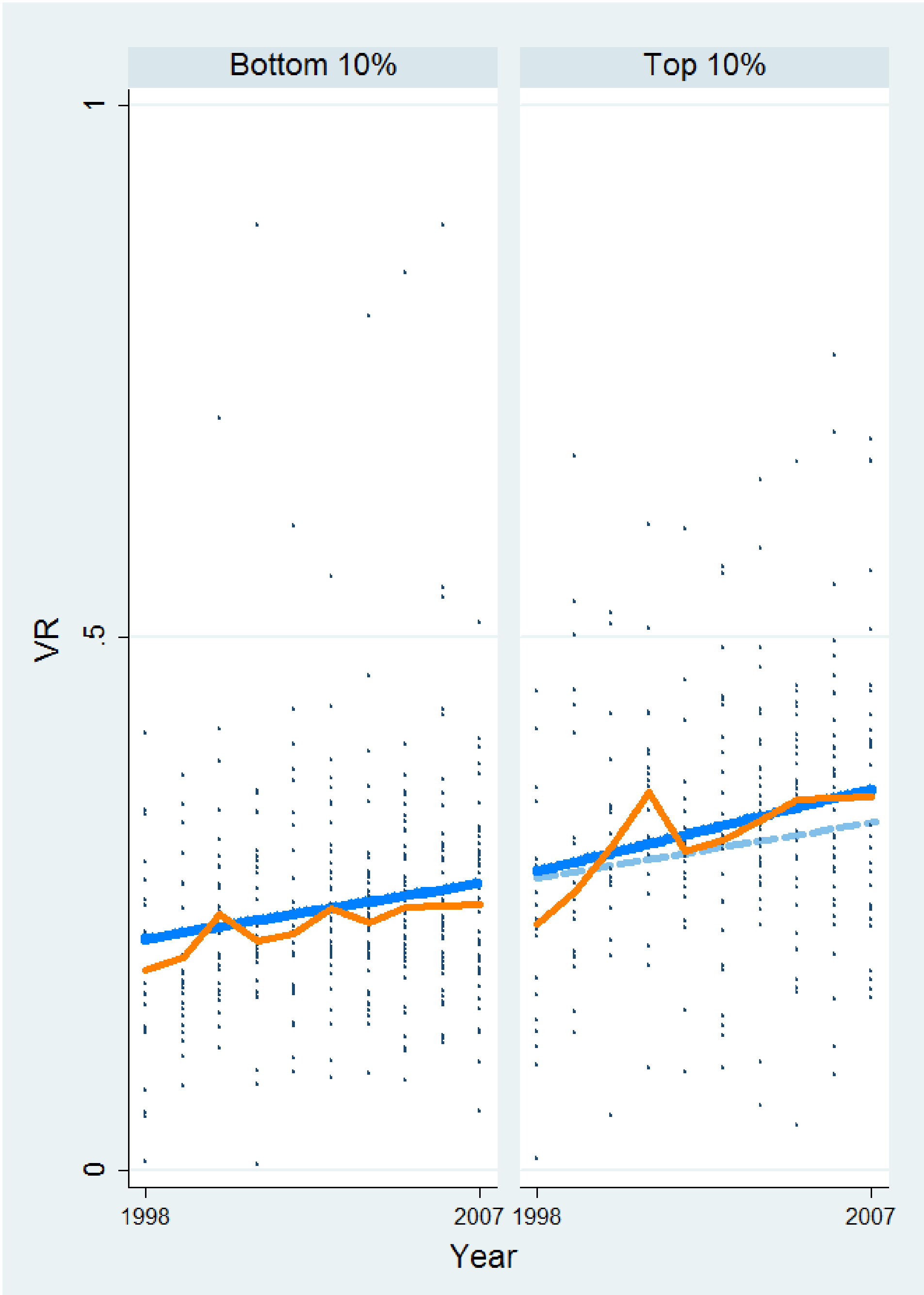
Note: A single dot represents a 4-digit industry.

Panel B. VR Growth, Two-digit Industries



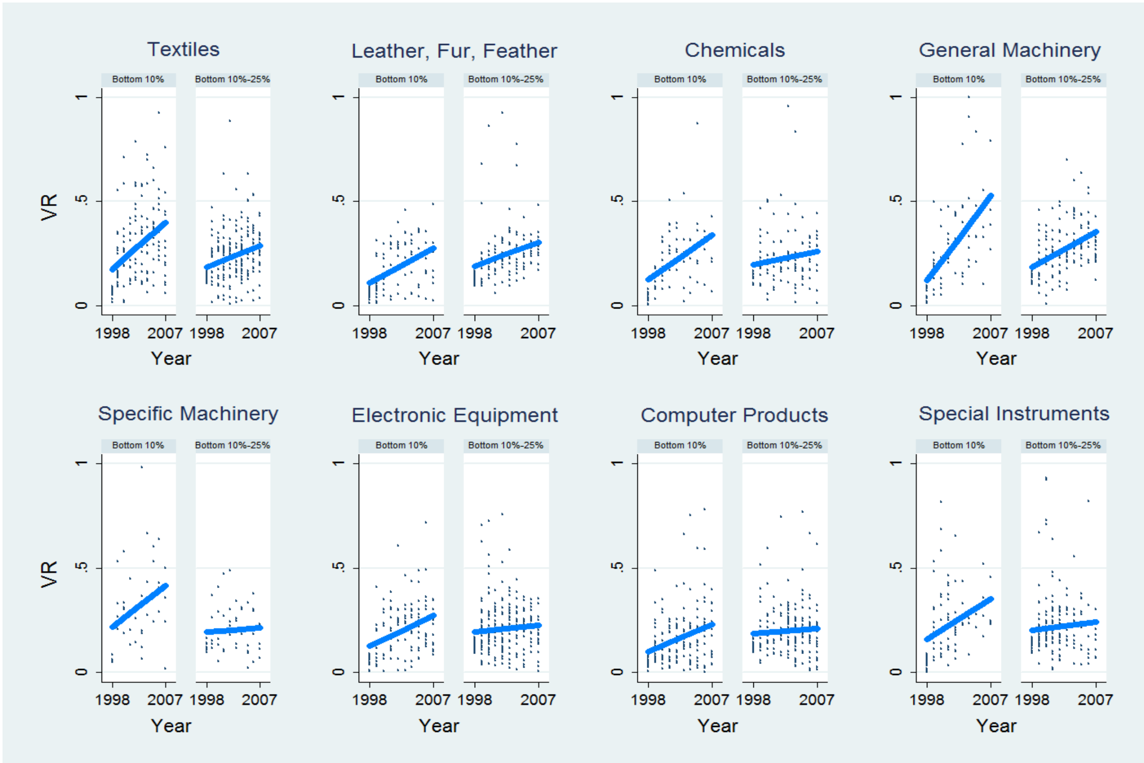
Note: A single dot represents a 4-digit industry under the 2-digit industry.

Figure 15. VR Growth and Learning Intensity



Note: The left (right) panel is for four-digit industries with top 10% (bottom 10%) training intensities, which is defined as (training expense) / (value of output). The light-color (yellow) solid line is the locus of VR's median across industries over time, and the dark-color (blue) line is the fitted linear trend. The dashed line in the right panel is with the same slope as the linear trend in the left panel.

Figure 16: VR Growth and the Initial VR



Note: For each industry, the left (right) panel contains the VRs of the subsidiaries with initial VRs in the bottom 10% (bottom 10%-25%) of the two-digit industry in the year 1998. The solid lines denote the fitted linear trends.

Figure 17. Decomposition of ΔVR, by Two-digit industries, 10-year change

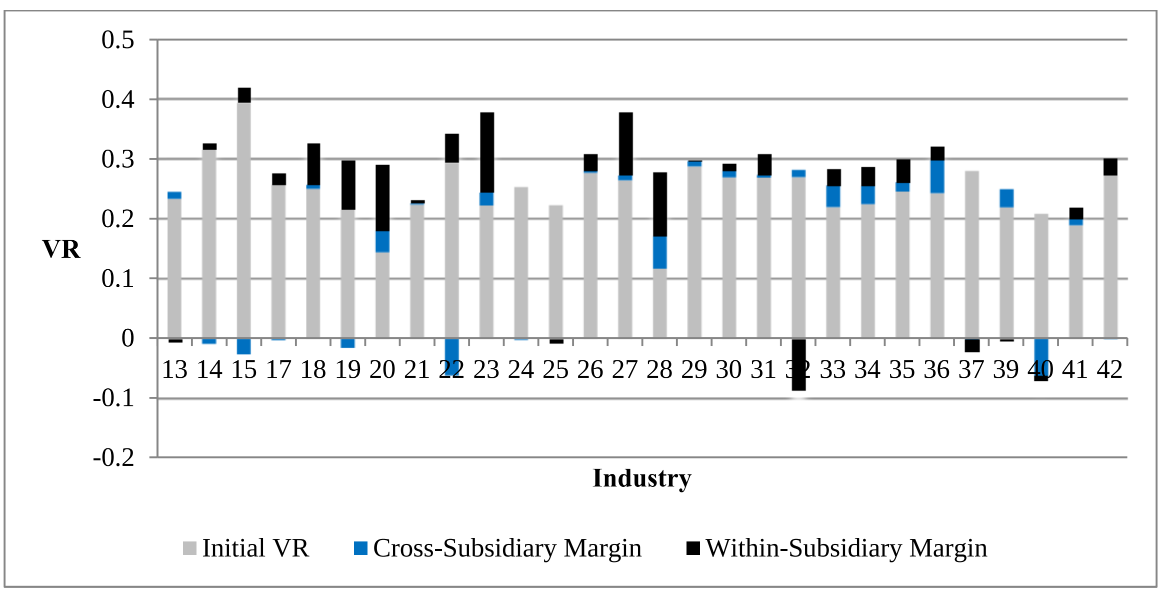


Table 1: Summary Statistics of Multinational Subsidiaries

Year	Output			Value-Added					Export		
	Mean	S.D.	Share*	Mean	S.D.	Share*	VR Mean	VR S.D.	Mean	S.D.	Share*
1998	79.6	516.9	3.13	18.5	119.9	2.47	0.265	0.161	50.4	250.8	12.30
2001	112.3	745.8	5.29	28.5	217.1	4.52	0.281	0.146	65.5	435.6	18.10
2004	143.8	1160	9.49	32.7	218.9	7.61	0.286	0.169	90.0	979.7	29.51
2007	232.3	2010	11.05	54.6	292.7	9.21	0.301	0.160	133.4	1870.0	33.70

Note: nominal values are in current price RMB and the unit is 1 million. * Share refers to the share in the whole manufacturing sector of China.

Table 2. Change in VR and the Two Margins, Four-digit Industries

Year	ΔVR		Within-Subsidiary Margin		Cross-Subsidiary Margin	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
1999	0.0116	0.1303	0.0119	0.1286	-0.0003	0.0188
2000	0.0094	0.1115	0.0101	0.1106	-0.0007	0.0171
2001	0.0057	0.1022	0.0045	0.1042	0.0013	0.0145
2002	0.0090	0.1111	0.0089	0.1103	-0.0002	0.0155
2003	0.0093	0.1060	0.0111	0.1051	-0.0018	0.0151
2004	-0.0083	0.1083	-0.0089	0.1080	0.0006	0.0184
2005	0.0056	0.1057	0.0072	0.1043	-0.0016	0.0189
2006	0.0148	0.0897	0.0138	0.0893	0.0010	0.0149
2007	-0.0036	0.0832	-0.0028	0.0809	-0.0008	0.0194

Table 3: ΔVR of Multinational Operation

	(1) Full sample	(2) Full sample	(3) High K/L industries	(4) Low K/L industries
Initial VR	-0.0760***	-0.0744***	-0.0695***	-0.0668***
	(0.0144)	(0.0142)	(0.0199)	(0.0202)
Year Trend (τ)	-0.00119*	-0.00120**	-0.00238***	-0.00005
	(0.000608)	(0.000607)	(0.000899)	(0.000821)
Training Intensity (β)	23.32***	24.30***	34.27**	16.14**
	(7.506)	(7.345)	(15.97)	(6.791)
Capital Intensity (K/L)		35.99*	41.21*	47.80
		(19.57)	(21.45)	(171.5)
Constant	0.0215***	0.0176***	0.0171	0.0135
	(0.00542)	(0.00553)	(0.0106)	(0.00988)
Observations	2,485	2,485	1,246	1,239
R-squared	0.014	0.015	0.024	0.012

Dependent variable is the two-year change in value added ratio (ΔVR).
The regression is at the level of (four-digit industry × year). Two-digit industry dummies are included. Robust standard errors (clustering within industries) are in parentheses.
Significance levels: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 4: Within-Subsidiary Margin of ΔVR, Multinational Operation

	(1) Full sample	(2) Full sample	(3) High K/L industries	(4) Low K/L industries
Initial VR	-0.0690***	-0.0666***	-0.0629***	-0.0588***
	(0.0143)	(0.0140)	(0.0197)	(0.0197)
Year Trend (τ)	-0.00108*	-0.00110*	-0.00225**	2.54e-05
	(0.000601)	(0.000601)	(0.000900)	(0.000800)
Training Intensity (β)	22.61***	24.02***	32.91**	16.14**
	(7.68)	(7.43)	(15.67)	(6.75)
Capital Intensity (K/L)		51.97***	57.73***	27.78
		(18.69)	(20.60)	(164.8)
Constant	0.0198***	0.0142**	0.0138	0.0122
	(0.00545)	(0.00558)	(0.0103)	(0.00987)
Observations	2,485	2,485	1,246	1,239
R-squared	0.013	0.014	0.023	0.012

Dependent variable is the within-subsidiary margin obtained from the decomposition of the two-year change in value added ratio (ΔVR).
The regression is at the level of (four-digit industry × year). Two-digit industry dummies are included. Robust standard errors (clustering within industries) are in parentheses.
Significance levels: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 5: Cross-Subsidiary Margin of ΔVR, Multinational Operation

	(1) Full sample	(2) Full sample	(3) High K/L industries	(4) Low K/L industries
Initial VR	-0.0070**	-0.0078**	-0.0066	-0.0079
	(0.00357)	(0.00342)	(0.00419)	(0.00671)
Year Trend (τ)	-0.000108	-0.000102	-0.000131	-7.44e-05
	(0.000129)	(0.000128)	(0.000196)	(0.000167)
Training Intensity (β)	0.712	0.278	1.366	-0.00301
	(1.784)	(1.728)	(2.973)	(2.805)
Capital Intensity (K/L)		-15.98***	-16.52**	20.01
		(5.789)	(6.906)	(44.95)
Constant	0.00165	0.00340**	0.00325	0.00133
	(0.00126)	(0.00140)	(0.00266)	(0.00273)
Observations	2,485	2,485	1,246	1,239
R-squared	0.011	0.014	0.016	0.016

Dependent variable is the cross-subsidiary margin obtained from the decomposition of the two-year change in value added ratio (ΔVR).
The regression is at the level of (four-digit industry × year). Two-digit industry dummies are included. Robust standard errors (clustering within industries) are in parentheses.
Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Table 6: ΔVR, Within-Subsidiary Margin, and Cross-Subsidiary Margin, Multinational Operation

Wage-Rate Index Included

Dependent Variables	(1) ΔVR Full sample	(2) ΔVR Full sample	(5) Within-Subsidiary Margin Full sample	(6) Within-Subsidiary Margin Full sample	(5) Cross-Subsidiary Margin Full sample	(6) Cross-Subsidiary Margin Full sample
Initial VR	-0.0759***	-0.0742***	-0.0689***	-0.0665***	-0.0070*	-0.0078**
	(0.0144)	(0.0142)	(0.0143)	(0.0140)	(0.00357)	(0.00342)
Wage Index	-0.2670**	-0.2700**	-0.2410**	-0.2450**	-0.0264	-0.0250
	(0.1160)	(0.1160)	(0.115)	(0.115)	(0.0268)	(0.0267)
Training Intensity (β)	23.29***	24.27***	22.58***	23.99***	0.709	0.275
	(7.502)	(7.341)	(7.68)	(7.43)	(1.784)	(1.728)
Capital Intensity (K/L)		36.14*		52.10***		-15.96***
		(19.57)		(18.70)		(5.793)
Constant	0.0264***	0.0225***	0.0242***	0.0186***	0.00219	0.00390**
	(0.00650)	(0.00663)	(0.00650)	(0.00666)	(0.00154)	(0.00166)
Observations	2,485	2,485	2,485	2,485	2,485	2,485
R-squared	0.014	0.015	0.013	0.014	0.012	0.014

The regression is at the level of (four-digit industry × year). Two-digit industry dummies are included. Robust standard errors (clustering within industries) are in parentheses.
Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Table 7: ΔVR, Within-Subsidiary Margin, and Cross-Subsidiary Margin, Multinational Operation

Various Initial Years

Dependent Variables	ΔVR	Within-Subsidiary Margin	Cross-Subsidiary Margin	ΔVR	Within-Subsidiary Margin	Cross-Subsidiary Margin
	Initial VR: Year 1999			Initial VR: Year 2001		
Initial VR	-0.108***	-0.106***	-0.00137	-0.106***	-0.101***	-0.00494
	(0.0161)	(0.0158)	(0.00338)	(0.0219)	(0.0212)	(0.00525)
Year Trend (τ)	-0.00113	-0.00103	-9.99e-05	-0.00206*	-0.00198*	-8.06e-05
	(0.000709)	(0.000703)	(0.000139)	(0.00111)	(0.00110)	(0.000220)
Training Intensity (β)	20.94**	22.09**	-1.147	19.51*	20.70*	-1.188
	(9.604)	(9.739)	(1.570)	(11.41)	(11.81)	(2.072)
Capital Intensity (K/L)	1.367	15.02	-13.66**	-11.72	7.502	-19.22***
	(23.51)	(22.22)	(6.078)	(24.04)	(23.14)	(7.158)
	Initial VR: Year 2003			Initial VR: Year 2005		
Initial VR	-0.133***	-0.128***	-0.00503	-0.258***	-0.249***	-0.00859
	(0.0313)	(0.0297)	(0.00529)	(0.0426)	(0.0422)	(0.00652)
Year Trend (τ)	0.000147	0.000396	-0.000249	-0.0197***	-0.0177***	-0.00195
	(0.00218)	(0.00212)	(0.000449)	(0.00656)	(0.00644)	(0.00125)
Training Intensity (β)	14.61	12.81	1.800	38.29***	39.20***	-0.905
	(14.41)	(15.30)	(2.659)	(7.537)	(7.493)	(1.025)
Capital Intensity (K/L)	43.81	56.53**	-12.72	18.23	36.09	-17.86*
	(32.33)	(28.40)	(10.72)	(36.39)	(36.39)	(10.47)

Specification is the same as column (2) in Tables 3-5.
Robust standard errors (clustering within industries) are in parentheses.
Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Table 8: ΔVR and the Two Margins, Local Production and HMT-Owned Operation

	(1)	(2)	(3)	(4)	(5)	(6)
	Domestically-Funded Production			HMT-Owned Production		
Dependent Variables	ΔVR	Within-Subsidiary Margin	Cross-Subsidiary Margin	ΔVR	Within-Subsidiary Margin	Cross-Subsidiary Margin
Initial VR	-0.0234	-0.0155	-0.0079*	-0.0861***	-0.0836***	-0.0024
	(0.0145)	(0.0157)	(0.00446)	(0.0137)	(0.0128)	(0.00406)
Year Trend (τ)	9.96e-05	-0.000159	0.000258***	0.000949	0.000767	0.000182
	(0.000211)	(0.000203)	(5.96e-05)	(0.000662)	(0.000659)	(0.000137)
Training Intensity (β)	-13.09**	-11.90*	-1.187	6.263	7.180	-0.917
	(5.978)	(6.440)	(0.777)	(6.911)	(6.608)	(1.822)
Capital Intensity (K/L)	-2.214	-0.490	-1.723	1.491	-3.386	4.877
	(8.500)	(7.324)	(3.912)	(31.43)	(31.66)	(5.442)
Constant	0.0129***	0.0107***	0.00221	0.0183***	0.0184***	-0.000176
	(0.00342)	(0.00373)	(0.00142)	(0.00542)	(0.00536)	(0.00121)
Observations	3,777	3,777	3,777	2,521	2,521	2,521
R-squared	0.020	0.020	0.019	0.019	0.020	0.008

The regression is at the (four-digit industry × year) level.
Two-digit industry dummies are included.
Robust standard errors (clustering within industries) are in parentheses.
Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Table A1: Description of Two-digit Industries

Industry code	Description	K/L (1,000 RMB per person)	Training intensity (% points, training expense/output)
13	Processing of Farm and Sideline Food	91.67	0.00028
14	Manufacture of Food Products	89.07	0.00043
15	Manufacture of Beverages	149.90	0.00044
16	Manufacture of Tobacco Products	221.70	0.00109
17	Manufacture of Textiles	67.97	0.00035
18	Manufacture of Wearing Apparel, Footwear, Hats and Caps	23.23	0.00036
19	Manufacture of Leather, Fur, Feather (Down) and Related Products	34.72	0.00030
20	Processing of Wood; Manufacture of Products of Wood, Bamboo, Rattan, Palm Coir and Articles of Straw	74.90	0.00032
21	Manufacture of Furniture	51.22	0.00040
22	Manufacture of Paper and Paper Products	116.10	0.00036
23	Printing and Reproduction of Recorded Media	125.60	0.00069
24	Manufacture of Sport and Recreational Goods (Sports Goods, Toys, Musical Instruments and Stationery Goods)	38.90	0.00038
25	Manufacture of Coke and Refined Petroleum Products; Manufacture of Nuclear Fuel Products	257.00	0.00042
26	Manufacture of Chemical Material and Chemical Products	161.90	0.00040
27	Manufacture of Pharmaceuticals and Medicinal Chemical Products	120.70	0.00061
28	Manufacture of Chemical Fiber	231.20	0.00026
29	Manufacture of Rubber Products	70.46	0.00035
30	Manufacture of Plastics Products	86.59	0.00031
31	Manufacture of Other Non-metallic Mineral Products	80.47	0.00044
32	Ferrous Metal Foundries and Presses	193.30	0.00027
33	Non-ferrous Metal Foundries and Presses	135.40	0.00029
34	Manufacture of Fabricated Metal Products (except machinery and equipment)	72.63	0.00044
35	Manufacture of General Purpose Machinery and Equipment n.e.c.	68.22	0.00054
36	Manufacture of Special Purpose Machinery	63.73	0.00063
37	Manufacture of Transport Equipment	89.14	0.00088
39	Manufacture of Electrical Equipment	74.74	0.00041
40	Manufacture of Computer and Electronic Products	120.70	0.00034
41	Manufacture of Special Instruments and Office Machinery	63.38	0.00068
42	Manufacture of Art Products; Other Manufacturing	45.43	0.00028
43	Waste Collection, Treatment and Disposal Activities; Materials Recovery	92.30	0.00043