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:

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

the optimal allocation of ownership rights along the value chain (e.g. Antras and Chor, 2012), and the in uence 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 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 Rodríguez-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,

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

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:

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

where J

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

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

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

$$\ln Y(j;t) = \ln Y(t) = \int_0^1 \ln x(j;z;t)dz, \qquad (7)$$

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

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

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]

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

where $\mathbb{1}\left\{\frac{a(z;t)}{a(z)} > 1\right\}$ 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 > 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 ($a(z;t) = a(z)$), 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

$a($

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

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

with $z(t)$ denoting the most sophisticated task that is conducted in the Southern plants.[16] Thus, for all firms within the industry, tasks with $z \in [0; z(t)]$ are allocated to the South, and tasks with $z \in (z(t);$

tions become

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

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

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

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

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

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

z^* serves as the threshold task of offshoring at the steady state if it is within the range of offshorable manufacturing tasks ($\frac{L_S}{(L_S+L_N)} \leq 1$).[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 o shoring will be $z^{0} = 1$. 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 o shoring 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 rm conducts tasks at which it is not particularly competent, the learning e ect will be positive in the sense that the production e ciency 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 o shorable tasks ($0 < z$ 1) and the initial stock of technology in the South is not adequate for 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 $T(0) < z^* \le 1$, $z(0) \in (T(0); z^*)$ 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

accumulation path:[21]

$$\frac{dT(t)}{dt} = \frac{L_S}{J(t)} \frac{z(t) \quad T(t)}{z(t)} = \quad f\,(1 \quad z(t))\,\frac{L_S}{L_N} \frac{z(t) \quad T(t)}{}$$

where $\dot{z}(t) \quad \frac{dz(t)}{dt}$. The rst-order Taylor series approximation shows that

$$\dot{z}(t) \qquad \left.\frac{d\dot{z}(t)}{dz(t)}\right|_{z(t)=z} \qquad (z(t) \quad z\ )\ ;$$

which implies that the o shoring 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 o shoring 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 o shoring ($z(t)$) 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), brand maintenance cost (f), variety substitutability in the industry (, and thus), and the countries' labor endowments (L_S and L_N) all have in uence on the convergence paths. Numerical simulations are performed here to examine how di erent variables may a ect 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 ine ciency { a larger although technically ine cient 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 rst, 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 o shoring threshold. Second, the higher theth]TJ 0 s2v its pr658(hnologies7-303(c(is)41434(F)83(or)-658DrJ 0 -ure)-378(4)-378658el)-312lity is

4.2 Variety Dynamics

Under monopolistic competition, consumers' love for variety provides the market with the incentive to create and maintain di erent 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 o shoring thus brings a change in industrial structure in the country. With more e orts 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

$$J = \frac{L_S + L_N}{f}: \tag{30}$$

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 bene ts 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 o shoring, 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 o shoring 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 re ected 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 1) and labor ows freely between sectors in the North. In the (tr763(the)-31)-313(traseectors)n o shored to the South (i.e., the o shoring threshold $z(t) < \bar{z}_y$

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

$$U_N = \frac{L_N}{L_S + L_N} \quad \frac{L_S + L_N}{f}^{1} \quad \frac{f}{a} \quad e^{\frac{1}{2}} \tag{38}$$

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 $z^{0} = 1$ 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 o shoring will not happen. However, the South's technical capability will still improve for some time, until it matches the range of tasks o shored ($T(t^{0}) = 1$; with $t^{0} > t_z$). 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 o shoring threshold $z(t)$ over time. O shoring 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 o shoring pattern ($T^{0} = z^{0} = 1$).

Consider other variables characterizing the economies, such as the wage rates and the number of varieties. At rst, before the South obtains all manufacturing activities to conduct ($z(t) < 1$), 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 o shored, the wage rates in the two countries stop changing. Thus, their evolution paths are not smooth { the time when o shoring hits its upper limit is a singular point when the wage rates reach their bounds and also their nal steady states. Given that z^{0} z

=

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

$$Y(t)' = \frac{L_S f}{L_N a} \quad e^{\;(T(t) \quad 1)^2 + \frac{1}{2}}; \tag{39}$$

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

$$Y' = \frac{L_S f}{L_N a} e^{\frac{1}{2}}; \tag{40}$$

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 ($J' > J$), while less of each brand is supplied ($Y' < Y$).

With regard to national welfare, before the o shoring threshold $z(t)$ 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 di erent possible patterns of growth over time. However, during the period of time when all tasks have been o shored and the South is still learning ($z(t) = 1$ and $T(t) < 1$), both countries will experience welfare growth. Speci cally, with the per-brand output expression derived above, the national welfares of the two countries are, respectively,

$$U_S(t)' = \quad \frac{L_N}{f}^{\;\frac{1}{}\;\;1} \quad \frac{L_S}{a} \quad e^{\;(T(t) \quad 1)^2 + \frac{1}{2}}; \tag{41}$$

and

$$U_N(t)' = (1 \quad) \quad \frac{L_N}{f}^{\;\frac{1}{}\;\;1} \quad \frac{L_S}{a} \quad e^{\;(T(t) \quad 1)^2 + \frac{1}{2}}: \tag{42}$$

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:

$$U_S^{?\prime} = \quad \frac{L_N}{f}^{\;\frac{1}{}\;\;1} \frac{L_S}{a} e^{\frac{1}{2}}; \tag{43}$$

and

$$U_N^{?\prime} = (1 \quad) \quad \frac{L_N}{f}^{\;\frac{1}{}\;\;1} \frac{L_S}{a} e^{\frac{1}{2}}: \tag{44}$$

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

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

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

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

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:

$$\frac{U_N}{U_N^A} = \left(\frac{L_S + L_N}{L_N}\right)^{\frac{1}{} \;\; 1} > 1. \tag{56}$$

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 Offshoringlengesg71091 b5 Td [(In)-381320(pro)028(w)28(ork.)]TJ/F17 1

and

$$\frac{U_N^{0}}{U_N^{A}} = \frac{L_S}{L_N} \quad \frac{1}{} \quad (1 \quad)^{2 \; \frac{1}{}} : \tag{58}$$

Close examinations show that on one side, there is no deterministic relationship between U_S^{0} and U_S^{A}, which implies that with extreme-end o shoring, although all tasks are ultimately o shored to the South, the country does not necessarily gain in the long run. The main reason is that the variety e ect is found not to be necessarily signi cant in the long run in this case.[40] On the other side, the North does see positive gains from o shoring in the long run ($\frac{U_N^{0}}{U_N^{A}} > 1$).[41] Thus, under extreme-end o shoring, 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 o shoring happens. This evolution process involves a shift of value added in the nal industrial products from the North to the South. For the overall industry, the nal 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 nal products. Within the nal industrial output value, the shares of the two countries are, respectively,

$$\mathrm{VR}_N(t) = \frac{w_N(t)L_N}{p(j;t)Y(j;t)J(t)} = 1 \quad z(t) ; \tag{60}$$

and

$$\mathrm{VR}_S(t) = \frac{w_S(t)L_S}{p(j;t)}$$

and at(d(;t)342 0 Td [(j)-2(;)d [85f -1.688 Td [(S)]TJ/F8 10.9091 Tf 6.09

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

$$VR_{S;i}(t) = \frac{\sum_{j \in \Omega_i(t)} p_j(t)y_j(t) - \sum_{j \in \Omega_i(t)} M_j(t)}{\sum_{j \in \Omega_i(t)} p_j(t)y_j(t)}; \qquad (62)$$

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 VR_S Using panel data of MIs over time, the convergence dynamics of VR_S can duction 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 ve 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 di erent types of rms such as state, private, and foreign rms. The foreign classi cation 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 de ned as multinational subsidiaries here. Table 1 shows the summary statistics for multinational subsidiaries. During the 10 years covered, there were signi cant 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 speci cation (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 classi es 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 classi cation 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 , the dependent variable in (63) could be the total change of in $VR_{i;}$, the within-subsidiary margin $\sum_{j \in i} VR_{j;} \frac{j; + j; 1}{2}$, or the cross-subsidiary margin $\sum_{j \in i} j; \frac{VR_{j;} + VR_{j; 1}}{2}$. 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 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., $\frac{dz(t)}{dt}$ depends also on parameters such as).

cross-subsidiary margin does not display a significant convergence pattern as for the total VR 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 VR 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 VR 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 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 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 coe cients 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 signi cant explanatory powers. Compared with domestic rms, 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 uni ed 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 nal industrial product. Tasks are ranked by their degree of technological sophistication, which enables l465(5odcit)1(hpla10(c)209(for))-320m7(ductio78ue)-304(c)288uealue chain4(c)28luecchaare rankedasingalue kicati 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 speci cally considered innovation in this framework. In other words, the learning-by-doing e ect 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 e ciency between the countries. This change may then lead to di erent 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.

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Mathematical Appendices

A.1 Derivation of Equation (26)

By equation (13) and (19),

$$L_S(z;t) = \frac{\quad}{w_S(t)} :$$

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

$$\frac{dT(t)}{dt} = \int_{T(t)}^{z(t)} \frac{L_S(z;t)}{J(t)} = \int_{T(t)}^{z(t)} \frac{\quad}{J(t)} \frac{\quad}{w_S(t)} dz = \int_{T(t)}^{z(t)} \frac{\quad}{J(t)} \frac{L_S}{z(t)} dz$$

$$= \frac{L_S}{J(t)} \frac{z(t) \quad T(t)}{z(t)} = \quad f(1 \quad z(t)) \frac{L_S}{L_N} \frac{z(t) \quad T(t)}{z(t)} :$$

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

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

By examining (26), it is obtained that

$$\frac{d^2T(t)}{dt^2} = \quad \frac{L_S}{J(t)} \quad \frac{1}{z(t)^2} \quad z(t) \frac{dT(t)}{dt(} \quad ($$

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

$$Y(t) = \frac{f}{a} e^{\frac{1}{2}} \quad e^{z(t)^2 \quad T(t)^2}:$$

(ii). Time Dynamics of Per-brand Output

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

$$\frac{dY(t)}{dt} = Y(t) \quad 2 \quad z(t)\frac{z(t)}{dt} \quad T(t)^{dT}$$

Given (39),

$$\frac{dY(t)^{0}}{dt} = \frac{L_S f}{L_N a} \quad e^{\quad (T(t) \quad 1)^2 + \frac{1}{2}} \quad [2(1 \quad T(t))] \quad \frac{dT(t)}{dt};$$

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

A.8 Proof of $\frac{U_N^{0}}{U_N^A} > 1$

From (58),

$$\frac{U_N^{0}}{U_N^A} = \frac{L_S}{L_N} \quad \frac{1}{} \quad (1 \quad)^{2 \quad \frac{1}{}}:$$

The function $\frac{1}{} \quad (1 \quad)^{2 \quad \frac{1}{}}$ is monotonically decreasing in . Thus, with $\quad < \frac{L_S}{L_S + L_N}$ in the extreme o shoring case,

$$\frac{U_N^{0}}{U_N^A} > \frac{U_N^{0}}{U_N^A}\left(\quad = \frac{L_S}{L_S + L_N}\right) = \quad \frac{L_S + L_N}{L_N}^{\quad \frac{L_N}{L_S}} > 1:$$

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

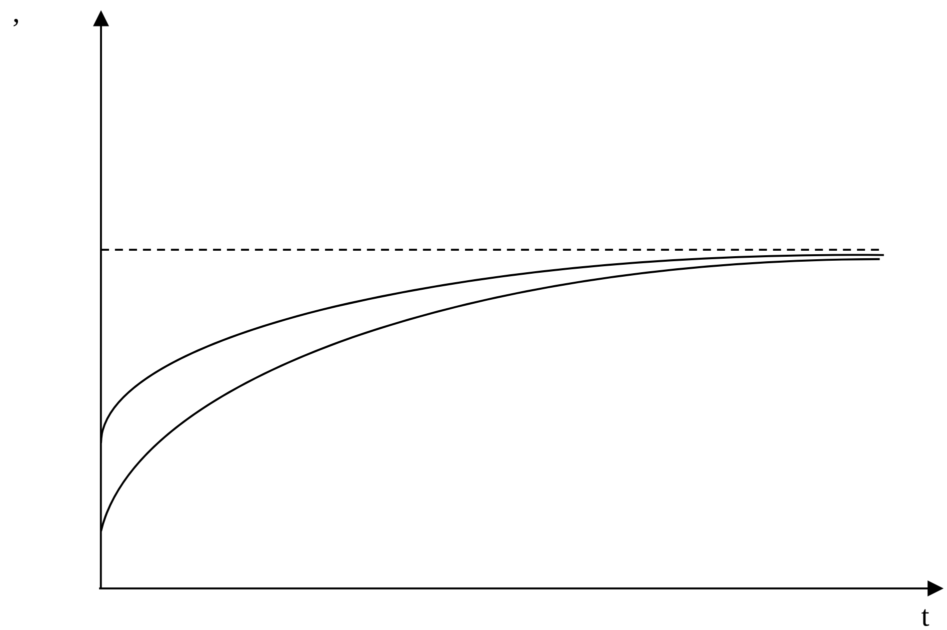
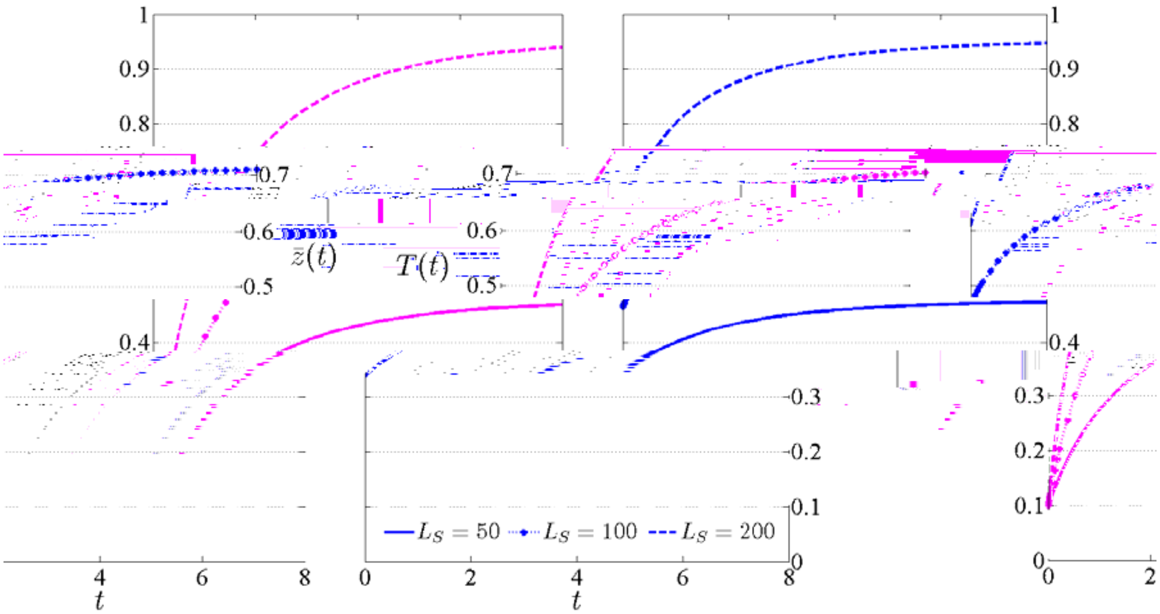


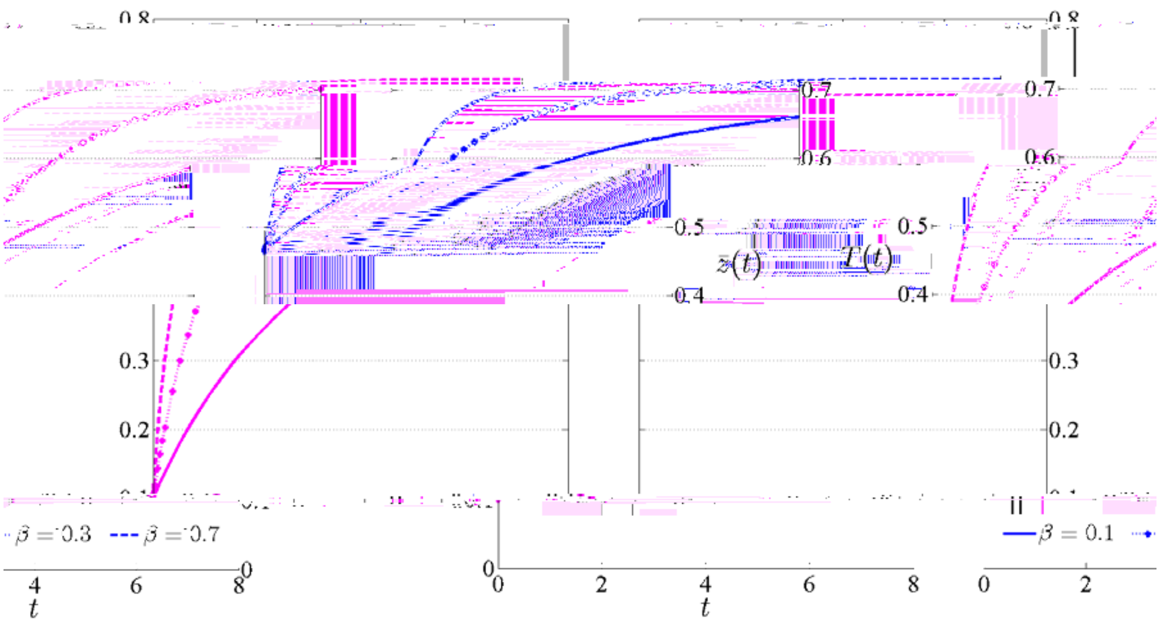
Figure 4. Task Dynamics – Simulations

Panel A. Labor Endowment in the South



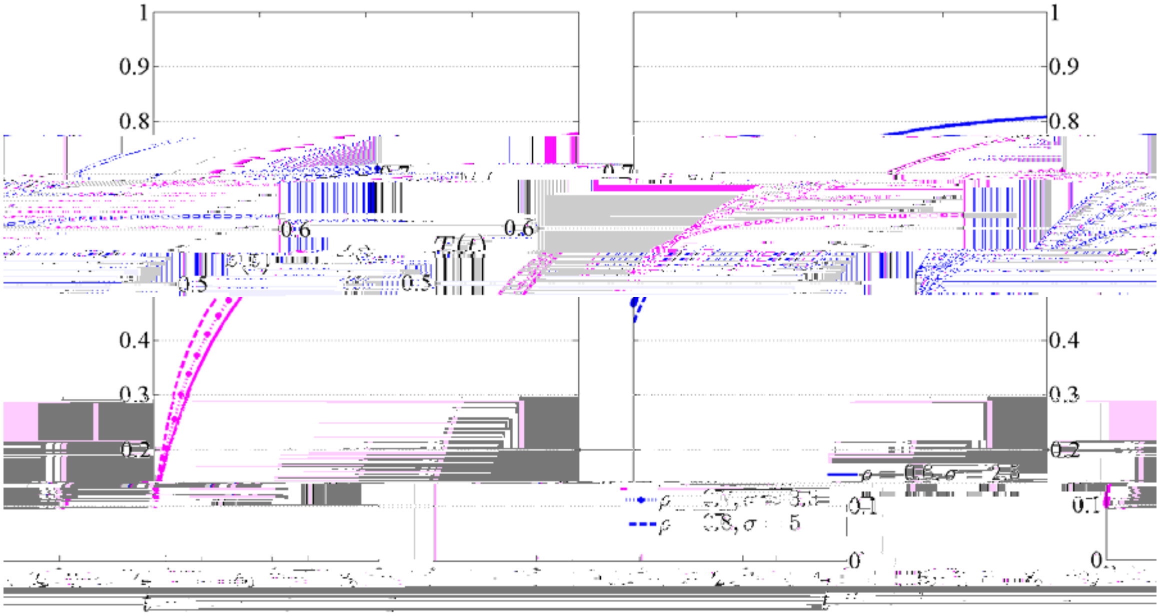
Note: .

Panel B. Learning Ability



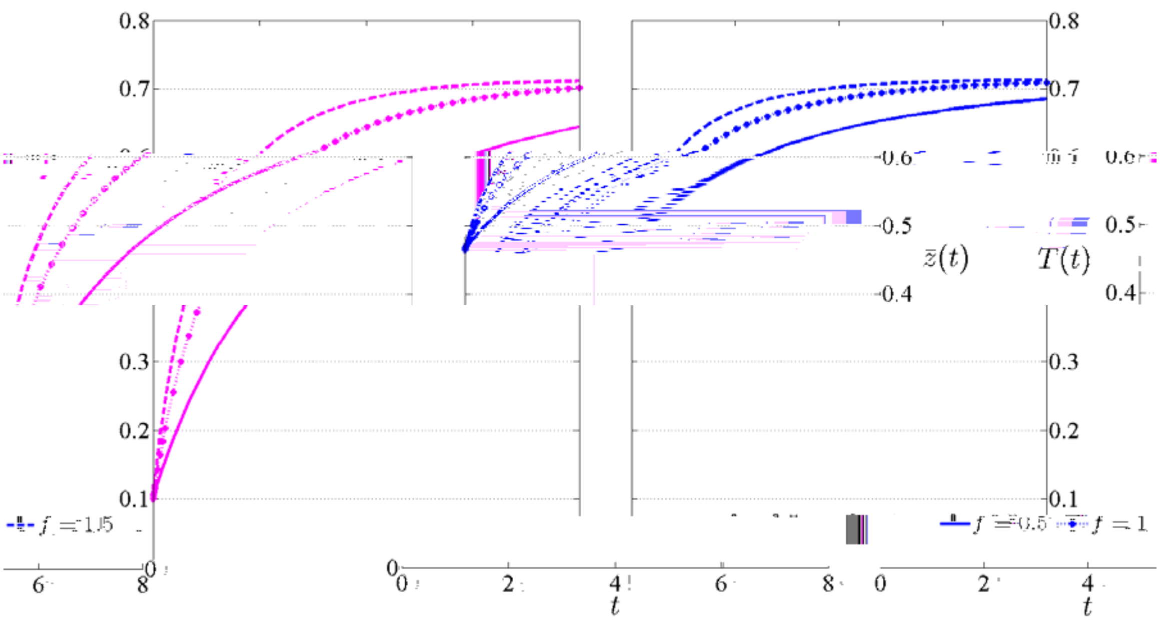
Note: .

Panel C. Variety Substitutability



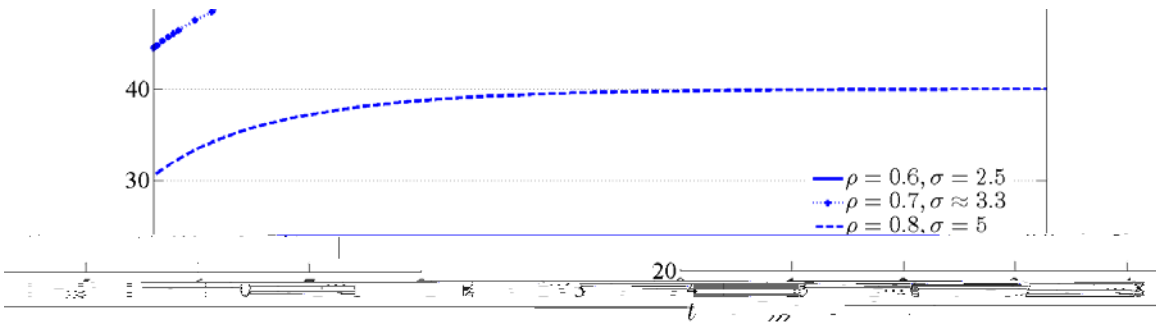
Note: .

Panel D. Fixed Cost for Branding



Note: .

Figure 5. Dynamics of Variety



Note: .

Figure 6. Dynamics of Wage Rates

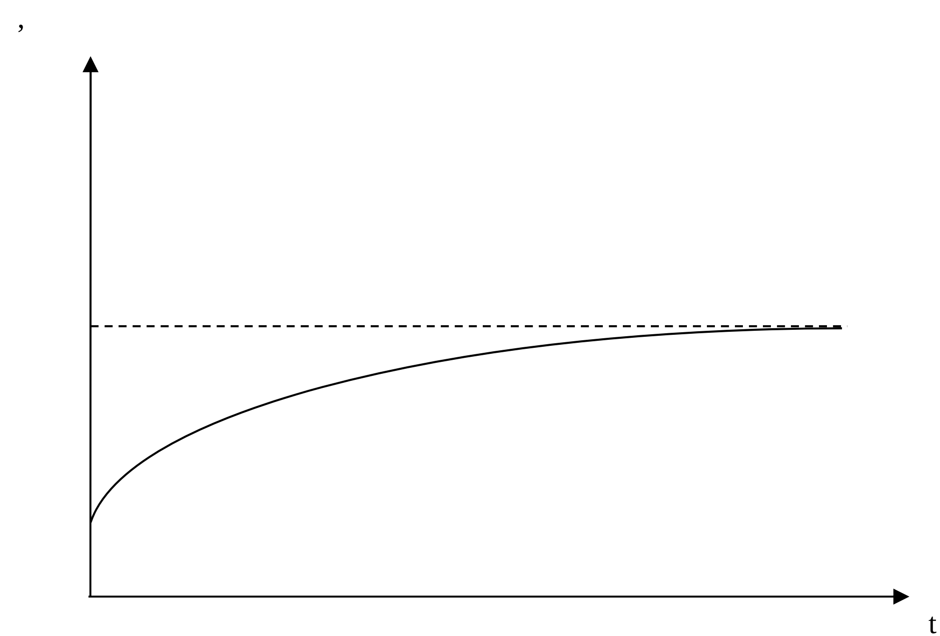
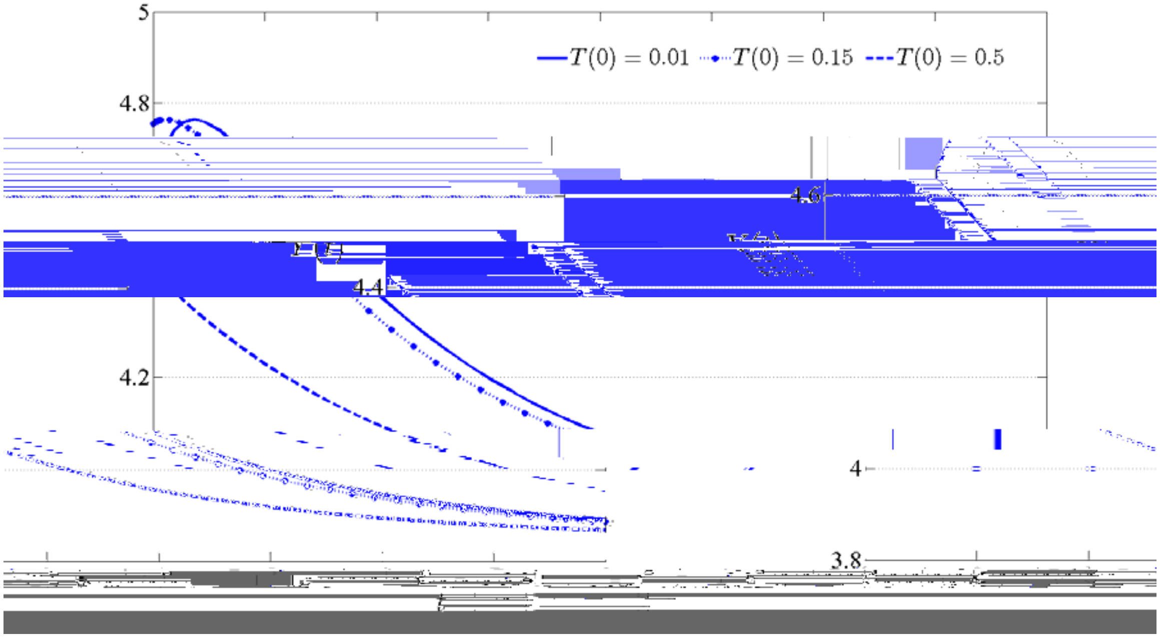


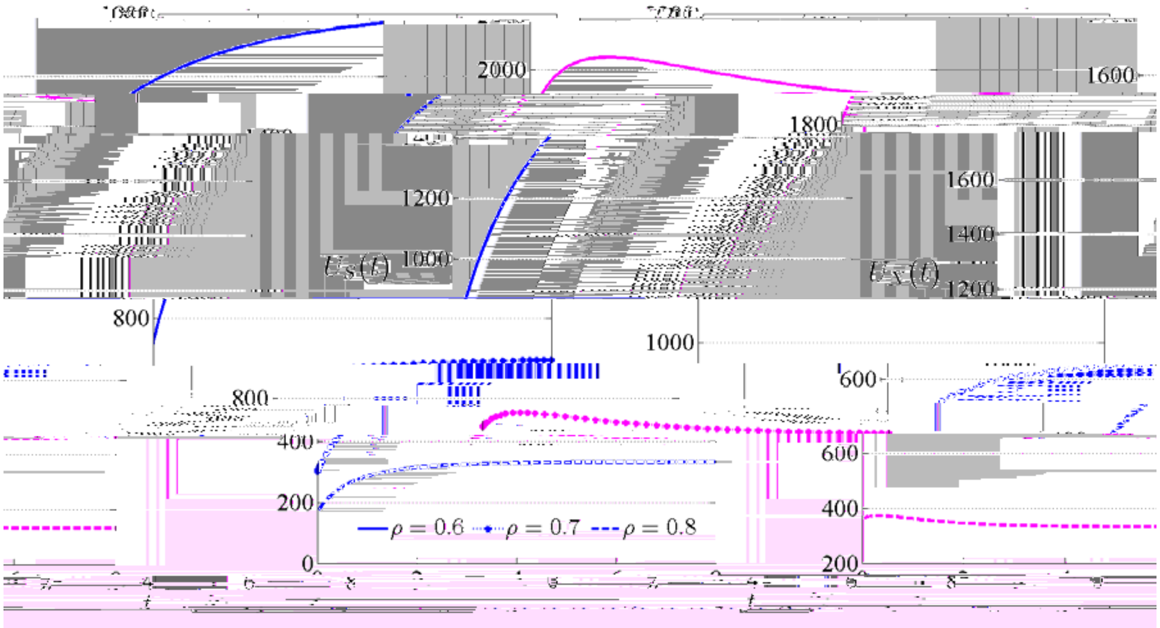
Figure 7. Dynamics of Per-brand Output



Note: .

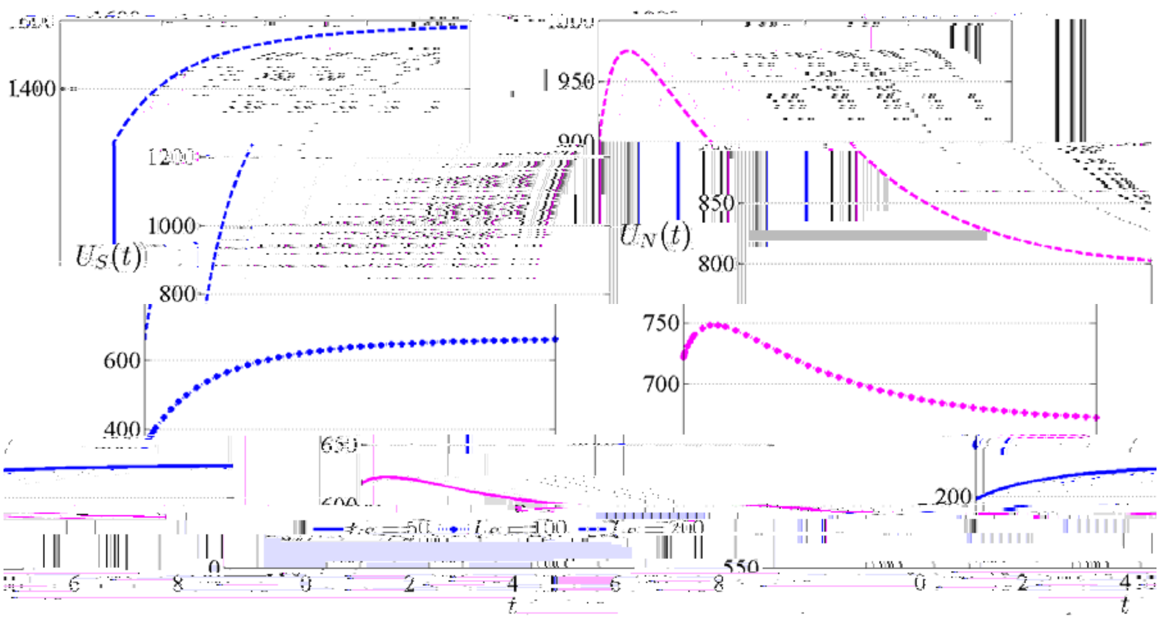
Figure 8. Dynamics of National Welfares

Panel A. Variety Substitutability



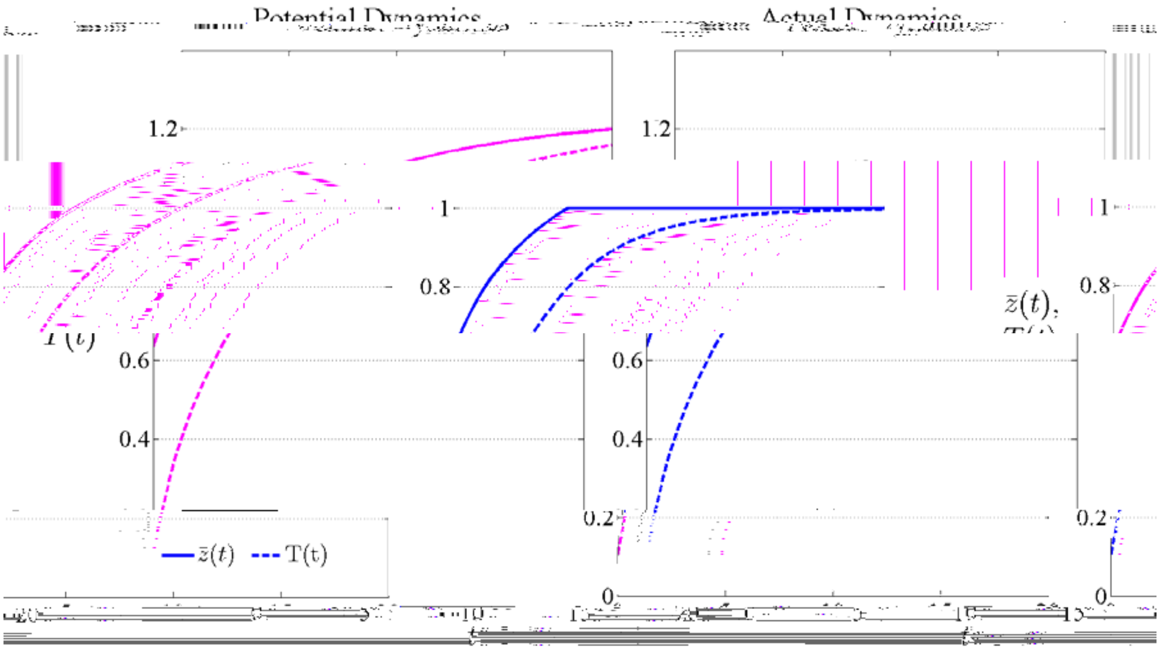
Note: .

Panel B. Size of the South



Note: .

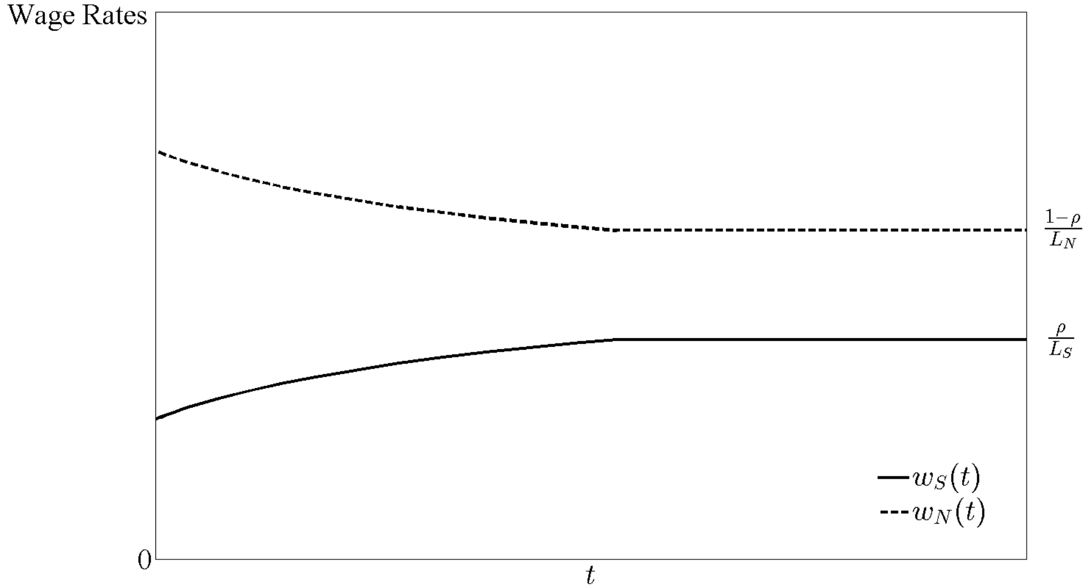
Figure 9. Task Dynamics under Extreme-end Evolution



Note: .

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

Panel A. Dynamics of Wage Rates



Panel B. Dynamics of Variety

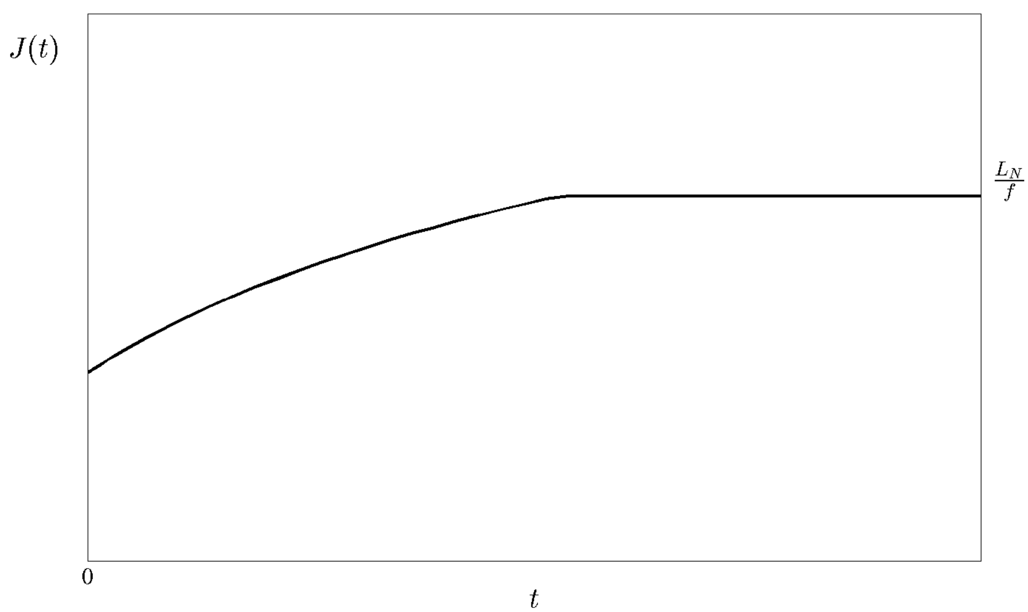
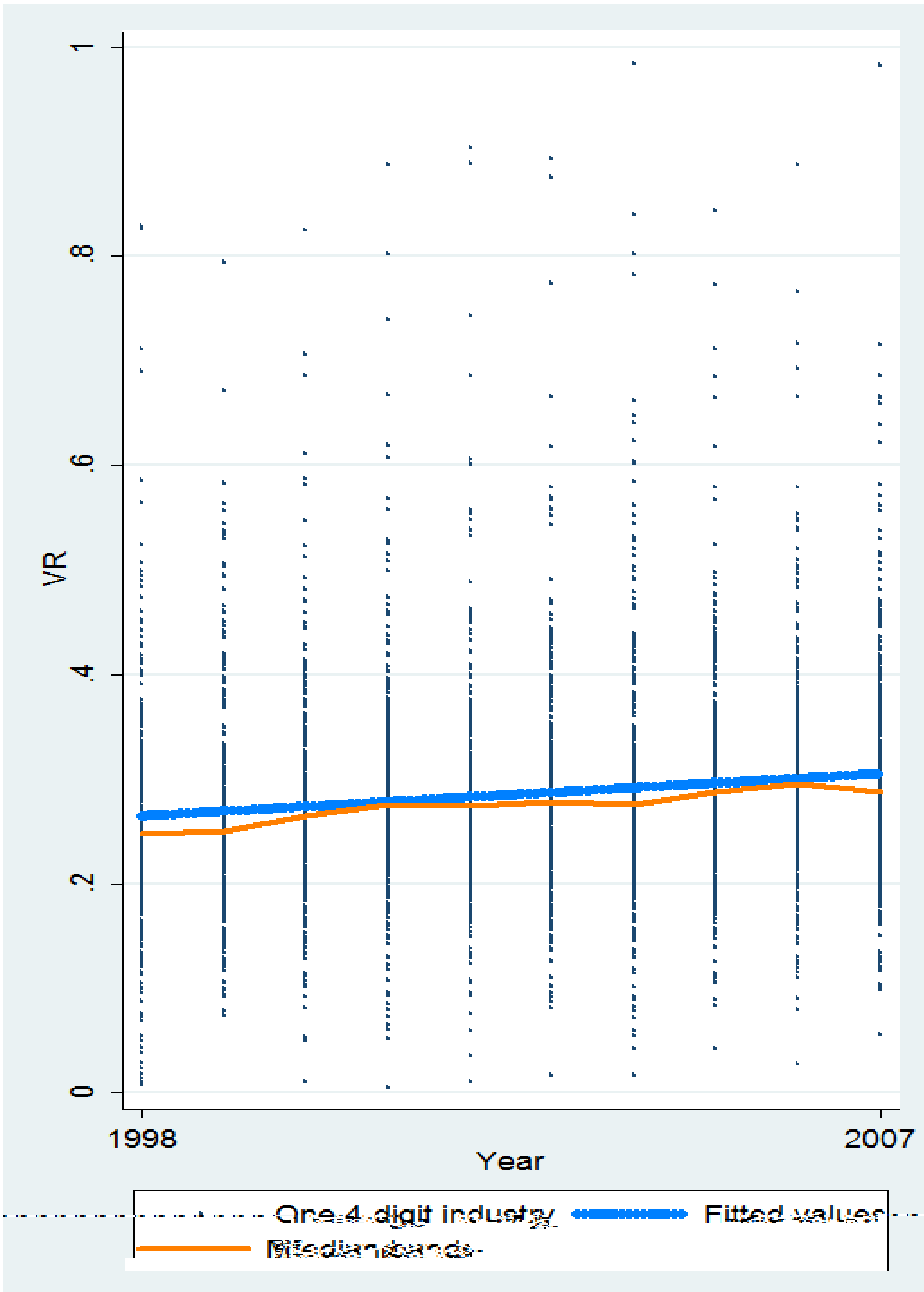


Figure 12. Welfare Gains from Offshoring – Normal Case

Note:

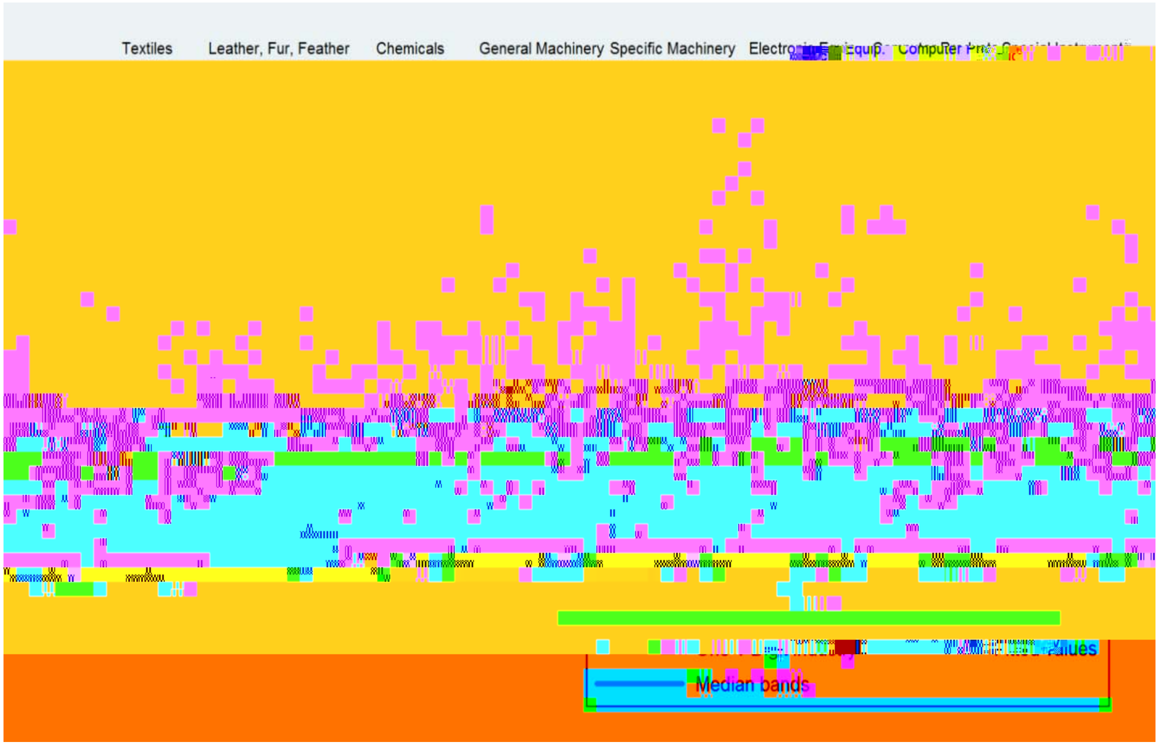
Figure 14. VR Growth

Panel A. VR Growth, Overall



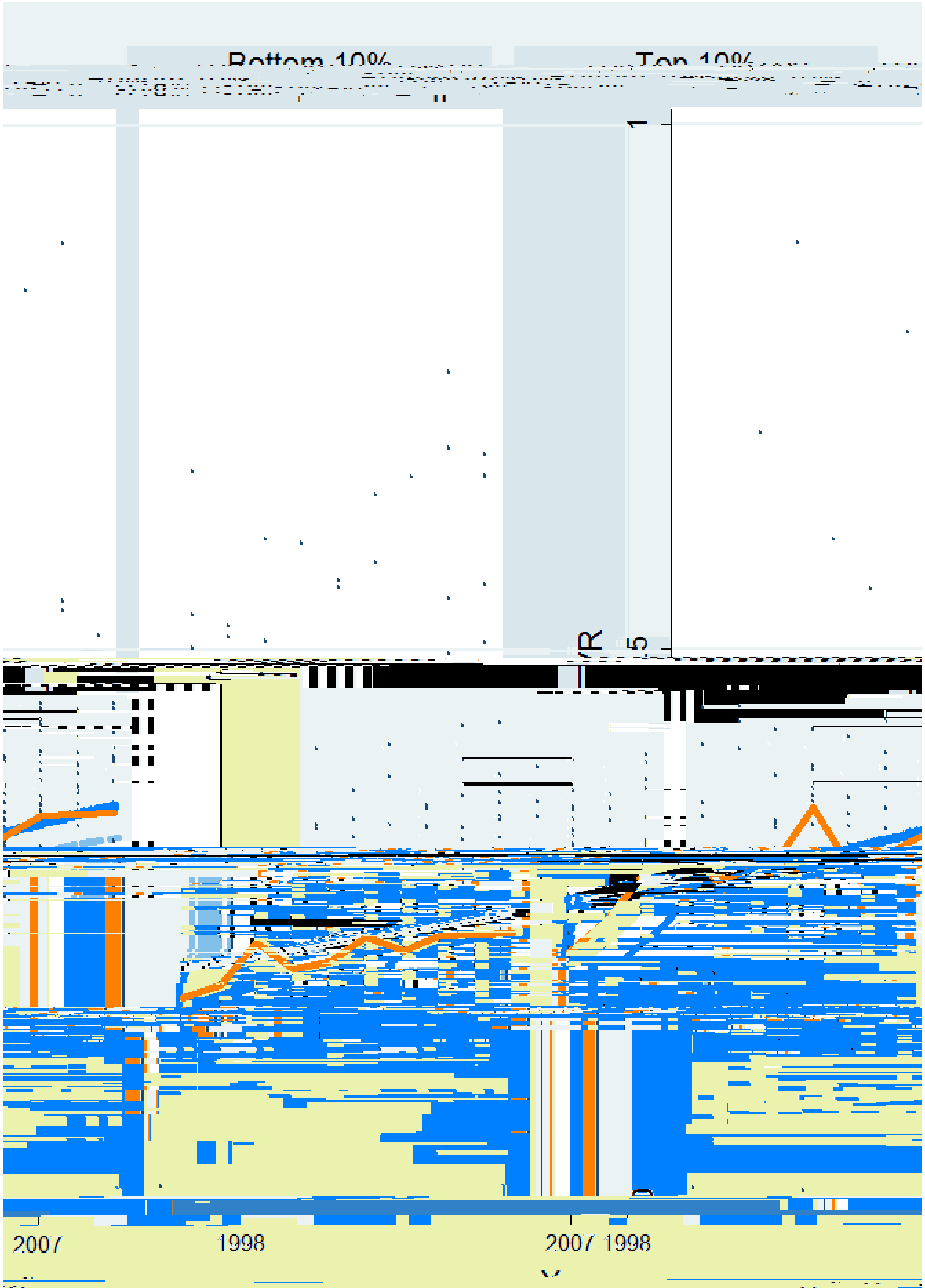
Note: A single dot represents a 4-digit industry.

Panel B. VR Growth, Two-digit Industries



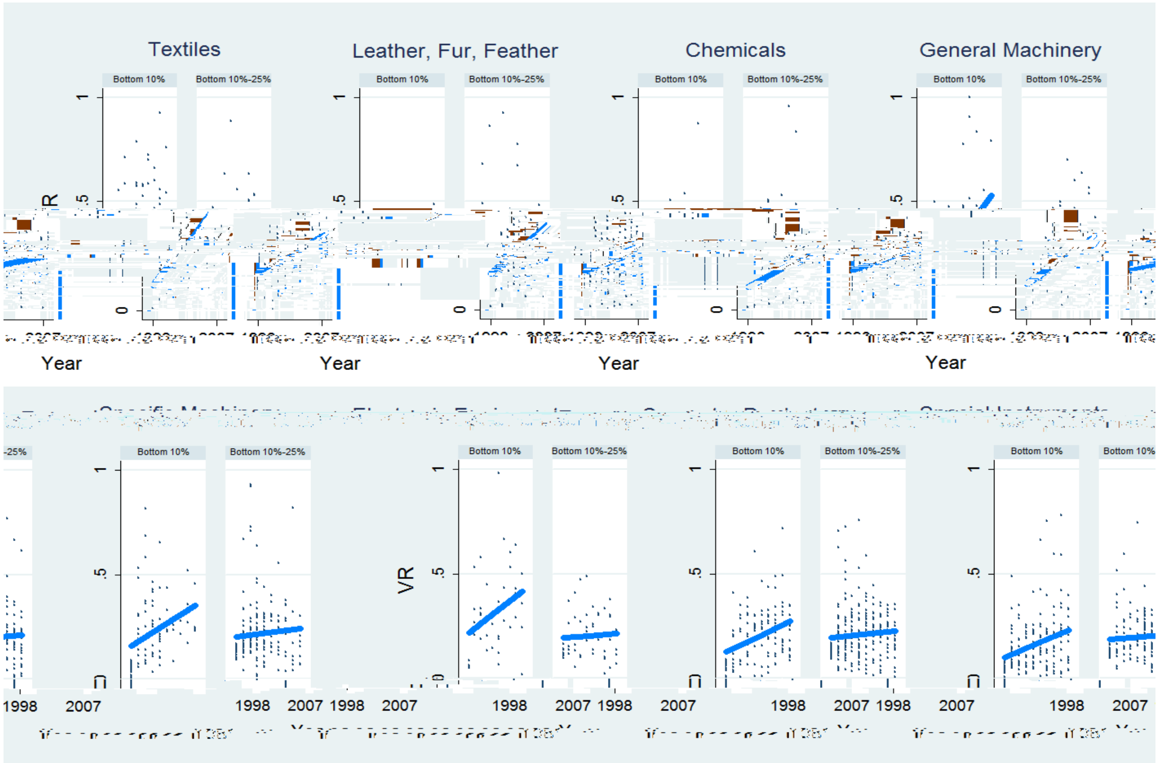
Note: A single dot represents a 4-digit industry under the 2-digit industry.

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 Δ

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

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

	(1)	(2)	(5)	(6)	(5)	(6)
Dependent Variables	ΔVR	ΔVR	Within-Subsidiary Margin	Within-Subsidiary Margin	Cross-Subsidiary Margin	Cross-Subsidiary Margin
	Full sample	Full sample	Full sample	Full sample	Full sample	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		Within-Subsidiary Margin	Cross-Subsidiary Margin
Initial VR	-0.0234	-0.0155	-0.0079*			
	(0.0145)	(0.0157)	(0.00446)			
Year Trend (τ)	9.96e-05	-0.000159	0.000258***			
	(0.000211)	(0.000203)	(5.96e-05)			

Training 0 0 10.02 8026ce02 8026sTraining rS1ly

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 Rwβc Tc0 97.0011 Tw.6(, R3)-4.4(2)]TJ-3.3293 -1.2695 TD.0r934 TD.C and (ecoTJ-3.der)4.7(d( )]TJ(r)-64.4(2)		