査読論文

Fixed Capital, Comparative Advantage and Regional Manufacturing Structures†

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Abstract

In this paper, we propose a two-industry, two-factor, and two-region model to investigate the formation of regional manufacturing structures, which are in terms of the shares of manufacturing industries of regions. We suppose that increasing returns are generated from the variety of intermediate inputs, which are resulted from the local fixed capital stock. We then show that the region with more fixed capital stock has an absolute advantage in both the high-tech and low-tech manufacturing industries and a comparative advantage in the high-tech industry, which uses more intermediate goods. The other region, which is endowed with less fixed capital stock, has only a comparative advantage in the low-tech industry. The corresponding regional manufacturing structures are that the region with more fixed capital stock has larger revenues of the two industries and a larger revenue ratio of the high-tech to low-tech industries. These theoretical inferences are supported by evidence from the data on the regional industrial structures in China.

Keywords

Fixed Capital, Increasing Returns, Comparative Advantage, Regional Manufacturing Structures, Labor Distribution

JEL Classification

F11, F12, R11, R12

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1. Introduction

The notable early contributions of Ricardo (1817) and Ohlin (1933) illustrated how comparative advantage and manufacturing structures[1] at the national level (or international trade patterns) are determined by the technology and natural endowment differences across countries. Krugman (1979, 1980) introduced differentiated consumer goods into this traditional trade theory, which became the foundation of the new trade theory (NTT). Noticing that “producer goods are in fact much more prominent in trade than are consumer goods”, Ethier (1979, 1982) shifted the view from consumer goods to differentiated producer goods (or intermediate goods), which were assumed to have increasing returns to scale (IRS) due to the division of labor. Later, along the line of differentiated intermediate goods, Mastuyama (1996) further divided the manufacturing activities with IRS into two industries based on their input intensities: the intermediate input-intensive high-tech industry and the labor-intensive commodity industry. He showed that the production costs of the two final products decrease with the increase in the variety of intermediate inputs (due to the increasing returns). Meanwhile, as assuming the intermediate inputs more intensively, the local high-tech industry benefits more from increasing returns generated by the variety of intermediate inputs. As the result, a country endowed with a wider variety of intermediate inputs acquires a comparative advantage in the high-tech industry and specializes in it. However, the above mentioned models fail to consider the movement of regional production factors, they are not able to explain the formation of comparative advantage and manufacturing structures at the subnational level, which is featured by the interregional movement of labor.

Turning to the regional economic literature, it seems that little attention has been paid to the formation of comparative advantage and regional manufacturing structure. Indeed, Krugman (1991) has built a two-region model showing that a low level of transport cost and a high level of elasticity of substitution toward variety induce the agglomeration of manufacturing activities in one region, which triggered extensive research along this line generally known as the new economic geography (NEG). However, under the *symmetric assumption* on the production of the variety goods (Dixit and Stiglitz 1977),[2] most NEG studies fail to model the characteristics of different manufacturing activities, and only think that manufacturing activities are generally aggregated into one set of the variety goods.[3] In this sense, few NTT and NEG studies have investigated the formation of regional manufacturing structures (Tan and Zeng 2104, p. 230).

In the real world, however, different manufacturing industries differ in the degree to which they rely on the local variety of intermediate goods, i.e., manufacturing activities are not symmetric. Early work by Porter highlighted the importance of clusters in a firm's strategic location decisions (Porter 1980, 1990). Porter (1998) argued that sharing the variety goods is especially important for "advanced and specialized industries involving embedded technology, information, and service content." In the footloose capital (FC) model (Martin and Rogers 1995), the local capital amount was used to represent the local variety of manufacturing activities. Generally, if high-tech industries can benefit more from the local variety, they will tend to locate in the capital-abundant regions, which supply a larger variety of intermediate inputs. In contrast, regions with less fixed capital tend to have a larger share of commodity or low-tech industries, such as the textile industry, which is labor-intensive.

Fujita and Hu (2001) investigated the regional manufacturing structure transition in China from 1980 to 1994. They and others showed that in the 1980s and 1990s, several plants were built using foreign direct investment (FDI) on the east coast of China (see Tables 1 and 2). In that region, the manufacturing structure became characterized by the agglomeration of high-tech industries, which were heavily based on the inputs of intermediate goods. For example, in 1980, only 10% of washing machines and 19% of electric fans were produced in Guangdong, a coastal province near Hong Kong. And, no recorders, color TVs, or cameras were produced at that time. However, since 1980 when FDI began to increase in Guangdong, an agglomeration of electronics industries appeared. As a result, in 1994, the shares of digital wristwatches, recorders, color TVs, and cameras produced in Guangdong increased to 90%, 86%, 27%, and 84%, respectively (see Table 3).

Similar, in Japan, the variety of the supply of local intermediate inputs is also very attractive to high-tech manufacturing industries. Fujita et al. (2004) examined the regional structures of manufacturing industries in East Asia and Japan and found that the spatial concentration of the machinery-metal industries presents a strong evidence of "*linkage-*

Table 1 Regional distribution of investment in fixed assets in China

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
East/West	1.12	1.12	1.23	1.38	1.48	1.49	1.44	1.47	1.63	1.79	1.93
Provincial CV	0.596	0.596	0.645	0.711	0.744	0.605	0.714	0.726	0.820	0.841	0.851

CV: coefficient of variation

East: the amount of investment in the coastal provinces (Liaoning, Hebei, Beijing, Tianjin, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangxi, Guangdong, Hainan)

West: the amount of investment in the other provinces

Data Source: Fujita and Hu (2001)

Table 2 Regional distribution of fixed capital stock in China

	1978	1985	1990	1995	2000	2004
East/West	0.80	1.01	1.27	1.67	1.82	1.88

East: the amount of fixed capital stock in the coastal provinces
West: the amount of fixed capital in the other provinces
Data Source: Zhang, Wu and Zhang (2007)

Table 3 Electronics production in Guangdong as a percentage of national total production

	1980	1985	1990	1993	1994
Washing machines	9.88	8.78	21.58	27.15	22.59
Electric fans	19.05	41.27	56.27	56.68	65.18
Recorders	0.00	35.87	53.81	76.93	86.25
Color TVs	0.00	18.15	25.40	29.38	26.76
Cameras	0.00	10.44	46.57	89.63	83.65

Data Source: Fujita and Hu (2001)

based agglomeration economies". That is, such industries tend to locate together and concentrate in Japanese Core prefectures (J-Core) (The prefectures of Tokyo, Kanagawa, Aichi, Osaka and Hyogo).[4] In contrast, however, the textile-apparel industries show weak linkage-based agglomeration economies. In 1955, they accounted for 15% of the total manufacturing GDP of Japan, of which 45% was concentrated in the J-Core. However, in 1985, Japan was among the weakest of these industries (within East Asia), and they were among the least agglomerated in the J-Core. Such an industrial structure change in Japan is illustrated in Fig. 1.

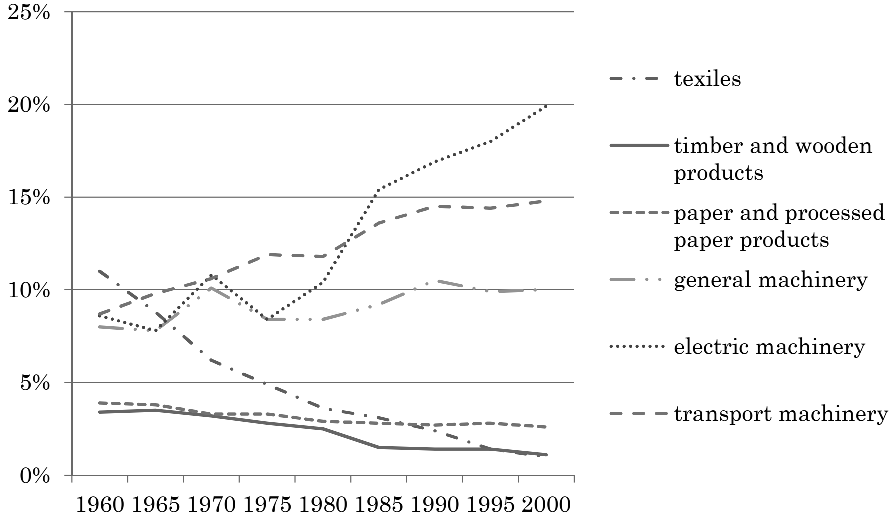

Fig. 1 Nominal revenue shares of selected two-digit industries in Japan's total manufacturing production[5]

As has been seen, the relations between regional fixed capital stocks and manufacturing structures are widely observed, but, to our knowledge, their microeconomic foundation has not been found. Recently, there appeared several following attempts at incorporating the classical comparative advantage theory into the NTT and NEG frameworks. Venables (1999) examined the role of *Ricardian differences* in the spatial distribution of different industries. In his model, labor was the only production factor and a comparative advantage arose from the exogenous technological difference among countries, as in Ricardo (1817). Adding capital as another production factor, Amiti (2005) extended the NEG model by embedding a vertical industrial linkage (Venables 1996) into a *Hechscher-Ohlin framework* to examine the location of vertically linked manufacturing firms. Recently, Tan and Zeng (2013) incorporated both Ricardian and Hechscher-Ohlin advantages into a FC model. Unfortunately, all of these studies were based on the assumed *exogenous interregional productivity gap,* which determined local comparative advantage and industrial structures, without explaining how the productivity gap was formed. As far as we know, this paper is the first attempt to endogenize both of regional productivities and comparative advantages. It can be considered a contribution to the literature of comparative advantage.

In addition, there have been several empirical studies attempting to deconstruct the sources of competitive advantage based on local embeddedness (Martin and Sunley 2003, Schotter et al 2017, Wójcik et al 2018, Goerzen, 2013). But they have not taken local fixed capital stock into consideration.

Based on the above literature review, this paper aims to answer the following questions. How does the local variety of intermediate inputs (as reflected by the local fixed capital stock) of a region relate to the local manufacturing productivity and the corresponding local comparative advantage? With this local comparative advantage, how are regional manufacturing structures formed, and how is the population distributed across regions?

Specifically, as done in the Matsuyama (1996) model, we distinguish manufacturing activities into intermediate-input-intensive high-tech industries and labor-intensive low-tech industries. And, similar to the FC model, we use the local fixed capital stocks to represent the local variety of intermediate inputs. We connect the local variety of intermediate input with the local productivity, which enables our endogenous analysis of the local productivity. Then, we show that the region enjoying more fixed capital has an absolute advantage in the two manufacturing industries and a comparative advantage in the capital-intensified high-tech industry. This leads to such regional manufacturing structures, that, the capital-abundant region has larger revenues of the two manufacturing industries (reflecting the absolute advantage) with a larger revenue ratio of the high-tech to low-tech industries (reflecting the comparative advantage).

In the next section, we describe the basic structure of the economy. In Section 3, we first discuss the role of the spatial distribution of fixed capital stock in the formation of regional absolute and comparative advantages and then show how such distribution determines the regional manufacturing structure. We also provide some empirical evidence from China. In Section 4, we examined the spatial distribution of population. Section 5 concludes the paper.

2. The Autarky Economy

In this section, we extend the Matsuyama (1996) model to an autarky economy with two industries and two production factors by introducing the fixed capital as an additional production factor as in the FC model. In particular, we assume that one unit of fixed capital associated with labor are inputted into the production of one variety of intermediates, so the amount of fixed capital stock is equal to that of the variety of intermediates. Such fixed capital stock can be considered as accumulated through all kinds of local fixed capital investments, such as investments in infrastructures, industrial plants and production equipment.

The endowment of the autarky economy is L units of labor and K units of fixed capital. Laborers are supplied to the high-tech industry, low-tech industry and intermediate goods sector. Due to the free movement of labor, wages are equal cross the three sectors, denoted by ω.

The fixed capital is owned in common by laborers, and the capital revenue is equally divided among the laborers. If one unit of fixed capital generates capital rental (r), then the total capital revenue becomes Kr. Laborers' (Consumers') total income $L\omega + Kr$ is used to consume T units of high-tech goods C units of the low-tech goods. Given that the amount of numeraire in the economy is denoted by Y, total revenue can be expressed as $Y = P^C C + P^T T$ (P^C and P^T are the prices of high-tech and low-tech goods, respectively), and total income can also be written as $Y = L\omega + Kr$.

2. 1 Consumption of Goods

Suppose that the representative consumer has a Cobb-Douglas preference over the two consumption goods, which can be represented by the following utility function:

$$U = R_u C^{1-\gamma} T^{\gamma},\ 0 < \gamma < 1 \tag{1}$$

where R_u is a constant parameter given as $R_u = (1-\gamma)^{\gamma-1}\gamma^{-\gamma}$, γ is the share of the high-tech goods in the consumer's expenditure, and $1-\gamma$ is that of the low-tech goods.

Denote P^C and P^T as the prices of the low-tech and high-tech goods, respectively. The consumer's problem is to maximize his or her utility function subject to the income budget constraint by choosing adequate amounts of consumption goods, which is expressed as follows:

$$\begin{aligned} &\max U = R_u C^{1-\gamma} T^{\gamma}; \\ &(C, T) \\ &\text{s. t. } Y = P^C C + P^T T \end{aligned} \tag{2}$$

The results of (2) yield:

$$Y^C = C^D P^C = (1-\gamma)\, Y \tag{3}$$

$$Y^T = T^D P^T = \gamma Y \tag{4}$$

where C^D and T^D denote the consumer's demand for the low-tech and high-tech goods, respectively, and Y^C and Y^T express the revenue of the low-tech and high-tech industries, respectively.

2. 2 Production of Consumption Goods

Suppose that the two consumption goods are produced competitively with constant-returns-to-scale technologies. The inputs are labor and the differentiated intermediate goods, which are combined with Cobb-Douglas technologies, with α_C and α_T being the input shares of intermediates in the low-tech and high-tech industries, respectively. So, the amount of the low-tech goods supplied, denoted as C^S, and that of the high-tech goods, denoted as T^S, can be given as follows:

$$C^S = R_C L^{C^{1-\alpha_C}} X^{C^{\alpha_C}},\ 0 < \alpha_C < 1 \tag{5}$$

$$T^S = R_T L^{T^{1-\alpha_T}} X^{T^{\alpha_T}},\ 0 < \alpha_T < 1 \tag{6}$$

where R_C $[\equiv (1-\alpha_C)^{\alpha_C - 1}\ \alpha_C{}^{-\alpha_C}]$ and R_T $[\equiv (1-\alpha_T{}^{\alpha_T - 1})\ \alpha_T{}^{-\alpha_T}]$ are two constants. X^C and X^T denote the amounts of intermediates inputted into the production of the low-tech and high-tech goods, respectively. L^C and L^T are the amounts of labor used in the low-tech and high-tech industries, respectively. α_C and α_T denote the shares of intermediates used in the production of low-tech and high-tech goods, respectively. Here, we impose an important assumption that $\alpha_C < \alpha_T$. That is, the high-tech industry uses the intermediate goods *more intensively* than does the low-tech industry.

The above Cobb-Douglas production functions imply that the rewards of intermediate goods and labor in the revenue of each industry can be expressed as follows:

$$X^C P^X = \alpha_C Y^C \tag{7a}$$

$$X^T P^X = \alpha_T Y^T \tag{7b}$$

$$L^C \omega = (1-\alpha_C)\, Y^C \tag{8a}$$

$$L^T \omega = (1-\alpha_T)\, Y^T \tag{8b}$$

where P^X denotes the price index of intermediate goods. That is, in the low-tech industry, proportion α_C of cost and hence of revenue goes to the intermediate goods sector, and $1-\alpha_C$ of that goes to laborers. In the high-tech industry, such proportions for labor and intermediate goods are α_T and $1-\alpha_T$, respectively.

2. 3 Production of Intermediate Goods

The differentiated intermediate goods are assumed to be supplied by local monopolistically competitive firms. Each of them is supplied by a monopolistic firm, which uses a marginal input of labor and a fixed input of fixed capital. Like many NEG works, we can choose the units of fixed capital and intermediate goods so that a fixed input of one unit of capital and a marginal input of $(\sigma-1)/\sigma$ units of labor are required to produce one unit of a variety. Thus, the variety of intermediate goods is equal to the fixed capital stock K. As done in Dixit-Stiglitz (1977), the local intermediate goods are aggregated as follows:

$$X = [\int_0^K x(z)^{\frac{\sigma-1}{\sigma}} dz]^{\frac{\sigma}{\sigma-1}},\ \sigma > 1 \tag{9}$$

where K is the range of differentiated intermediate goods (or the amount of fixed capital), $x(z)$ is the amount of the zth variety of intermediate goods, and $\sigma(>1)$ represents the elasticity of substitution between any two intermediate varieties. The cost minimization in using the intermediates yields the price index of intermediates as follows:

$$P^X = \left(\int_0^K p(\mathrm{z})^{\frac{\sigma}{\sigma-1}}\, dz\right)^{\frac{\sigma-1}{\sigma}} \tag{10}$$

where $p(\mathrm{z})$ is the price of intermediate goods of the zth variety.

Given that a fixed input of one unit of capital and a marginal input of $(\sigma - 1)/\sigma$ units of labor are inputted in the production of each variety, the profit for a plant to produce $x(\mathrm{z})$ units of the zth intermediate good can be written as:

$$\pi(z) = p(z)x(z) - \omega\frac{\sigma-1}{\sigma}x(z) - r \tag{11}$$

where r is the capital rental of using one unit of fixed capital. Since the supply of intermediate goods is monopolistically competitive, that is, each plant determines its price of intermediate goods monopolistically, its profit-maximizing solution yields:

$$p(\mathrm{z})\left(1 - \frac{1}{\sigma}\right) = \frac{\sigma-1}{\sigma}\omega$$

which can be simplified to:

$$p(\mathrm{z}) = p = \omega \tag{12}$$

Because the production technology is the same for all varieties, we can drop the subscript z in the relevant variables.

Furthermore, the zero-profit condition yields the rental of using one unit of fixed capital as follows:

$$\mathrm{r} = px - \omega\frac{\sigma-1}{\sigma}x = \frac{1}{\sigma}px \tag{13}$$

which means that the share of capital payment in the revenue for each intermediate goods plant is $\frac{1}{\sigma}$, and the share of labor payment becomes $1-\frac{1}{\sigma} = \frac{(\sigma-1)}{\sigma}$.

As the production technology is the same for all varieties, the share of labor payment and the share of capital payment are also the same across all intermediate goods plants, which are then equal to the shares in the revenue of the whole intermediate sector. Thus, the total labor payment in the revenue of the intermediate sector can be expressed as:

$$L^X \omega = \frac{(\sigma-1)}{\sigma} X P^X \tag{14}$$

where L^X denotes the amount of labor inputted in the intermediate goods sector. Similarly, the total capital payment in the revenue of the intermediate sector becomes

$$Kr = \frac{1}{\sigma} X P^X \tag{15}$$

Recall that in the low-tech industry, proportion α_C of production cost and hence of revenue goes into the intermediate goods sector, and $1 - \alpha_C$ of that goes to laborers. And, in the high-tech industry, the shares of labor and intermediate goods payments are α_T and $1 - \alpha_T$, respectively.

We can express the payment for the total capital in the autarky economy as follows:

$$Kr = \frac{1}{\sigma}(\alpha_C Y^C + \alpha_T Y^T) \tag{16}$$

And, the total labor payment in the autarky economy is equal to the total revenue minus the total capital payment, that is:

$$L\omega = (Y^C + Y^T) - \frac{1}{\sigma}(\alpha_C Y^C + \alpha_T Y^T) = \frac{(\sigma-\alpha_C)}{\sigma} Y^C + \frac{(\sigma-\alpha_T)}{\sigma} Y^T \tag{17}$$

where $Y^C = P^C C$ and $Y^T = P^T T$ are the revenues of the low-tech and high-tech industries, respectively. It should be noted that (a) total labor payment here consists of not only the labor payments in the two final goods sectors but also the labor payment in the intermediate goods sector.[6] (b) Although neither industry uses fixed capital directly, their revenues flow indirectly to the fixed capital payment through the use of intermediate goods. This can be confirmed by Equation (16), which implies that the payment shares of fixed capital in the high-tech and low-tech industries are $\frac{1}{\sigma}\alpha_T$ and $\frac{1}{\sigma}\alpha_C$, respectively. Under the perfect competition in the final goods markets, the shares of labor payment in each industry are equal to one minus the payment shares of fixed capital, i.e., $1 - \frac{1}{\sigma}\alpha_T = \frac{(\sigma-\alpha_T)}{\sigma}$ and $1 - \frac{1}{\sigma}\alpha_C = \frac{(\sigma-\alpha_C)}{\sigma}$ in the high-tech and low-tech industries, respectively. Because the input intensities of fixed capital in the two industries have such a relation as $\frac{1}{\sigma}\alpha_T > \frac{1}{\sigma}\alpha_C$, or the input intensities of labor have such one as $\frac{(\sigma-\alpha_T)}{\sigma} < \frac{(\sigma-\alpha_C)}{\sigma}$, we can say that the high-tech industry is fixed-capital intensified while the low-tech industry is labor-intensified.

2. 4 Unit Production Costs and Local Increasing Returns

To see how increasing returns (the productivity of each industry) are associated with the local fixed capitals stock, we need to calculate the unit production costs of the two final goods industries.

Substituting Equation (12) into Equation (10), the price index of the intermediate goods can be simplified to:

$$P^X = K^{\frac{\sigma-1}{\sigma}}\omega \tag{18}$$

The Cobb-Douglas production functions, Equations (5) and (6), imply that the unit production costs in the two industries can be written as follows:

$$C^C = P^{X\alpha_C}\omega^{1-\alpha_C} \tag{19}$$

$$C^T = P^{X\alpha_T}\omega^{1-\alpha_T} \tag{20}$$

where C^C and C^T denote the unit production costs of low-tech and high-tech goods, respectively. Under the perfect competition in the final goods markets, they are equal to the corresponding market prices, that is, $C^C = P^C$ and $C^T = P^T$. Furthermore, using Equation (18) to replace P^X in (19) and (20) yields:

$$P^C = K^{\frac{\alpha_C}{1-\sigma}}\omega \tag{21}$$

$$P^T = K^{\frac{\alpha_T}{1-\sigma}}\omega \tag{22}$$

Since $\sigma > 1$, Equations (21) and (22) imply that the unit production costs of low-tech and high-tech goods decline with the variety of intermediate goods K. The increasing of local productivity cause by the variety of intermediate inputs was originally modeled by Ethier (1977, 1982), who attributed them to the division of labor suggested by Adam Smith using the examples of pin factory and Swiss watch industry. In the traditional NEG model, it is assumed that consumers benefit from the variety of final goods, i.e., the increasing returns to the utility. In this paper, we assume that the final goods industries benefit from the variety of intermediate inputs because the unit production costs of low-tech and high-tech goods decline with the variety of intermediate goods. Furthermore, we also assume that $\alpha_C < \alpha_T$, which implies that the unit production cost declines faster in the high-tech industry than in the low-tech industry.

3. A Two-region Economy

In this section, we extend the above autarky economy to a two-region economy comprising the eastern region (Region E) and western region (Region W), while the numeraire endowment of the two-region economy is retained to be Y. Suppose that Region E is endowed with more fixed capital stock than Region W (like the case of China), and the ratio of the local fixed capital stock in Region E to that in Region W is denoted as φ, that is, $\varphi \equiv \frac{K_E}{K_W}(> 1)$, where K_E and K_W are the amount of fixed capital stock in Region E and W, respectively. Such a spatial distribution of fixed capital stock, or, K_E, K_W and φ, are exogenously given by historical, geographical or political factors that are not studied here.

Denote the capital rentals in the two regions as r_E and r_W, respectively, the total capital revenue can be written as $K_E r_E + K_W r_W$, which is equally allocated to each laborer, no matter what his location.

In addition, we assume that the intermediate goods are not tradable, while the interregional trade of final goods incurs no transportation costs, as in Fujita (1988) and Rivera-Batiz (1988). Considering the shared fixed capital stock and the relatively high transportation costs of intermediate goods compared to the transportation costs of final goods, this assumption is not far from reality.[7]

3. 1 Regional Absolute and Comparative Advantages

Here, we investigate what determines regional absolute and comparative advantages, which are associated with the formation of regional manufacturing structures to be discussed later.

Using K_E to replace K in Equations (21) and (22), the unit production costs of low-tech and high-tech goods (or their market prices denoted as P_E^C and P_E^T, respectively) in Region E can be expressed as follows:

$$P_E^C = K_E^{\frac{\alpha_C}{1-\sigma}}\omega \tag{23a}$$

$$P_E^T = K_E^{\frac{\alpha_T}{1-\sigma}}\omega \tag{23b}$$

Similarly, the corresponding unit production costs or market prices denoted as P_W^C and P_W^T, respectively, in Region W can be given as:

$$P_W^C = \mathrm{K}_W^{\frac{\alpha_C}{1-\sigma}}\omega \tag{24a}$$

$$P_W^T = \mathrm{K}_W^{\frac{\alpha_T}{1-\sigma}}\omega \tag{24b}$$

Since $K_E > K_W$ and $\sigma > 1$, it is easy to see that the unit production costs of low-tech and high-tech goods are lower in Region E, that is, $P_E^C < P_W^C$ and $P_E^T < P_W^T$, which implies that Region E has an absolute advantage in both the high-tech and low-tech industries.

Furthermore, using Equations (23a) and (23b), the relative unit production cost of low-tech goods in terms of that of high-tech goods in Region E, denoted by Q_E, can be written as:

$$Q_E = \frac{P_E^C}{P_E^T} = K_E^{\frac{\alpha_C-\alpha_T}{1-\sigma}} \tag{25}$$

Similarly, the relative unit production cost of low-tech goods in terms of that of high-tech goods in Region W, denoted by Q_W, can be written as:

$$Q_W = \frac{P_W^C}{P_W^T} = K_W^{\frac{\alpha_C-\alpha_T}{1-\sigma}} \tag{26}$$

So, to see the comparative advantage of each region, we compare the relative unit costs between the two regions, obtaining:

$$\frac{\mathrm{Q}_E}{\mathrm{Q}_W} = \left(\frac{\mathrm{K}_E}{\mathrm{K}_W}\right)^{\frac{\alpha_C-\alpha_T}{1-\sigma}} = (\varphi)^{\frac{\alpha_C-\alpha_T}{1-\sigma}} \tag{27}$$

This means that the comparative advantage is determined by the distribution of fixed capital or φ. Given that $\alpha_C < \alpha_T$ and $\varphi > 1$, it is easy to gain $\frac{\mathrm{Q}_E}{\mathrm{Q}_W} > 1$. So, we obtain the following Proposition.

Proposition 1 *The capital-abundant region has an absolute advantage in both high-tech and low-tech industries and has a comparative advantage in the high-tech industry, which uses fixed capital more intensively. In contrast, the region with less fixed capital has no absolute advantage but has a comparative advantage in the labor-intensive low-tech industry.*

Although some studies (e.g. Amiti, 2005; Tan and Zeng, 2013) also considered both Ricardian advantages (the productivity gap) and Hechscher-Ohlin comparative advantages (the factor endowment gap), they were based on the assumed exogenous interregional productivity gap. The endogenous explanation of both the productivity gap (absolute advantage) and the comparative advantage is a major difference between this paper and the usual comparative advantage theory.

Differentiating Equation (27) with respect to φ yields $\frac{d\frac{Q_E}{Q_W}}{d\varphi} > 0$, which means that an increase in φ will enhance the capital-abundant region's comparative advantage in the high-tech industry and the capital-poor region's comparative advantage in the low-tech industry. Moreover, $\frac{Q_E}{Q_W}$ increases with the gap of the intensities using the intermediates between the high-tech and low-tech industries, that is, $\alpha_C - \alpha_T$. In other word, larger intensity gap implies larger absolute and comparative advantages.

3. 2 Regional Manufacturing Structures

To investigate regional manufacturing structures, we define two following indexes, $\mu_E \equiv Y_E^T/Y_E^C$ and $\mu_W \equiv Y_W^T/Y_W^C$, to represent the manufacturing structures in Region E and Region W, respectively, where Y_E^T and Y_E^C are the revenues of the high-tech and low-tech industries in Region E, respectively, and Y_W^T and Y_W^C are the corresponding revenues in Region W.

Matsuyama (1996) showed that one country specializes in one manufacturing industry in which it has a comparative advantage. A slight change in the variety of intermediate inputs brings about a catastrophic change in the manufacturing industry in which the country specializes. To avoid catastrophic changes, using the Armington (1969) assumption,[8] we treat the final goods of the same industry but produced in different regions as differentiated goods. Specifically, we maintain the assumption that the representative consumer has a Cobb-Douglas preference for high-tech and low-tech goods with the consumption shares being γ and $1-\gamma$, respectively, which ensures the perfect competition in the final goods markets. Furthermore, we assume that the representative consumer has an Armington (1969) type of constant elasticity of substitution (CES) subutility function about the two final goods produced in each region.[9] That is, each region produces a kind of differentiated high-tech good and a kind of differentiated low-tech good.

Specifically, regarding the low-tech goods, we define the following subutility function:

$$C = (C_E^{\frac{\eta-1}{\eta}} + C_W^{\frac{\eta-1}{\eta}})^{\frac{\eta}{\eta-1}},\ \eta > 1 \tag{28}$$

Regarding the high-tech goods, the following subutility function is defined:

$$T = (\mathrm{T}_E^{\frac{\eta-1}{\eta}} + \mathrm{T}_W^{\frac{\eta-1}{\eta}})^{\frac{\eta}{\eta-1}},\ \eta > 1 \tag{29}$$

In (28) and (29), and C_E are C_W the consumption amounts of the low-tech goods produced in Region E and Region W, respectively. T_E and T_W are the consumption amounts of the high-tech goods produced in Region E and Region W, respectively. η denotes the elasticity of substitution between the similar final goods produced in different regions. The price elasticity of demand for each final goods is also η.

The representative consumer's problem is solved in two steps. First, the consumer chooses the consumption proportions of high-tech and low-tech goods under the Cobb-Douglas preference (Equation 1), which yields:

$$Y^C = Y_E^C + Y_W^C = (1-\gamma)\,Y \tag{30a}$$

$$Y^T = Y_E^T + Y_W^T = \gamma Y \tag{30b}$$

Second, regarding the consumption amounts of low-tech goods (C_E and C_W), given their prices in each region as P_E^C and P_W^C,[10] the representative consumer maximizes the total consumption subject to the expenditure on the low-tech goods (Y_C), which implies the following maximization problems:

$$\max_{(C_E,\, C_W)} C = (\mathrm{C}_E^{\frac{\eta-1}{\eta}} + \mathrm{C}_W^{\frac{\eta-1}{\eta}})^{\frac{\eta}{\eta-1}} \tag{31}$$

$$\text{s. t. } P_E^C C_E + P_W^C C_W = Y^C = (1-\gamma)\,Y$$

Similarly, regarding the high-tech goods produced in the two regions, the consumer maximizes the total consumption subject to the expenditure on these goods (Y^T) by choosing the consumption amounts (T_E and T_W), which can be described as follows:

$$\max_{(\mathrm{T}_E,\, \mathrm{T}_W)} T = \left(\mathrm{T}_E^{\frac{\eta-1}{\eta}} + \mathrm{T}_W^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}} \tag{32}$$

$$\text{s. t. } P_E^T \mathrm{T}_E + P_W^T \mathrm{T}_W = Y^T = \gamma Y$$

It can be obtained that the first-order condition of the maximization problem (31) yields the following revenues of low-tech industries in Regions E and W:

$$Y_E^C = Y^C \frac{1}{1+(\frac{P_W^C}{P_E^C})^{1-\eta}} = \frac{(1-\gamma)Y}{1+(\frac{P_W^C}{P_E^C})^{1-\eta}} \tag{33}$$

$$Y_W^C = Y^C \frac{1}{1+(\frac{P_E^C}{P_W^C})^{1-\eta}} = \frac{(1-\gamma)Y}{1+(\frac{P_E^C}{P_W^C})^{1-\eta}} \tag{34}$$

Under the assumptions of zero transportation costs and perfect competition in the interregional final goods market, each region's unit production costs of the low-tech and high-tech goods are equal to their corresponding local market prices. Thus, using Equations (23a) and (24a) to replace P_E^C and P_W^C in (33) and (34) yields:

$$Y_E^C = \frac{(1-\gamma)Y}{1+(\varphi^{\frac{\alpha_C}{\sigma-1}})^{1-\eta}} \tag{35}$$

$$Y_W^C = \frac{(1-\gamma)Y}{1+(\varphi^{\frac{\alpha_C}{1-\sigma}})^{1-\eta}} \tag{36}$$

For simplicity, we assume $\sigma = \eta$, that is, the elasticity of substitution among varieties is equal to that among final goods.[11] So, (35) and (36) become:

$$Y_E^C = \frac{(1-\gamma)Y}{1+\varphi^{-\alpha_C}} \tag{37}$$

$$Y_W^C = \frac{(1-\gamma)Y}{1+\varphi^{\alpha_C}} \tag{38}$$

Regarding the high-tech goods, through a similar calculation process, we can obtain:

$$Y_E^T = \frac{\gamma Y}{1+\varphi^{-\alpha_T}} \tag{39}$$

$$Y_W^T = \frac{\gamma Y}{1+\varphi^{\alpha_T}} \tag{40}$$

Equations (37), (38), (39), and (40) give the revenues of the two final goods industries in the two regions. Differentiating them with respect to φ yields: $\frac{dY_E^C}{d\varphi} > 0$, $\frac{dY_E^T}{d\varphi} > 0$; $\frac{dY_W^C}{d\varphi} < 0$, $\frac{dY_W^T}{d\varphi} < 0$, which imply that the local revenues of both the high-tech and low-tech industries in Region E increases with the ratio of the local fixed capital stock in region E to that in region W, while the local revenues in region W decreases with the ratio.

Using Equations (39) and (37), the manufacturing structure of Region E can be expressed as:

$$\mu_E \equiv Y_E^T / Y_E^C = \frac{\gamma}{1-\gamma} \frac{1+\varphi^{-\alpha_C}}{1+\varphi^{-\alpha_T}} \tag{41}$$

Similarly, using equations (38) and (40), we can express the manufacturing structure of Region *W* as follows:

$$\mu_W \equiv Y_W^T / Y_W^C = \frac{\gamma}{1-\gamma} \frac{1+\varphi^{\alpha_C}}{1+\varphi^{\alpha_T}} \tag{42}$$

Equations (41) and (42) yield the following Lemma.

Lemma

(i) For all $\varphi \in (1, \infty)$, we have $\mu_E > \mu_W$. That is, the capital-abundant region will relatively specialize in the high-tech industry, while the region with less capital will relatively specialize in the low-tech industries.

(ii) The solution of $\frac{d\mu_E}{d\varphi} = 0$ (denoted as "$\overline{\varphi}$") within $(1, \infty)$ is unique. For any $\varphi > \overline{\varphi}$, we have $\frac{d\mu_E}{d\varphi} > 0$. For any $\varphi < \overline{\varphi}$ $(\varphi > 1)$, we have $\frac{d\mu_E}{d\varphi} < 0$. When $\varphi \to \infty$, $\mu_E \to \frac{\gamma}{1-\gamma}$. That is, as long as $\varphi < \overline{\varphi}$, the revenue share of the high-tech industry in Region E increases with φ. When $\varphi \to \infty$, the manufacturing structure in Region E (denoted by μ_E) approaches to the consumer's expenditure share $\frac{\gamma}{1-\gamma}$.

(iii) For all $\varphi \in (1, \infty)$, we have $\frac{d\mu_W}{d\varphi} < 0$. When $\varphi \to \infty$, $\mu_W \to 0$. That is, the revenue share of the high-tech industry in Region W deceases with φ. When $\varphi \to \infty$, the manufacturing structure in Region W (denoted by μ_W) approaches to zero.

Lemma (i) is based on $\mu_E > \frac{\gamma}{1-\gamma}$ and $\mu_W < \frac{\gamma}{1-\gamma}$. And the proofs of Lemma (ii) and (iii) are given in Appendixes A and B.

Lemma (i) corresponds to Proposition 1, suggesting that the capital-abundant and capital-poor regions have comparative advantage in the high-tech and low-tech industries, respectively.

Furthermore, as long as $\varphi < \overline{\varphi}$, the revenue share of the high-tech industry in Region *E* increases with φ, while that in Region *W* decreases with φ. That is, the larger the fixed capital gap between Region *E* and *W*, the larger the manufacturing structure gap between them.

In addition, a special case occurs only in the capital-abundant region (Region *E*). When

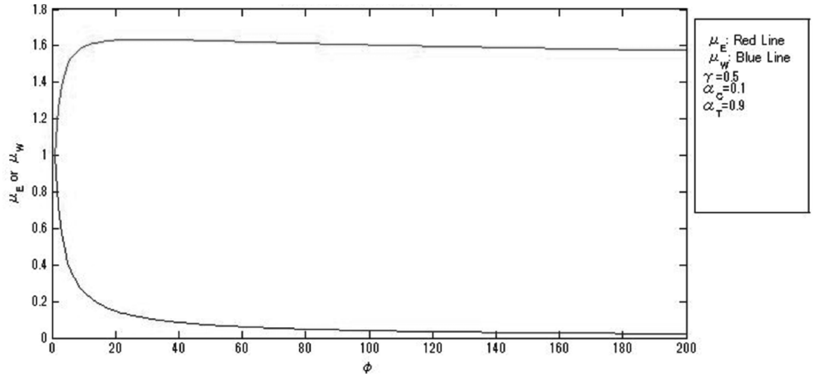

Fig. 2 The relationship between ϕ, μ_E andμ_W

φ is beyond a critical level $\overline{\varphi}$, i.e., $\varphi \in (\overline{\varphi}, \infty)$, with the increase in φ, μ_E will gradually decease and finally approach $\frac{\gamma}{1-\gamma}$. The reason is that when the fixed capital continues to agglomerate in Region E, the interregional productivity gap brought about by the interregional fixed capital gap becomes bigger and bigger, all manufacturing activities of both industries will also agglomerate to Region E. In fact, in Equation (41), when $\varphi \to \infty$, $Y_E^C \to (1-\gamma)\,Y$ and $Y_E^T \to \gamma Y$, which means that when all fixed capital agglomerates in Region E, all manufacturing activities will also agglomerate there. Finally, when $\varphi \to \infty$, the index of manufacturing structure in Region E approaches to the consumer's expenditure share: $\frac{\gamma}{1-\gamma}$. At the same time, as Lemma (iii) implies, the index of manufacturing structure in Region W will approach to zero. That is, there will be no high-tech industries remaining there.

The main parts of this lemma and their meanings can be concluded in the following Proposition 2. Fig. 2 presents a simulation result about the relationship among φ, μ_E and μ_W, which is based on Equations (41) and (42).

Proposition 2 *The capital-abundant region has a manufacturing structure dominated by relatively more high-tech industries than that of the region with less capital. Within a certain range, larger fixed capital gap between the two regions will bring about larger manufacturing structure gap between them.*

In the usual Hechscher-Ohlin comparative advantage analysis, the industrial structure is caused by the factor endowment differences. In this paper, the industrial structure is caused both by the endogenous productivity gap and the endowment difference of fixed capital stock.

3. 3 Empirical Evidence from China

To provide some evidence for the obtained propositions, here we present some regional data from China. We divide China into the Eastern Region and Western Region based on Fujita and Hu (2001). Table 2 showed that from 1978 to 2004, the fixed capital ratio of the Eastern to Western Regions kept on increasing. We use the Manufacture of Textiles to represent the low-tech industry and use the Manufacture of Communication Equipment, Computers and other Electric Equipment to represent the high-tech industry following the OECD classification.[12] To match the time period in Table 2, we calculate the regional manufacturing structures of the two regions for the years of 1987, 1992, 1997, 2002 and 2006,[13] which are given by Table 4.

Table 4 Regional manufacturing structures in China

	1987	1992	1997	2002	2006
Ele.E / Tex.E (Standardized): μ_E	1.05	1.06	1.17	1.11	1.12
Ele.W / Tex.W (Standardized): μ_W	0.81	0.81	0.53	0.48	0.31
Ele .E / Ele .W	3.07	3.87	6.06	11.8	21.29
Tex.E / Tex.W	2.27	2.95	2.8	4.95	5.93
$\varphi = (K_E / K_E)$	1.01	1.27	1.67	1.82	1.88

Source: calculated by the authors[14]

Ele.E: the nominal revenue of the manufacture of communication equipment, computers and other electric equipment (Ele industry afterwards) in the eastern provinces (The eastern provinces are defined below Table 1)

Tex.E: the nominal revenue of the manufacture of textile (Tex industry afterwards) in the eastern provinces

Ele.W: the nominal revenue of Ele industry in the western provinces (The western provinces are defined below Table 1)

Tex.W: the nominal revenue of Tex industry in the western provinces

Ele.E / Tex.E (Standardized): the nominal revenue ratio of Ele.E to Tex.E, divided by the nominal revenue ratio of Ele industry to Tex industry of the whole China (Corresponding to μ_E in the last section)

Ele.W / Tex.W (Standardized): the nominal revenue ratio of Ele.W to Tex.W, divided by the nominal revenue ratio of Ele industry to Tex industry of the whole China (Corresponding to μ_W in the last section)

Tex.E / Tex.W: the ratio of Tex industry in the eastern provinces to that in western provinces

Ele.E / Ele.W: the ratio of Ele industry in the eastern provinces to that in the western provinces

From the second row in Table 4, we can see that from 1987 to 2006, in the capital-abundant Eastern Region, the standardized ratios of the high-tech to low-tech industries were always larger than 1, which implies that the high-tech industry dominated the regional manufacturing structure.[15] On the contrary, from the third row, we observe that the Western Region with less fixed capital has such a local manufacturing structure that is dominated by the low-tech industry. These facts are corresponding to Lemma (i).

From the second row, we can also see that in the Eastern Region, as the interregional fixed capital gap was increasing (see the last row), the standardized ratio of the high-tech to low-tech industries increased at first, then turned to decrease toward the ratio of the whole China. This finding is consistent with Lemma (ii).

From the third row, we can observe that in the Western Region, as the interregional fixed capital gap was increasing, the standardized ratio of the high-tech to low-tech industries kept on decreasing, which has been suggested by Lemma (iii).

Moreover, the fourth and fifth rows show that the capital-abundant eastern region had a larger nominal revenue of both the high-tech and low-tech industries, which is consistent with Proposition 1 that the capital-abundant region has an absolute advantage in both the high-tech and low-tech industries. It can also be found that the interregional revenue difference of the high-tech industry is larger than that of the low-tech industry, which supports our assumption that the high-tech industry has a stronger linkage with the local variety of intermediate goods and benefits more from it than does the low-tech industry.

Hu (2002, pp. 315–316) showed that trade and FDI have played more and more important roles in the Chinese economy in the period of 1980–1994, e.g. the ratio of trade volume to GDP increased from 15% in 1980 to nearly 45% in 1994, export of manufactured goods shows a strong and steadily increasing trend, FDI surged after 1990 and accounted for 15% of the total investment in fixed assets. He also highlighted that the uneven distribution of trade is associated with the uneven distribution of FDI over regions, e.g. in 1994, exports from the 12 coastal provinces accounted for 86% of China's total export value, and from 1984 to 1994, more than 90% of total FDI inflow went to the coast.

Because that the formation of such regional manufacturing structures has not been modeled and investigated in the previous NEG literature, Propositions 1 and 2 could be considered as a contribution to the NEG literature.

4. Spatial Distribution of Labor

To date, we have investigated the formation of regional comparative advantage and manufacturing structures. However, the spatial distribution of labor remains to be examined.

We denote λ as the ratio of the labor amount in Region E to that in Region W, i.e.,

$\lambda \equiv L_E / L_W$, which presents the spatial distribution of labor in equilibrium. Differing from the traditional NEG models in which the variety of consumption goods and transportation costs are major considerations in the analysis of the spatial distribution of labor, we focus on the role of the local fixed capital, which determines the local labor productivity.

First of all, we examine the wages in Region E, denoted by ω_E. According to Equation (17), the total wage payment in Region W can be written as:

$$L_E \omega_E = \frac{(\sigma-\alpha_C)}{\sigma} Y_E^C + \frac{(\sigma-\alpha_T)}{\sigma} Y_E^T \tag{43}$$

Similarly, the total wage payment in Region W, denoted as ω_W, can be expressed as follows:

$$L_W \omega_W = \frac{(\sigma-\alpha_C)}{\sigma} Y_W^C + \frac{(\sigma-\alpha_T)}{\sigma} Y_W^T \tag{44}$$

Due to the equal capital rental interest and the equal prices of final goods across regions (since the trade of final goods incur no transportation costs), the local wages become the only consideration when laborers decide on their location. In equilibrium, there are equal wages across regions, i.e., $\omega_E = \omega_W = \omega$. Then, Equations (43) and (44) yield

$$\lambda \equiv L_E/L_W = \frac{\frac{(\sigma-\alpha_C)}{\sigma} Y_E^C + \frac{(\sigma-\alpha_T)}{\sigma} Y_E^T}{\frac{(\sigma-\alpha_C)}{\sigma} Y_W^C + \frac{(\sigma-\alpha_T)}{\sigma} Y_W^T} \tag{45}$$

Substituting Equations (37), (38), (39) and (40) into Equation (45), we obtain:

$$\lambda \equiv L_E/L_W = \frac{\frac{(\sigma-\alpha_C)}{\sigma}\frac{(1-\gamma)}{(1+\varphi^{-\alpha_C})} + \frac{(\sigma-\alpha_T)}{\sigma}\frac{\gamma}{(1+\varphi^{-\alpha_T})}}{\frac{(\sigma-\alpha_C)}{\sigma}\frac{(1-\gamma)}{(1+\varphi^{\alpha_C})} + \frac{(\sigma-\alpha_T)}{\sigma}\frac{\gamma}{(1+\varphi^{\alpha_T})}} \tag{46}$$

Regarding Equation (46), we know that $0 < \alpha_C < \alpha_T < 1$, $0 < \gamma < 1$, $\sigma > 1$ and $\varphi > 1$. So, $\frac{(\sigma-\alpha_C)}{\sigma} > 0$, $\frac{(\sigma-\alpha_T)}{\sigma} > 0$ and $\frac{(1-\gamma)}{1+\varphi^{-\alpha_C}} > \frac{(1-\gamma)}{1+\varphi^{\alpha_C}} > 0$, $\frac{(1-\gamma)}{1+\varphi^{-\alpha_T}} > \frac{(1-\gamma)}{1+\varphi^{\alpha_T}} > 0$, which leads to $\frac{(\sigma-\alpha_C)}{\sigma}\frac{(1-\gamma)}{(1+\varphi^{-\alpha_C})} > \frac{(\sigma-\alpha_C)}{\sigma}\frac{(1-\gamma)}{(1+\varphi^{\alpha_C})} > 0$ and $\frac{(\sigma-\alpha_T)}{\sigma}\frac{\gamma}{(1+\varphi^{-\alpha_T})} > \frac{(\sigma-\alpha_T)}{\sigma}\frac{\gamma}{(1+\varphi^{\alpha_T})} > 0$, therefore $\frac{(\sigma-\alpha_C)}{\sigma}\frac{(1-\gamma)}{(1+\varphi^{-\alpha_C})} + \frac{(\sigma-\alpha_T)}{\sigma}\frac{\gamma}{(1+\varphi^{-\alpha_T})} > \frac{(\sigma-\alpha_C)}{\sigma}\frac{(1-\gamma)}{(1+\varphi^{\alpha_C})} + \frac{(\sigma-\alpha_T)}{\sigma}\frac{\gamma}{(1+\varphi^{\alpha_T})} > 0$. That is, $\lambda > 1$.

Examining (45), we can see that the spatial distribution of labor is associated with the revenues of the two industries in the two regions (Y_E^C, Y_E^T, Y_W^C, Y_W^T). The shares of labor payments in the two industries are constant (which are $\frac{(\sigma-\alpha_T)}{\sigma}$ and $\frac{(\sigma-\alpha_C)}{\sigma}$ of the high-tech and low-tech industries, respectively). And, the revenue of each industry in each region depends on the spatial distribution of fixed capital stock. In fact, from Equations 37, 38, 39 and 40, we have $\frac{dY_E^C}{d\varphi} > 0$, $\frac{dY_E^T}{d\varphi} > 0$; $\frac{dY_W^C}{d\varphi} < 0$, $\frac{dY_W^T}{d\varphi} < 0$. So, we can obtain $\frac{d\lambda}{d\varphi} > 0$, which means that λ increases with the increase in φ.

To conclude the above discussions on $\lambda > 1$ and $\frac{d\lambda}{d\varphi} > 0$, we can have the following proposition:

Proposition 3 *In the two-region economy considered, the majority of labor is located in the capital-abundant region, and the amount of labor in this region increases as the local fixed capital stock in it increases.*

Proposition 3 can be supported by the evidence from the spatial distribution of population in China. The rapid increase in fixed capital investment in the Eastern Region caused the agglomeration of manufacturing activities there (see Tables 1 and 4), which leads to the interregional migration of laborers from the Western Region to the Eastern Region. These facts are widely observed in the Chinese economy.

5. Conclusion

Concerning the fact that the main line of NEG study (Krugman, 1991) fails to explain the formation of regional comparative advantage and manufacturing structures, in this paper, we extended a NTT model (Matsuyama, 1996) to a two-region economy to answer the following questions. How does the regional variety of intermediate inputs (as reflected by the local fixed capital stock) relate to the regional productivity and production advantage? Under the free movement of labor, how are regional manufacturing structures formed?

Based on the present model, we drew the major conclusions as follows. First, the region with more fixed capital stock has an absolute advantage in both the high-tech and low-tech industries. It also has a comparative advantage in the high-tech industry, which uses the fixed capital more intensively. In contrast, the region with less fixed capital stock has no absolute advantage, but it has a comparative advantage in the labor-intensified low-tech industry. Second, the capital-abundant region has a manufacturing structure dominated by relatively more high-tech industries than that of the region with less fixed capital stock. With the exception that the fixed capital stock gap between the two regions is beyond a certain value, larger gap brings larger gap of manufacturing structures. Third, the majority of labor is located in the capital-abundant region, and the amount of local labor in this region increases as the local fixed capital stock in it increases.

The present paper indicated the importance of the local fixed capital stock in the formation of regional comparative advantage and manufacturing structures. So, in the real world, to develop high comparative advantage to attract manufacturing companies to locate in a region, we need to promote the construction and investment about the region's local infrastructure and other fixed capital stock. Meanwhile, to raise the level of a region's industrial structure, we should strengthen the local fixed capital stock so as to attract more and more high-tech industries to agglomerate to the region.[16] These are the main policy implications involved in the present theoretical analysis.

Notes

1 In this paper, we define the manufacturing structure as the allocation of different manufacturing activities across manufacturing industries. Notice that this is different from that in the "industrial transformation" literature, which focuses on the reallocation of economic activity across broad sectors such as agriculture, manufacturing and services (Clark 1957, Chenery 1960, Kuznets 1966. See Herrendorf et al. 2014 for a review).

2 In Dixit and Stiglitz (1977, pp. 304–308) they considered a case in which there are two sets of variety goods with different production technologies and a constant elasticity sub-utility functions. But, within each set, firms are still symmetric and only one set of variety goods appear in equilibrium.

3 Specifically, most models divided economic activities into an agricultural sector with constant returns to scale agricultural sector and a manufacturing sector consisting of a set of variety goods, without distinguishing among different manufacturing activities.

4 Porter (1990) extensively discussed such linkage-based agglomeration economies in Japan.

5 Data Source: Census of Manufacturers (http://www.meti.go.jp/statistics/tyo/kougyo/library/library_1.html#menu1, checked on 2018.11.20)

6 Another way to calculate the total labor payment is to add the labor payments in two final goods sectors $(1-\alpha_C)\,Y^C + (1-\alpha_T)\,Y^T$ to the labor payment in the intermediate sector $\frac{\sigma-1}{\sigma}(\alpha_C Y^C + \alpha_T Y^T)$, which yields the same result as in Equation (17).

7 We can consider three factors to justify this assumption: (1) intermediate goods (or local services) supplied by local infrastructure are non-tradable because of their nature; (2) the existence of economies of scale in manufacturing production (Henderson 2003) will make production-related firms agglomerate together, hence weakening the need for cross-

regional trading of parts and components; (3) these components, generally, have a larger weight per unit of value than final goods.

8 The Armington (1969) assumption is widely used in the NTT and NEG literature. See Overman et al. (2003) for a review.

9 Adding the preference heterogeneity of consumers among the two regions will not change the major conclusion of this paper, as long as the consumers all have Cobb-Douglas preferences for high-tech and low-tech goods and Armington (1969) type of constant elasticity of substitution (CES) subutility functions about the two final goods produced in each region.

10 Consider that each final goods industry in each region comprises many individual small production plants with Cobb-Douglas production technology defined in Equations (5) and (6). Then the plant will view itself as having a constant returns to scale production function, which ensures the perfect competition in the interregional final goods markets, as explained in Chipman (1970) and Henderson (1974).

11 It is harmless to assumption $\sigma = \eta$ since σ and η are both exogenous parameters which are larger than one. Removing this assumption will not change the major conclusions of this paper.

12 http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:High-tech_classification_of_manufacturing_industries (Checked on 2018.09.03).

13 Each statistical year of fixed capital stock is matched to the closet statistical year of the Industry Statistical Yearbook with a two-year advance. For example, regional fixed capital amounts data in the year of 1985 is matched to regional manufacturing structures data in the year of 1987. Considering the time lag between the change in regional fixed capital and the change in manufacturing structure, this matching approach is reasonable.

14 Data Source: China Industry Statistical Yearbook (1988, 1993, 1998, 2003, 2007).

15 If the industrial structure (the ratio of Ele.E to Tex.E) of the Eastern Region is similar to that of the whole China, μ_E will be one. If the region has a larger (smaller) ratio of Ele. E to Tex. E compared to that of the whole China, μ_E will be larger (smaller) than one.

16 For example, in year 2000, to balance the economic growth and industrial structure between West and East region, Chinese government implemented the western development strategy which includes many infrastructure projects using large amounts of fixed capital investments, such as the constructions of Qinghai-Tibet Railway, the Xiaowan hydropower station, the Xian and Chengdu airport et.al.

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Appendixes

A1. Proof of Lemma (ii)

Regarding Equation (41), differentiating μ_E with respect to φ, we obtain:

$$\frac{d\mu_E}{d\varphi} = \frac{\gamma}{1-\gamma}\left(\frac{\alpha_T\varphi^{-\alpha_T-1}}{1+\varphi^{-\alpha_T}} * \frac{1+\varphi^{-\alpha_C}}{1+\varphi^{-\alpha_T}} - \frac{\alpha_C\varphi^{-\alpha_C-1}}{1+\varphi^{-\alpha_T}}\right) \tag{A1.1}$$

Multiplying $\frac{1-\gamma}{\gamma} * \frac{1+\varphi^{-\alpha_T}}{\alpha_T\varphi^{-\alpha_C-1}}$ to both sides of (A1.1) yields:

$$\frac{d\mu_E}{d\varphi} * \frac{1-\gamma}{\gamma} * \frac{1+\varphi^{-\alpha_T}}{\alpha_T\varphi^{-\alpha_C-1}} = \frac{\varphi^{\alpha_C-\alpha_T}+\varphi^{-\alpha_T}}{1+\varphi^{-\alpha_T}} - \frac{\alpha_C}{\alpha_T} \tag{A1.2}$$

We define the right side of (A1.2) as:

$$F(\varphi) = \frac{\varphi^{\alpha_C-\alpha_T}+\varphi^{-\alpha_T}}{1+\varphi^{-\alpha_T}} - \frac{\alpha_C}{\alpha_T} \tag{A1.3}$$

If $\varphi = 1$, $F(\varphi) = 1 - \frac{\alpha_C}{\alpha_T} > 0$, and when $\varphi \to \infty$, $F(\varphi) \to -\frac{\alpha_C}{\alpha_T} < 0$.

Furthermore, by differentiating (A.13) with respect to φ we obtain:

$$F'(\varphi) = \frac{(\alpha_C-\alpha_T)\varphi^{\alpha_C-\alpha_T-1}-\alpha_T\varphi^{-\alpha_T-1}}{1+\varphi^{-\alpha_T}} + \frac{\alpha_T\varphi^{-\alpha_T-1}}{1+\varphi^{-\alpha_T}} * \frac{\varphi^{\alpha_C-\alpha_T}+\varphi^{-\alpha_T}}{1+\varphi^{-\alpha_T}} \tag{A1.4}$$

$$=\left(\frac{\varphi^{\alpha_C-\alpha_T}+\varphi^{-\alpha_T}}{1+\varphi^{-\alpha_T}} - 1\right)\frac{\alpha_T\varphi^{-\alpha_T-1}}{1+\varphi^{-\alpha_T}} + \frac{(\alpha_C-\alpha_T)\varphi^{\alpha_C-\alpha_T-1}}{1+\varphi^{-\alpha_T}}$$

Given that $\alpha_C < \alpha_T$ and $\varphi > 1$, $F'(\varphi) < 0$. Since when $\varphi = 1$, $F(\varphi) > 0$; and for $\varphi \to \infty$, $F(\varphi) < 0$, we obtain that the solution of $F(\varphi) = 0$ is unique (denoted as $\overline{\varphi}$), and for any $\varphi \in (1, \overline{\varphi})$, $F(\varphi) > 0$ while for any $\varphi \in (\overline{\varphi}, \infty)$, $F(\varphi) < 0$.

Since $\frac{1-\gamma}{\gamma} * \frac{1+\varphi^{-\alpha_T}}{\alpha_T\varphi^{-\alpha_C-1}} > 0$, $\frac{d\mu_E}{d\varphi}$ has the same sign as $F(\varphi)$. That is, there is an unique solution, $\overline{\varphi}$, which satisfies $\frac{d\mu_E}{d\varphi} = 0$. For any $\varphi \in (\overline{\varphi}, \infty)$, $\frac{d\mu_E}{d\varphi} > 0$, and for any $\varphi \in (1, \overline{\varphi})$, $\frac{d\mu_E}{d\varphi} < 0$. This also implies that there is an inverted U-shape relationship between μ_E and φ.

When $\varphi \to \infty$, $\varphi^{-\alpha_C} \to 0$ and $\varphi^{-\alpha_T} \to 0$. Thus using Equation (41), $\mu_E = \frac{\gamma}{1-\gamma} * \frac{1+\varphi^{-\alpha_C}}{1+\varphi^{-\alpha_T}} \to \frac{\gamma}{1-\gamma}$.

Q.E.D.

A 2. Proof of Lemma 1 (iii)

Regarding Equation (42), differentiating μ_W with respect to φ, we obtain:

$$\frac{d\mu_W}{d\varphi} = \frac{\gamma}{1-\gamma}\left(\frac{\alpha_C\varphi^{\alpha_C-1}}{1+\varphi^{\alpha_T}} - \frac{\alpha_T\varphi^{\alpha_T-1}}{1+\varphi^{\alpha_T}} * \frac{1+\varphi^{\alpha_C}}{1+\varphi^{\alpha_T}}\right) \tag{A2.1}$$

Multiplying $\frac{1-\gamma}{\gamma} * \frac{1+\varphi^{\alpha_T}}{\alpha_T\varphi^{\alpha_C-1}}$ to both sides of (A2.1) yields:

$$\frac{d\mu_W}{d\varphi} * \frac{1-\gamma}{\gamma} * \frac{1+\varphi^{\alpha_T}}{\alpha_T\varphi^{\alpha_C-1}} = \frac{\alpha_C}{\alpha_T} - \frac{\varphi^{\alpha_T-\alpha_C+\varphi^{\alpha_T}}}{1+\varphi^{\alpha_T}} \tag{A2.2}$$

Given that $\varphi > 1$ and $\alpha_T > \alpha_C$, we have $\frac{\alpha_C}{\alpha_T} < 1$ and $\frac{\varphi^{\alpha_T-\alpha_C+\varphi^{\alpha_T}}}{1+\varphi^{\alpha_T}} > 1$. Then, $\frac{\alpha_C}{\alpha_T} - \frac{\varphi^{\alpha_T-\alpha_C+\varphi^{\alpha_T}}}{1+\varphi^{\alpha_T}} < 0$, which means

$$\frac{d\mu_W}{d\varphi} * \frac{1-\gamma}{\gamma} * \frac{1+\varphi^{\alpha_T}}{\alpha_T\varphi^{\alpha_C-1}} < 0 \tag{A2.3}$$

Since $\frac{1-\gamma}{\gamma} * \frac{1+\varphi^{\alpha_T}}{\alpha_T\varphi^{\alpha_C-1}} > 0$, we have $\frac{d\mu_W}{d\varphi} < 0$.

When $\varphi \to \infty$, $1 + \varphi^{\alpha_C} \to \varphi^{\alpha_C}$, $1 + \varphi^{\alpha_T} \to \varphi^{\alpha_T}$ and $\frac{\varphi^{\alpha_C}}{\varphi^{\alpha_T}} \to 0$. So, using Equation (42) we have $\mu_W = \frac{\gamma}{1-\gamma} * \frac{1+\varphi^{\alpha_C}}{1+\varphi^{\alpha_T}} \to \frac{\gamma}{1-\gamma} * \frac{\varphi^{\alpha_C}}{\varphi^{\alpha_T}} \to 0$.

Q.E.D.