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Specialization, Firm Dynamics and Economic Growth *

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Productivity in agriculture or services has long been understood as playing an important role in the growth of manufacturing. In this paper we present a general equilibrium model in which manufacturing growth is stimulated by non-manufacturing sectors that provides goods used in both research and final consumption. The model permits the evaluation of two policy options for stimulating manufacturing growth: (1) a country imports more non-manufacturing goods from a foreign country with higher productivity and (2) a country increases productivity of domestic non-manufacturing. We find that both policies improve welfare of the economy, but depending on the policy the manufacturing sector responses differently. Specifically, employment and value-added in manufacturing increase with policy (1), but contract with policy (2). Therefore, specialization of the import non-manufactured goods helps explain why some Asian economies experience rapid growth in the manufacturing sector without progress in other sectors.

Keywords: Firm Heterogeneity, Firm Innovation, Economic Growth, Specialization, Unbalanced Sector Growth
JEL Classification: F11, F43, F63

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I. INTRODUCTION

A large literature in economic development has discussed the important role that productivity in agriculture or services has played for the growth of manufacturing and the economy as whole.[1] However, empirical evidence from major Asian economies (including Japan, Korea and China) is inconsistent with this literature. These countries achieved unprecedented growth in the manufacturing sector without significant productivity improvement in other sectors.[2] This raises a question: is high productivity in other sectors necessary to achieving rapid manufacturing growth?

To answer this question, we build a general equilibrium model comprising two sectors: manufacturing and non-manufacturing. In the manufacturing sector, heterogeneous firms grow endogenously by investing in innovation. The non-manufacturing sector meanwhile provides a non-manufactured good, which is a source of the final good in either innovation investment or final consumption. To test the model, we weigh two policy choices that exogenously expand the output of the non-manufactured good. The first exogenous change involves increasing the productivity of the firm in the domestic non-manufacturing sector, a structural transformation emphasized in previous literature. The second change consists of expanding imports of the non-manufactured good from a foreign country that has higher productivity in the non-manufacturing sector. We then study how these two exogenous changes affect the innovation decisions of firms and economic growth in the manufacturing sector.

The model predicts that both exogenous policies increase overall economic welfare due to the falling price of the non-manufacturing good, but predicts contrary outcomes in the manufacturing sector. When the economy imports more non-manufactured goods from foreign countries, firms in the manufacturing sector have an increased incentive to conduct innovation because of the lower price of non-manufactured goods.

[1] The literature highlights that increases of productivity in the agriculture sector are an essential condition to reallocate labor from the agriculture sector to the manufacturing sector and to initiate manufacturing sector growth on structural transformation. See Kuznets (1966), Matsuyama (1992), Kögel and Prskawetz (2001) and Gollin, Parente, and Rogerson (2002). Moreover, recent literatures also focuses on productivity of the service sector, especially financial or business supports. See Francois (1990), Neusser and Kugler (1998), Francois and Hoekman (2010) and Kehoe and Ruhl (2012)

[2] See Ito and Weinstein (1996) for Japan, Eichengreen, Perkins, and Shin (2012) for Korea and Bosworth and Collins (2008) for China

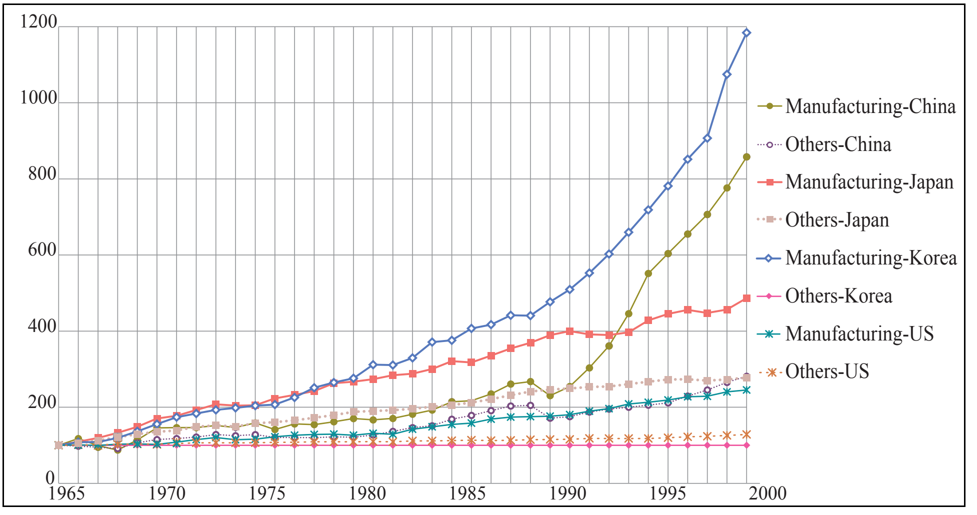
As the rate of productivity increases, labor moves from the non-manufacturing sector to the manufacturing sector. On the other hand, when the policy entails increasing the productivity of the domestic firm in the non-manufacturing sector, the productivity of firms in the manufacturing sector increases relatively slowly and can even decrease depending on parameters in the model. In this last case, labor can even shift from the manufacturing sector to the non-manufacturing sector.

This consequence has an intuitive explanation. Both policy changes reduce the price of the non-manufactured good and give firms in the manufacturing sector more incentive to innovate. However, if the economy increases the productivity of the firm in the non-manufacturing sector, this firm will hire more labor. Thus, this change increases the demand for labor – and labor cost – throughout the economy. Higher costs lower the profitability of firms in the manufacturing sector and cause them to pursue less innovation. On the other hand, importing more non-manufactured goods benefits firms in the manufacturing sector by lowering the price of the non-manufactured good, but has no impact on labor costs. This stimulates innovation and growth in the manufacturing sector, and encourages manufacturing specialization in the economy as a whole.

The motivation for this research is the experience of Asian economies such as Japan, Korea and China. Each experienced unprecedented rapid economic growth even as growth in non-manufacturing sectors lagged. Figure 1 shows changes in labor productivity normalized as of 1965 by sector in Asian economies and the United States from 1965 to 2000. As shown by the data, the increase in labor productivity of the manufacturing sector (marked by solid lines) in Asian economies such as Korea and China is relatively prominent compared to that of non-manufacturing industries (marked by dotted lines). In the United States, however, the increase in labor productivity in the manufacturing sector outweighs that in the non-manufacturing sector, but the difference is barely noticeable. In Japan, labor productivity in the manufacturing and non-manufacturing sectors has been increasing since the 1990s, but up to the 1980s – generally considered a high-growth period – a pattern similar to that of the other Asian economies is observed.

For more specific instance, consider the pattern of Korean economic growth. From 1977 to 1988, Korean total labor productivity increased by 6.6% yearly, while total labor productivity in the manufacturing sector increased by 8.9% yearly and that in

Figure 1. Sectoral Labor Productivity



Note: We calculate labor productivity by sectoral value added in 2005 prices divided by employment based on Timmer, De Vries, and De Vries (2016). Non-manufacturing includes utilities, trade, restaurants and hotels, transport, storage and communication, finance, insurance, real estate and business services, government services and community, social and personal services. To compare changes in labor productivity, we normalize it as of 1965.

Source: Groningen Growth and Development Centre. <https://www.rug.nl/ggdc/productivity/10-sector/> (accessed April 8, 2019)

Table 1. Growth Rate of Labor Productivity from 1977-1988

	Korea	EU15	US
Total Industries	6.6%	2.4%	1.1%
Agriculture, Hunting, Forestry and Fishing	6.7%	6.0%	2.9%
Mining and Quarrying	-0.3%	4.6%	2.0%
Manufacturing	8.9%	3.2%	2.7%
Electricity, Gas and Water Supply	11.8%	3.3%	-0.2%
Construction	4.1%	1.7%	-1.5%
Wholesale and Retail Trade	1.6%	1.9%	2.2%
Hotels and Restaurants	5.4%	-0.9%	0.0%
Transport and Storage and Communication	5.4%	3.3%	2.0%
Finance, Insurance, Real Estate and Business Services	1.9%	0.3%	-1.0%
Community Social and Personal Services	-0.3%	0.5%	0.1%

Note: We calculate growth rate of labor productivity using gross value-added per hour from EU KLEMS.

other sectors stagnated.[3] Even compared to the respective sectoral growth rates of the EU and US during the same time period, the manufacturing sector in Korea grew faster while the other sectors did not. The growth miracle in Japan, which experienced rapid economic expansion before Korea, demonstrated a similar pattern. Ito and Weinstein (1996) show that the primary source of Japan's rapid growth was the high rate of productivity growth in the manufacturing sector and the shift of resources to the manufacturing sector is observable during the rapid growth period.

Consistent with our modeling framework, we also observe a significant increase in imports of non-manufactured goods during the same period in Korea. From 1977 to 1988, agriculture and raw materials imports increased by 16.8% yearly and services imports increased by 18.5% annually.[4]

The economy imported more goods from non-manufacturing sectors where domestic production grew slowly. These facts suggest that comparative advantage in specific industries led to unbalanced growth, where some sectors of the economy improved while other stagnated.[5] This differs from the pattern exhibited by the developed countries during their structural transformations.

We also use the model to conduct several numerical experiments. We obtain three findings with implications for national development. First, we show that allowing the import of more non-manufactured goods from abroad makes firms in the manufacturing sectors grow more rapidly than increasing the productivity of the non-manufacturing sector quantitatively. Second, we show that the growth of the manufacturing sector is slower with higher productivity in the non-manufacturing sector when the economy allows the imports of more non-manufactured goods. Lastly, we find that a larger economy derives a greater increase in welfare from a policy that focuses on increasing domestic productivity of the non-manufacturing sector and developing both sectors in tandem.

Our research is related to previous works in economic growth and development. Specifically, it is in line with the development literature that attempts to explain how a

[3] We choose this period because the share of Korean labor in the manufacturing sector increased until 1988. Extending the time period to 1970 does not affect the conclusion. We exclude electricity, gas and water supply. However, this sector constitutes a small share of the total economy.

[4] World Development Indicator.

[5] We use balanced and unbalanced growth terminology from Rauch (1997). In an economy which has two sectors, Rauch (1997) defined "balanced growth" as equal growth rates among the sectors and "unbalanced growth" as unequal growth rates among the sectors.

country initiates manufacturing sector growth and the role of other sectors in that process. Matsuyama (1992), Kögel and Prskawetz (2001) and Gollin, Parente, and Rogerson (2002) emphasize the importance of the development of the agriculture sector in allowing for labor or other resources to be transferred to the manufacturing sector. Moreover, other literature such as Francois (1990), Neusser and Kugler (1998), Francois and Hoekman (2010) and Kehoe and Ruhl (2012) emphasize the importance of the development in the service sector, including the provision of financial or business services, as intermediates for manufacturing. While the previous works consider the development of the non-manufacturing sector as the only determinant in the production of non-manufacturing goods, we consider the additional alternative of imported non-manufacturing goods embedded with better technology.

Our work is related to the broad range of literature in endogenous growth that incorporates endogenous R&D decisions in driving economic growth as in Romer (1990), Aghion and Howitt (1992) and Grossman and Helpman (1993).[6] The success of innovation is stochastic as in Griliches (1979) and Ericson and Pakes (1995). We incorporate endogenous innovation decisions of firms in the manufacturing sector similar to Klette and Kortum (2004), Lentz and Mortensen (2008) and Atkeson and Burstein (2010). Finally, the model is closely related to that of Atkeson and Burstein (2010) which incorporates firm-level innovation decisions. While they consider symmetrical countries to focus on gains from trade, we focus on growth of developing countries by considering an asymmetric cases with a small open economy. Because our model features two industries, specialization is a key mechanism to evaluate the effects of two-policy changes.

At first glance, the main thrust of our work may appear to diverge from the results of prominent research on the Asian economic miracle, but it is actually complementary.[7] Superficially, our emphasis on the importance of imports in non-manufacturing sectors may seem to contradict previous research that assigns great significance to export-

[6] We use a model where labor is the only input following the previous literature, so productivity determined by R&D investment is labor productivity, which could be increased by increases in other inputs such as capital accumulation as well as TFP. In this regard, it does not conflict with previous studies, e.g. Young (1995) in which East Asian growth is a result of factor accumulation rather than growth in TFP.

[7] We appreciate the comments of a referee on the need for this discussion.

driven growth in Asian economies.[8] But in fact our research documents how imports in the non-manufacturing sectors led to increases in manufacturing exports and productivity. Our work focuses on explaining how the manufacturing sector grew and exports increased without increased productivity in the non-manufacturing sectors. Seen in this light, our work complements previous studies that stressed the importance of export-driven growth in East Asia.

A recent work by Gersbach, Schneider, and Schneller (2013) evaluates the effects of similar policies. They argue that if an economy imports leading technologies from foreign countries instead of investing in public research, domestic innovation suffers. The main findings of our research seem to contradict this, but in their work, openness to foreign technology discourages the optimization of domestic innovation because foreign technology substitutes domestic technology. In our model, however, there are two sectors, and openness to foreign technology means that an economy imports more non-manufactured goods. Non-manufactured goods as a part of research goods complements innovations in the manufacturing sector. This difference accounts for the seemingly contradictory result produced by our model.[9]

The remainder of the paper is organized as follows. Section 2 describes a two-sector general equilibrium model where firms in the manufacturing sector grow endogenously and the non-manufacturing sector provides parts of research goods for firms in the manufacturing sector for use in developing innovations. In Section 3, we demonstrate how the two policies result in different consequences, especially in the manufacturing sector. In Section 4, we test the model and describe the implications carried by the results as they relate to the development path of different countries. Section 5 is the conclusion.

[8] Regarding the relationship between trade and economic growth, Krueger (1990) refers to East Asian economies as Superexporters. Furthermore, Westphal (1990) and Diao, Roe, and Yeldan (1999) discuss how the governments of East Asian economies long pursued the export-led industrialization policy through selective intervention, which affects the allocation of resources among industrial activities such as R&D incentives and export promotion.

[9] While we focus on endogenous growth in manufacturing related to productivity in the non manufacturing sector in a developing country, Gersbach, Schneider, and Schneller (2013) understand domestic optimal innovation with an option to adopt foreign technology in a developed country.

II. MODEL

1. Environment

We consider a small open economy surrounded by one continent. The economy has two industrial sectors: manufacturing and non-manufacturing respectively. We assume that goods in manufacturing are perfectly tradable but goods in non-manufacturing are only partially tradable. In the manufacturing sector, firms are heterogeneous in terms of productivity and they can grow endogenously by investing in R&D while there is a homogeneous firm with a productivity in the non-manufacturing sector.[10] There is a measure L of infinitely lived homogeneous households in the economy who only value consumption and are endowed with one unit of labor.

2. Manufacturing sector

There is a continuum number of varieties between 0 and N·K produced from either $(0, N]$ domestically or from $(N, N K]$ internationally in the manufacturing sector, indexed by i. In each variety i, there is only one firm, either a domestic firm, or a foreign firm. A firm is the only monopolist for its own variety, but engages in monopolistic competition with firms producing other varieties.

There are two possible states for a firm's productivity for each variety, indexed by z_L and z_L. The firm with productivity index z, has labor productivity $\exp(z)^{\frac{1}{\sigma-1}}$. The firm uses labor l as its only input. The firm's output is the following production technology,

$$x_i = (e^{z_i})^{\frac{1}{\sigma-1}} l_i \tag{1}$$

Output from firms in the manufacturing sector is aggregated through integration with other varieties in the same sector. We call the good which is aggregated by all

[10] We are particularly interested in the growth miracle in East Asian countries. Sachs and Warner (1995) emphasize that if a country is not endowed with natural resources like some East Asian economies, then it does not have comparative advantage. In the economy, export firms in manufacturing lead economic growth.

varieties, denoted by y_i, in the manufacturing sector as the manufacturing good. There is no trade cost for the manufacturing good and it can be used both domestically and internationally. Therefore, the aggregation function for the manufacturing good is as follows:

$$M = \left(\int_0^N y_i^{\frac{\sigma-1}{\sigma}} di + \int_N^{NK} y_i^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}} \tag{2}$$

The small open economy produces variety from $(0, N]$ domestically while foreign firms produces varieties from $(N, NK]$ and $K \rightarrow \infty$ to be satisfied that the domestic economy is a small open economy.

1) Firm innovation

A firm in the manufacturing sector can grow endogenously by investing in R&D to boost future productivity. The final goods variable Y is used as the input for such investment. If a firm spends $c(q)$ on innovation where $c(\cdot)$ is the second-order differential and it satisfies $c'(\cdot) > 0$ and $c''(\cdot) > 0$, regardless of its productivity is today, its productivity z' tomorrow would be

$$z' = \begin{cases} z_H & with\ probability\ q \\ z_L & with\ probability\ 1-q \end{cases} \tag{3}$$

2) The manufacturing firm's problem

The objective of the firm to maximize its value is determined by the sum of current and future values. From the assumption of a small open economy, each individual firm takes the total market size for the manufacturing sector denoted by M and the global price for the manufactured good, P_M as given. Since entry and exit is not built into our model, the mass of domestic firms is fixed as N.[11]

[11] The main goal of the paper is not to analyze a change of the number of firms but growth in the size of incumbent firms. If we allow the free entry condition to determine the number of firms endogenously, we can have different size in the manufacturing sector instead of individual firms' growth patterns.

A firm with productivity index z can be solved by the following recursive problem.

$$V(z) = \max_{p,l,q} p * \exp(z)^{\frac{1}{\sigma-1}} l - \omega l - c(q) + \beta[qV(z_H) + (1-q)V(z_l)] \quad (4)$$

s.t.

$$d(p, P_M, M) = \exp(z)^{\frac{1}{\sigma-1}} l \quad (5)$$

where $d(\cdot)$ is final demand for the firm in the manufacturing sector that we will define later. $p \cdot \exp(z)^{\frac{1}{\sigma-1}} l - \omega l$ is the profit variable that determines the firm's current value, $c(q)$ represents the value of investments made in R&D, and $qV(z_H) + (1-q)$ $V(z_L)$ is the expected future value of the firm, which is discounted at rate β.

3. Non-Manufacturing Sector

The non-manufacturing sector consists of perfectly competitive producers and perferctly-competitive aggregators. A representative firm in the non-manufacturing sector uses labor with constant return to scale production technology and produce non-manufactured goods.

The production function of the firm in the non-manufacturing sector is:

$$S_D = \theta L_N \quad (6)$$

where S_D is the finished non-manufacturing good produced by the domestic firm, while L_N is the total labor engaged in the non-manufacturing good production. We normalize the productivity of the firm as one in the continent, and let θ be the productivity of the domestic firm in the non-manufacturing sector, where $\theta < 1$.

Since the non-manufactured good is partially tradable, some of the foreign non-manufactured goods are also available in the domestic market. However, the imported non-manufactured goods and domestic non-manufactured goods are not perfect substitutes. The elasticity of substitution between the two types of non-manufactured goods is ρ.

Final non-manufactured goods producers are also built into the model by aggregating non-manufactured goods from both domestic and foreign sources. And both domestic and foreign non-manufactured goods are aggregated into final non-manufactured goods via the following function,

$$S = \left(\lambda^{\frac{1}{\rho}} S_F^{\frac{\rho-1}{\rho}} + (1-\lambda)^{\frac{1}{\rho}} S_D^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}} \tag{7}$$

S_F represents imported non-manufactured goods, and S_D stands for domestically produced non-manufactured goods. ρ determines the substitutability of S_F and S_D.

Here θ and λ are the parameters that relate to productivity of the non-manufacturing sector. We are interested in two exogenous changes in these parameters. If θ increases alongside productivity in the domestic non-manufacturing sector, the economy creates more domestic non-manufactured goods and S_F becomes higher in the equilibrium. However, if λ increases, we consider it a case wherein the non-manufacturing market becomes more accessible to foreign firms. Then, S_F becomes lower in the equilibrium.

4. Final Good Sector

The final good producers are perfectly competitive producers who use manufactured goods bundles (M_c) and non-manufactured goods bundles (S) and are aggregated into the final output. They take the price of manufactured goods bundles P_M, and the price of non-manufactured goods bundles P_S as given.

The production function of final good production is taken as follows:

$$Y = M_c^{\alpha} S^{1-\alpha} \tag{8}$$

The final output is used in consumption and making R&D investments.

5. Households

A stand-in consumer is endowed with L unit of labor each period. He derives utility from final good consumption, and chooses consumption allocations $\{c_t\}$, $t = 0, 1, ...$, to maximize lifetime utility subject to the budget constraints.

$$max \sum \beta^t \ \ log \ \ C_t \tag{9}$$

$$\sum p^t P_t(C_t) \leq \sum p^t\big(\omega_t L + E(d_t)\big), t = 0,1, \dots \tag{10}$$

Here, p^t is the Arrow-Debru price, P_t is the final good price, ω_t is the wage rate, and $E(dt) = \int_0^N [p_i * \exp(z_i)^{\frac{1}{\sigma-1}} l_i - \omega l_i - c(q_i)] d\mu(i)$ is the expected dividend from firms in the manufacturing sector.

The consumer does not value leisure in our model, so he devotes all his labor endowment into production. Nor does the consumer accumulate any capital, consuming the exact same amount of consumption goods for each period following the permanent income hypothesis.

6. Equilibrium

A stationary recursive equilibrium is a list of aggregate state variables, the distribution of firms' productivity $\{\mu(z)\}$, and individual state variables, (z_i), for each firm in the manufacturing sector,
a list of prices:

$$P(\mu(z)), \omega(\mu(z)), p_i(z, \mu(z))$$

and a list of decision functions:

a) $V(z, \mu(z))$, $d(z, \mu(z))$, $l(z, \mu(z))$, $x(z, \mu(z))$, $q(z, \mu(z))$ for a manufacturing firm
b) $S_D(\mu(z))$, $L_N(\mu(z))$ for a non-manufacturing firm
c) $S(\mu(z))$, $S_F(\mu(z))$, $S_D(\mu(z))$ for a non-manufacturing aggregator
d) $Y(\mu(z))$, $M_c(\mu(z))$, $S(\mu(z))$, for a final aggregator
e) $c(\mu(z))$

and an updating rule for the state variables:

$$z' = \begin{cases} z_H \text{ with probability } q \\ z_L \text{ with probability } 1 - q \end{cases}$$

$$\mu(z) = H(\mu(z))$$

such that

1) The consumer takes wages as given, future dividends, and the other prices. The consumer maximizes lifetime utility through consumption equal to life-time income.
2) Firms in the manufacturing sector take the demand function and the wage as given, choosing $d(z, \mu(z))$, $l(z, \mu(z))$ and innovation intensity $q(z, \mu(z))$ that maximize the value of this firm $V(z, \mu(z))$.
3) The firm in the non-manufacturing sector takes prices as given and produces $S_D(\mu(z))$, domestic non-manufactured goods, to maximize its profit using $L_N(\mu(z))$.
4) The non-manufacturing aggregator takes prices as given and it produces final non-manufactured goods, $S(\mu(z))$, using $S_F(\mu(z))$ and $S_D(\mu(z))$ as inputs.
5) The final aggregator takes prices as given and it produces a final output, $Y(\mu(z))$ using $S(\mu(z))$ and $M_c(\mu(z))$ as inputs.
6) How to aggregate each good is consistent with the updating rule of $\mu(z)$.
7) All market clearings and the trade balance conditions hold.

7. Equilibrium Results

1) Non-manufacturing sector:

Since the non-manufacturing sector is perfectly competitive, the price of the non-manufactured good will be equal to the firm's marginal unit cost:

$$P_N = W/\theta \tag{11}$$

The non-manufacturing aggregator combines both domestic and foreign non-manufactured goods into final non-manufactured goods using CES technology. Given P_T^* as the price of the non-manufactured good imported, its unit cost for producing non-manufacturing goods in the equilibrium will be:

$$P_S = \left(\lambda P_T^{1-\rho} + (1-\lambda) P_N^{1-\rho}\right)^{\frac{1}{1-\rho}} \tag{12}$$

which equals the equilibrium price for the non-manufactured goods.

Then the demand for domestic non-manufacturing inputs should satisfy:

$$P_N S_D = (1-\lambda)\left(\frac{P_N}{P_S}\right)^{-(\rho-1)} P_S S \tag{13}$$

which equals the total wages paid to the workers in the domestic non-manufacturing sectors, ωL_N

On the other hand, the total amount of non-manufactured goods from a foreign country is:

$$P_T S_F = \lambda\left(\frac{P_T}{P_S}\right)^{-(\rho-1)} P_S S \tag{14}$$

2) Manufacturing sector

A firm with productivity z in the manufacturing sector maximizes its profit under the monopolistic competition, given the world market size for manufacturing goods, M.

In the equilibrium, the demand for labor at manufacturing firms with productivity index z given wage(ω) and price of manufacturing goods (P_M) will be:

$$l(z) = \left(\frac{\sigma}{\sigma-1}\right)^{-\sigma}\left(\frac{\omega}{P_M}\right)^{-\sigma} M\, exp(z_H) \text{ [12]} \tag{15}$$

And its profit will be:

$$\pi(z) = \frac{P_M^{\sigma} M \omega^{1-\sigma}}{\sigma^{\sigma}(\sigma-1)^{1-\sigma}} exp(z) \tag{16}$$

The innovation cost function is $c(q)=Phe^q$.[13] Let $\pi = \frac{P_M^{\sigma} M}{\sigma^{\sigma}(\sigma-1)^{1-\sigma}}$ for simplicity in writing. In the equilibrium, the value function of a manufacturing industry firm is:

[12] Combining Equation (15) with Equation (5), we can derive the final demand for the firm at equilibrium.

[13] h is a parameter to determine the innovation productivity.

$$V(z_L) = \pi\omega^{1-\sigma}[C_1 + C_2(ln(\pi(\omega)) - ln(P)]^{14} \tag{17}$$

$$V(z_H) = V(z_L) + \pi(z_H) - \pi(z_L) \tag{18}$$

The optimal innovation cost $c(q) = \beta(1-\delta)[\pi(z_H) - \pi(z_L)]$ and the optimal q is

$$q = ln(\pi\beta(1-\delta)[\exp(z_H) - \exp(z_L)]/h) + (1-\sigma)\, ln\, \omega - ln\, P \tag{19}$$

3) Final aggregation sector

Since the production function is Cobb-Douglas and the final good sector is perfectly competitive, the two first order conditions give the equilibrium demand for manufactured goods and non-manufactured goods:

$$\frac{P_M M_c}{P_S S} = \frac{\alpha}{1-\alpha} \tag{20}$$

And correspondingly, the equilibrium price of the final goods will be

$$P = \frac{P_M^{\alpha} P_S^{1-\alpha}}{\alpha^{\alpha}(1-\alpha)^{(1-\alpha)}} \tag{21}$$

4) Market clearing

The labor demand for the manufacturing sector and the non-manufacturing sector are

$$L_M = N\left(\frac{\sigma}{\sigma-1}\right)^{-\sigma}\left(\frac{\omega}{P_M}\right)^{-\sigma} M(\mu\, exp(z_H) + (1-\mu)\, exp(z_L)) \tag{22}$$

$$L_N = (1-\alpha)\left(\frac{\lambda}{1-\lambda} P_T^{*1-\rho}\left(\frac{\omega}{\theta}\right)^{\rho-1} + 1\right)^{-1}\left(L + \frac{N}{\omega}(\mu d(z_H) + (1-\mu)d(z_L))\right) \tag{23}$$

[14] Where $C_1 = \frac{\exp(z_L)+\beta(1-\delta)[\exp(z_H)-\exp(z_L)]\left(\ln\left(\frac{\beta(1-\delta)[\exp(z_H)-\exp(z_L)]}{h}\right)-1\right)}{1-\beta(1-\delta)}$ and $C_2 = \frac{\beta(1-\delta)[\exp(z_H)-\exp(z_L)]}{1-\beta(1-\delta)}$.

$L_M + L_N$ equals to the labor supply, $L_S = L$.

The final good market is cleared for each period:

$$PC = \omega L + N(\mu\pi_H + (1-\mu)\pi_L - \beta(1-\delta)[\pi_H - \pi_L]) \quad (24)$$

The trade balance condition is

$$\int_0^N (x_i - y_i)p_i di = \int_N^{NK} y_i p_i di + P_T S_T \quad (25)$$

Since the country is a small country, the above euation could be trasformed to

$$\int_0^N x_i p_i di = \int_N^{NK} y_i p_i di + P_T S_T \quad (26)$$

Futhermore, from $\int_0^{NK} y_i p_i d_i = P_M M_C$ and $\int_0^N x_i p_i d = \omega * L_M + N[\mu\pi_H + (1-\mu)\pi_L]$, we can derive the following condition

$$\omega * L_M + N[\mu\pi_H + (1-\mu)\pi_L] = P_M M_c + P_T S_T \quad (27)$$

Proposition 1. *There exists a unique stationary recursive equilibrium in the model.*

Proof. See Appendix.

III. COMPARATIVE STATICS FOR PARAMETERS θ AND λ

The model equilibrium is characterized by the equilibrium wage and prices. Since a unique equilibrium exists in the model, we conduct an comparative analysis by altering parameters θ and λ and seeing how the equilibrium responds.

As we discussed before, a higher λ means the economy is allowed to import more non-manufactured goods from a foreign country.[15] Otherwise, a higher θ means the economy has higher productivity in the non manufacturing sector. Both changes are favorable to firm innovation in the manufacturing sector by lowering the costs of non-manufactured goods and thus the costs of innovation.[16]

Since the equilibrium (ω^*, P^*) is characterized by market clearing for final goods and labor.
The equilibrium condition gives us,

$$P = \left(\frac{P_M}{\alpha}\right)^{\alpha}\left(\frac{P_S}{1-\alpha}\right)^{1-\alpha} \tag{28}$$

$$P_S = \left((1-\lambda)\left(\frac{\omega}{\theta}\right)^{1-\rho} + \lambda P_T^{1-\rho}\right)^{\frac{1}{1-\rho}} \tag{29}$$

We rewrite the market clearing condition for the final goods as

$$P^* = P^*(\omega, \theta, \lambda) \tag{30}$$

and substitute it into the market clearing condition for labor. Then the equilibrium ω^* satisfies

$$L_M(\omega^*, P^*(\omega^*, \theta, \lambda), \theta, \lambda) + L_N(\omega^*, P^*(\omega^*, \theta, \lambda), \theta, \lambda) - \mathrm{L} = 0 \tag{31}$$

Let $\upsilon(\omega, \theta, \lambda)$ be the wedge between the demand and supply of the labor:

$$\upsilon(\omega, \theta, \lambda) = L_M(\omega, P^*(\omega, \theta, \lambda), \theta, \lambda) + L_N(\omega, P^*(\omega, \theta, \lambda), \theta, \lambda) - L \tag{32}$$

[15] Government policies affecting λ can take into account both tariff and non-tariff barriers to imports in the non-manufacturing sector.

[16] Considering labor productivity in the model, policies that enhance productivity in the non-manufacturing sector, θ, may consider promoting investment in input elements besides labor such as capital.

We take first order derivatives of the wedge equation with respect to ω, θ and λ Because $\frac{\partial L_M}{\partial P}$, $\frac{\partial L_N}{\partial P}$, $\frac{\partial L_N}{\partial \lambda}$, $\frac{\partial P}{\partial \lambda}$, $\frac{\partial P}{\partial \theta}$ are negative and $\frac{\partial P}{\partial \omega}$, $\frac{\partial L_N}{\partial \theta}$ are positive in the equilibrium.

$$\frac{\partial \nu}{\partial \omega} = \underbrace{\frac{\partial L_M}{\partial P}\frac{\partial P}{\partial \omega} + \frac{\partial L_N}{\partial P}\frac{\partial P}{\partial \omega}}_{\textit{Indirect Effect} \ominus} + \underbrace{\frac{\partial L_N}{\partial \omega}}_{\textit{Indirect Effect} \ominus} + \underbrace{\frac{\partial L_M}{\partial \omega}}_{\textit{Direct Effect} \ominus} \tag{33}$$

$$\frac{\partial \nu}{\partial \lambda} = \underbrace{\frac{\partial P}{\partial \lambda}\left(\frac{\partial L_M}{\partial P} + \frac{\partial L_N}{\partial P}\right)}_{\textit{Indirect Effect} \oplus} + \underbrace{\frac{\partial L_N}{\partial \lambda}}_{\textit{Direct Effect} \ominus} \tag{34}$$

$$\frac{\partial \nu}{\partial \theta} = \underbrace{\frac{\partial P}{\partial \theta}\left(\frac{\partial L_M}{\partial P} + \frac{\partial L_N}{\partial P}\right)}_{\textit{Indirect Effect} \oplus} + \underbrace{\frac{\partial L_N}{\partial \theta}}_{\textit{Direct Effect} \oplus} \tag{35}$$

The indirect effect comes from changes in prices. Regardless of whether an economy imports more non-manufactured goods from a foreign country or produces non-manufactured goods domestically with higher productivity, it can use cheaper non-manufactured goods to reduce the costs of final goods and innovation. So firms in the manufacturing sector grow and attract labor.

Whereas the direct effect of the two possible parameter changes moves the equilibrium in opposite directions. When the economy can import more non-manufactured goods from a foreign country, domestic non-manufacturing goods are replaced by the foreign non-manufactured goods. Then, labor demand in the non-manufacturing sector decreases resulting in a surplus labor supply. On the other hand, when the economy increases productivity of the non manufacturing sector, labor demand in the non-manufacturing sector increases, resulting in labor shortages.

From the three equations above, the implicit function theorem tells us that

$$\frac{\partial \omega^*}{\partial \lambda} = -\frac{\frac{\partial \nu}{\partial \lambda}}{\frac{\partial \nu}{\partial \omega}} : sign\ unknown \tag{36}$$

$$\frac{\partial \omega^*}{\partial \theta} = -\frac{\frac{\partial \nu}{\partial \theta}}{\frac{\partial \nu}{\partial \omega}} < 0 \tag{37}$$

We do the same thing for P^* when rewriting the market clearing condition for the final good. We plug the market clearing condition rewritten into $\omega(P, \theta, \lambda)$ and substitute it into the market clearing condition for labor. Then we can show

$$\frac{\partial P^*}{\partial \lambda} = -\frac{\frac{\partial \psi}{\partial \lambda}}{\frac{\partial \psi}{\partial P}} < 0 \tag{38}$$

$$\frac{\partial P^*}{\partial \theta} = -\frac{\frac{\partial \psi}{\partial \theta}}{\frac{\partial \psi}{\partial P}} : sign\ unknown \tag{39}$$

As similar to wages, we argue that when an economy imports more non-manufactured goods, represented by an increase in λ, both the direct effect and the indirect effect move in the same way, bringing down the price. But the effect of an increase in θ is ambiguous.

Lemma 1. *If $\rho \to \infty$, there is a pair of (θ, λ) satisfying* $\frac{\partial \omega^*}{\partial \lambda}=0$ *and* $\frac{\partial P^*}{\partial \theta}=0$.

Proof. See Appendix.

Proposition 2. *If $\rho \to \infty$ and a pair of (θ,λ) satisfies* $\frac{\partial \omega^*}{\partial \lambda}=0$ *and* $\frac{\partial P^*}{\partial \theta}=0$, *increases in θ and λ both increase the welfare of the economy, but the effect on productivity and labor in the manufacturing sector is the opposite.*

Proof. See Appendix.

IV. QUANTITATIVE ANALYSIS

1. Extended Model for Simulation

In this section, we extend the baseline model to an infinite number of possible productivity levels for firms in the manufacturing sector in order to a conduct quantitative analysis. Following Atkeson and Burstein (2010), a firm in the manufacturing sector invests $C(q, z) = P\, he^{q}e^{z}$ units of final output in innovation. This results in the following innovation outcomes:

$$z' = \begin{cases} z + \Delta & \text{with probability q} \\ z - \Delta & \text{with probability } 1 - \text{q} \end{cases} \tag{40}$$

exp(Δ) is the productivity difference between the two adjacent productivity indexes. Now $\mu(z)$ is the distribution of infinite possible productivity indexes, so we can define a equilibrium as we have done in Section 2.

Table 2. Parameters of the Model for the Simulations

Parameter	Description	Value
P_M	The final good price level	0.85
P_T	Price level of continental non-manufactured goods	1
M	The world market size of manufactured intermediate goods	10
N	Measure of domestic manufacturing firms	10
K	Measure of total manufacturing firms	unnecessary[a]
L	Total domestic labor force	100000
β	Discount rate	0.96
δ	Exogenous quit rate	0.005
α	Manufacturing share	0.3
ρ	Elasticity of substitution between service goods	10
σ	Elasticity of substitution between manufacturing goods	5
Δ	Step Length for innovation	0.1
θ	Firm productivity in the domestic non-manufacturing sector	
λ	Parameter to determine the weight for foreign non-manufactured goods[b]	

Note: [a] Specifically, N·K is the measure of total manufacturing firms in the world. However, we assume that the economy is a small open economy, so we do not need to know the value of *K* for the quantitative analysis.

[b] Both θ and λ are the parameters for the comparative static.

For conducting some simulation results, we parameterize the model. We provide the values of the parameters used in Table 2.[17]

2. Simulation Analysis

Using the extended model, we will conduct some counterfactual analysis. We focus especially on two exogenous changes in λ and θ. Both changes result in lower prices of non-manufactured goods but as shown earlier, the impact on the manufacturing sector is different. First, we show how λ and θ affects the innovation decisions of firms in the manufacturing sectors, which provides theoretical results from the simple model before. This analysis will tell us the growth patterns brought about by different policies. Second, we show the effect of a change in λ given a different level of θ. This result will tell us how much specialization will benefit on the economics, depending on different levels of development in the non-manufacturing sector. Finally, we show that how the size of an economy matters in relation to the effects of the two exogenous changes.

Experiment 1. *Effects of two policies on distribution of the manufacturing sector*

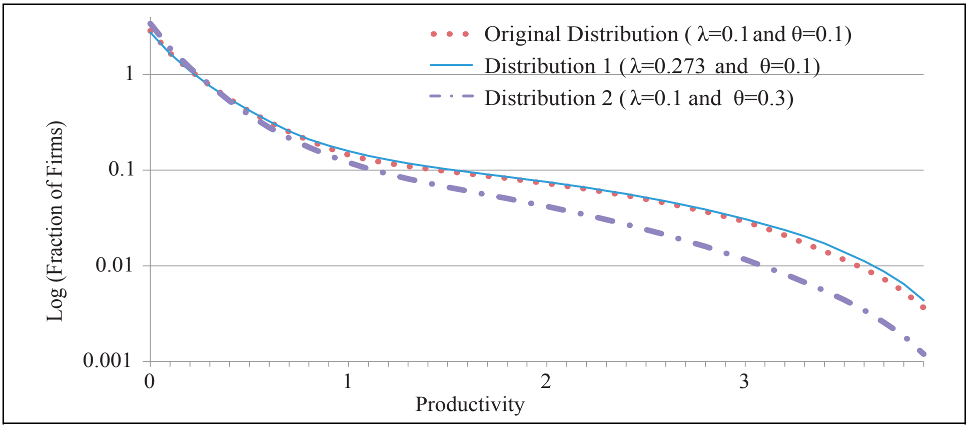
In Experiment 1, we show Proposition 2 quantitatively with heterogeneity in firms' productivity but with multiple productivity levels using the extended model. For the experiment, we start from a specific (θ, λ) pair as (0.1, 0.1). We do not construct an explicit cost function for the two policies. To consider changes wrought by the two policies comparably, first we change θ to 0.3 and calculate the changes in household welfare. From the change in household welfare, we find the change in λ that guarantees an equal change in household welfare, $\lambda = 0.273$. We then compare the changes in each policy, which increase θ from 0.1 to 0.3 and λ from 0.1 to 0.273. We provide the probability density function for firm productivity following implementation of the two policies in Figure 2.[18]

[17] Our goal is not to give an accurate quantitative analysis for the sake of policy-making but to describe the implications carried by different policies. Accordingly, parameters were not precisely calibrated.

[18] An evaluation of which of the two policies is better for overall growth would require a more precise calibration. This paper instead focuses on the comparison of manufacturing firm dynamics

Figure 2 says that the increase in λ leads to a more favorable change in firm innovation in the manufacturing sector than an increase in θ. In the experiment, an increase in λ has a higher fraction of firms with an increase in productivity and a lower fraction of firms with lower productivity ex-post. On the other hand, an increase in θ even lowers firms' productivity ex-post compared to before the policy change. We calculate the change in average productivity of firms in the manufacturing sector using $\int_0^N z_i \mu(z) dz$. Although both changes were designed to result in identical changes in welfare, the change in λ increases firms' average productivity by four percent, the change in θ decreases productivity by 34 percent. With regards to labor movement, the two changes produce opposite results. The change in λ leads manufacturing firms to hire more labor at a rate of 0.9 percent, while the change in θ leads to hiring gains amounting to just half of the figure.

Figure 2. Distribution of Firm Productivity after Increases in θ and λ

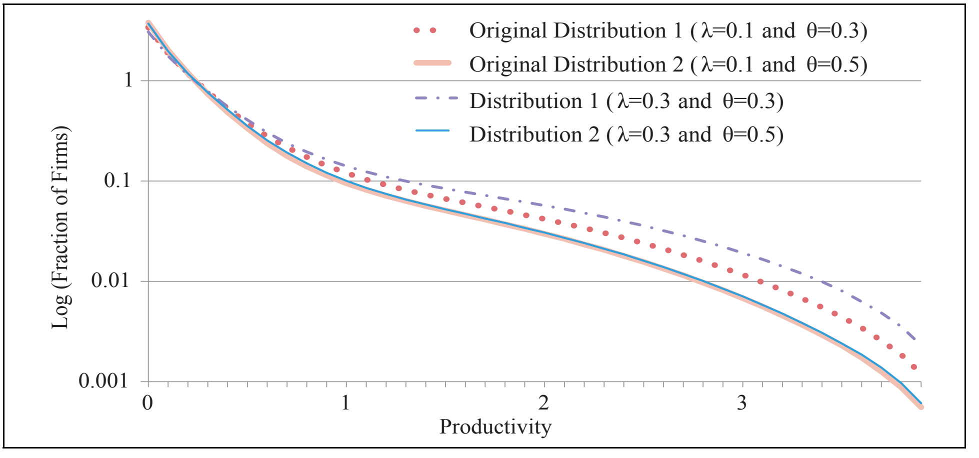


The quantitative result is consistent with Proposition 2 in Section 2 which comprises the analytical result with two possible productivity levels. As we explained in the model, this is related to specialization. Due to lower prices of non-manufactured goods, both parameter changes incentivize innovation. However, an increase in λ precipitates relatively higher labor costs for firms in the manufacturing sector, as there is no change of productivity at non-manufacturing firms. Meanwhile firms in the manufacturing

in responding to policies. A quantitative assessment of the effects of both policies on overall economic growth is a subject for future research.

sector record higher profits and conduct more innovation when compared to an increase in θ., which reflects the economy becoming specialized in the manufacturing sector without a concomitant improvement in the non-manufacturing sector.

Figure 3. Distribution of Firm Productivity after Increases in λ on Different θs



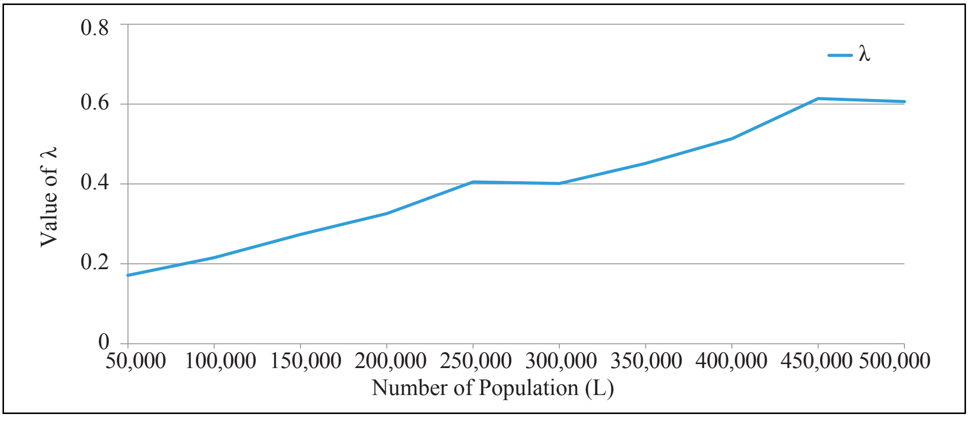
Experiment 2. *Effects of λ increase on the manufacturing sector in different θs*

For Experiment 2, we start from two different pairs (θ, λ) as (0.3, 0.1) and (0.5, 0.1), then we increase λ to 0.3. As we show in the firm's productivity distribution in Figure 3, the increase in λ is likely to drive more rapid growth in the manufacturing sector with a lower θ. This happens because higher productivity of the non-manufacturing sector makes the equilibrium price of labor higher, decreasing profits of firms in the manufacturing sector and discouraging innovation. Openness in the non-manufacturing sector is therefore less desirable when a country already has high non-manufacturing productivity. Reversely, a country with low productivity in non-manufacturing fields finds it necessary to import more goods for growth in the manufacturing sector.

Quantitatively, a change in *lambda* from 0.1 to 0.3 will induce a 17 percent increases in average productivity at manufacturing firms with $\theta = 0.3$, while the same change increases productivity by only 1.4 percent when $\theta = 0.5$. And also, the first change makes the firms in the manufacturing sector hire much more labor than the second one, by 40 percent and 11 percent respectively.

The result implies that when a country has very low productivity across all industries, the manufacturing sector seizes comparative advantage through the opening if the non-manufacturing sector. The county then experiences rapid growth and specializes in the manufacturing, as was the case of "miracle" economies in Asia. However, when a country's income levels increase due to higher productivity in the non-manufacturing sector, then comparative advantage evaporates. This can explain why manufacturing firms in a developing country can grow extremely rapidly compared to those in a developed country.

Figure 4. Relation between λ and Labor



Experiment 3. *Effect of θ and λ on household welfare by amount of labor*

In Experiment 3, we describe the impact of different policies based on the size of the countries in which they are implemented. We start from a specific (θ, λ) pair : (0.1, 0.1). We increase θ to 0.3 and then try finding each level of λ to produce the same change in household welfare according to differing labor volumes. This suggests that we implicitly find out λ, which provides the same benefit as an increase in θ by 0.3 depending on the size of the economy in equation. As we show in Figure 4, if we have more labor, we need a higher λ to elicit the same welfare gain from an identical change in θ. Similarly, a larger country, which has more labor, will see smaller welfare gains from a change in λ, which allows it to import more non-manufactured goods than would be possible in a smaller country.

The result carries the implication that a larger country could achieve rapid growth in the manufacturing sector through specialization. However, in terms of overall benefits to welfare, gains large countries reap by opening the non-manufacturing sector relative to increasing their own productivity in the non-manufacturing sector are smaller, owing to their size. This tells us that balanced growth that includes increasing productivity in the non-manufacturing sector as well is a necessary policy for larger countries.

Eichengreen, Park, and Shin (2012) analyze historical growth experiences of countries, and have argued that a country experiences a slowdown of economic growth when per capita GDP reaches \$13,000 per year, the so-called “Middle income trap”. To avoid it, they stress increasing productivity in the non-manufacturing sector. From a historical analysis of other countries, They argue that China too will spring the trap when its income level reaches \$13,000. However, our model suggests that it is necessary that low-income countries increase productivity in the non-manufacturing sector for better welfare returns; as China is much bigger than other low-income countries its experience is fundamentally different.

V. CONCLUSION

In this paper, we build a model with two sectors. In it, the manufacturing sector grows endogenously and the non-manufacturing sector provides goods used for both research and final consumption, stimulating innovation at firms in the manufacturing sector. Through the model we examine the effects of two exogenous changes that expand the output of goods in the non-manufacturing sector. The first policy increases domestic productivity in the non-manufacturing sector. The second increases imports of non-manufactured goods from a foreign country with higher productivity. Even though both changes improve the welfare of the economy, both theoretically and quantitatively, we show that effects on the manufacturing sector are different. Our model predicts that the latter change makes manufacturing firms grow faster and attract more labor than the former. Based on our results, we argue that specialization through importing non-manufactured goods contributes to Asian economic growth, but not increasing productivity in the non-manufacturing sector, as the previous literature on structural transformation has emphasized.

We also conduct experiments using the model that have implications for economic development. Our experiments suggest that manufacturing growth is slower with higher productivity in the non-manufacturing sector when the economy allows imports of more non-manufactured goods. This implies that in terms of manufacturing growth, a developing country has greater incentive than a developed country to specialize in manufacturing by importing the non-manufactured goods it consumes because its productivity in the non-manufacturing sector is lower. Furthermore, a larger economy realizes larger welfare gains from increasing the domestic productivity of the non-manufacturing sector and developing both sectors in a balanced way. This result carries obvious implications for the growth of the Chinese economy. A similar pattern of economic growth as seen in Japan or Korea could guarantee fast growth in Chinese manufacturing.[19] In terms of welfare, however, China might see slower improvements relative to that of Japan and Korea because China is much larger than either country.

Some assumptions of the model did not address a number of issues. For example, the model in this study assumes the free mobility of labor between two sectors, equalizing wages between them. As a result, labor always moves to manufacturing when importing non-manufacturing goods and the transition has a positive effect on manufacturing growth. In practice, however, these mechanisms would vary depending on wage differences between the sectors. This would require a more complex labor market in the model accurately calibrated to the actual data. Using such a model, it would be possible to study labor mobility during the structural transformation leading to the economic growth period and also analyze changes in prices and wages of goods between sectors. We leave this to future research.

[19] Bosworth and Collins (2008) show, using growth accounting, that productivity of the industrial sectors including manufacturing, utilities and construction increased by 6.1% while in the agriculture and service sectors productivity increased by 1.7% and 0.9% respectively from 1993 to 2004.

APPENDIX: PROOF OF LEMMA AND PROPOSITION

Lemma 1. *Total labor demand is decreasing in ω and decreasing in P in the general equilibrum.*

Proof. Step 1: L_M is decreasing in ω and decreasing in P.

In the equilibrium, the distribution of firm productivity μ is endogenously decided by a firm's optimal investment decisions, where

$$\mu = \ln(\pi\beta(1-\delta)[\exp(z_H) - \exp(z_L)]/h) + (1-\sigma)\ln(\omega) - \ln(\mathrm{P})$$

So

$$\frac{\partial \mu}{\partial \omega} = \frac{1-\sigma}{\omega} < 0$$

and

$$\frac{\partial \mu}{\partial P} = -\frac{1}{P} < 0$$

given the expression of labor engaged in the manufacturing sector in the equation (22), and apply the chain rule:

$$\frac{\partial L_M(\mu,\omega,P)}{\partial \omega} = \frac{\partial L_M(\mu,\omega,P)}{\partial \mu}\frac{\partial \mu}{\partial \omega} + \frac{\partial L_M(\mu,\omega,P)}{\partial \omega} < 0$$

and

$$\frac{\partial L_M(\mu,\omega,P)}{\partial P} = \frac{\partial L_M(\mu,\omega,P)}{\partial \mu}\frac{\partial \mu}{\partial P} < 0$$

Step 2: L_N is decreasing in ω and decreasing in P.

$$L_N = (1-\alpha)\left(\frac{\lambda}{1-\lambda}P_T^{*1-\rho}\left(\frac{\omega}{\theta}\right)^{\rho-1}+1\right)^{-1}\left(L+\frac{N}{\omega}(\mu d(z_H)+(1-\mu)d(z_L))\right)$$

Let

$$\mathrm{A}\big(\omega(\mu)\big) = (1-\alpha)\left(\frac{\lambda}{1-\lambda}P_T^{*1-\rho}\left(\frac{\omega}{\theta}\right)^{\rho-1}+1\right)^{-1}$$

and

$$B\big(\mu,\omega(\mu)\big) = L+\frac{N}{\omega}\big(\mu d(z_H)+(1-\mu)d(z_L)\big)$$

Then

$$L_N = \mathrm{A}\big(\omega(\mu)\big) * B\big(\mu,\omega(\mu)\big)$$

We can easily show that $\frac{\partial A(\omega)}{\partial \omega}<0$

From the definition of dividend,

$$\mu d(z_H)+(1-\mu)d(z_L) = (\mu\pi(z_H)+(1-\mu)\pi(z_L)) - Phe^{qH}$$

By the equation (16) and (19)

$$= \pi\omega^{1-\sigma}(\mu\exp(z_H)+(1-\mu)\exp(z_L)) - \beta(1-\delta)[\exp(z_H)-\exp(z_L)]$$

So,

$$\begin{aligned} B(\mu,\omega) = L + N\pi\omega^{-\sigma}\big((\mu\exp(z_H)+(1-\mu)\exp(z_L)) \\ - \beta(1-\delta)[\exp(z_H)-\exp(z_L)]\big) \end{aligned}$$

Since we know $\frac{\partial \mu}{\partial \omega}=\frac{1-\sigma}{\omega}<0$ and $\frac{\partial \mu}{\partial P}=\frac{1}{P}<0$, and through the chain rule:

$$\frac{\partial B(\mu,\omega)}{\partial \omega}=\frac{\partial B(\mu,\omega)}{\partial \mu}\frac{\partial \mu}{\partial \omega}+\frac{\partial B(\mu,\omega)}{\partial \omega}<0$$

and

$$\frac{\partial B(\mu,\omega)}{\partial P}=\frac{\partial L_M(\mu,\omega)}{\partial \mu}\frac{\partial \mu}{\partial P}<0$$

So

$$\frac{\partial L_N(\mu,\omega,P)}{\partial \omega}=\frac{\partial A(\omega)}{\partial \omega}+\frac{\partial B(\mu,\omega)}{\partial \omega}<0$$

and

$$\frac{\partial L_N(\mu,\omega,P)}{\partial P}=\frac{\partial B(\mu,\omega)}{\partial P}<0$$

Since the total demand of labor equals the sum of demand from the manufacturing and non-manufacturing sector.

$$L_M+L_N\equiv L_D,\frac{L_D(\omega,P)}{\partial \omega}<0\ and\ \frac{L_D(\omega,P)}{\partial P}<0$$

Proposition 1. *There exists a unique stationary recursive equilibrium.*

Proof. In the equilibrium, wage and price levels are weighed down by labor market and final market clearing conditions.

1. Labor market clearing condition: $L_D = L$

Since L_S is a fixed number, L_D is decreasing in ω and decreasing in P.
All the equilibrium P satisfying the labor market clearing condition must monotonically decreasing with equilibrium wage level ω.

2. Final good clearing condition under optimal choice of aggregating firms gives:

$$\mathrm{P} = \left(\frac{P_M}{\alpha}\right)^{\alpha}\left(\frac{P_S}{1-\alpha}\right)^{1-\alpha}$$

$$P_S = \left((1-\lambda)\left(\frac{\omega}{\theta}\right)^{1-\rho} + \lambda P_T^{*1-\rho}\right)^{\frac{1}{1-\rho}}$$

All the equilibrium P satisfying the final good and intermediate good clearing condition must monotonically increase in equilibrium wage level ω.

So, the (ω, P), which satisfied both equilibrium conditions must be unique.

And from this wage price level pair, the entire equilibrium under this price system is unique.

Lemma 2. *If $\rho \to \infty$, there is a pair of (θ, λ) satisfying* $\frac{\partial \omega^*}{\partial \lambda}$ =0 and $\frac{\partial P^*}{\partial \theta}$ =0.

Proof. Let's explore the direct effect and indirect effect separately.

Direct Effect:

By the equation (23)

$$\frac{\partial L_N}{\partial \lambda} = -(1-\alpha)\left(L + \frac{N}{\omega}(\mu d(z_H) + (1-\mu)d(z_L))\right)$$
$$\left(P_T^{1-\rho}\left(\frac{\omega}{\theta}\right)^{\rho-1}\right)\left(\lambda P_T^{1-\rho}\left(\frac{\omega}{\theta}\right)^{\rho-1} + 1 - \lambda\right)^{-2}$$

As $\lambda \to 0$, $\frac{\partial L_N}{\partial \lambda} \to -\infty$ while as $\lambda \to 1$, $\frac{\partial L_N}{\partial \lambda} \to 0$

Indirect Effect:

By the equation (21), (12), (22) and (23)

$$\frac{\partial P}{\partial \lambda}\left(\frac{\partial L_M}{\partial P}+\frac{\partial L_N}{\partial P}\right)>0 \ \textit{for all}\ \lambda$$

Since $\lim\limits_{\rho\to\infty}\frac{\partial L_N}{\partial \lambda}$ $\to$ -∞, there exist an $\bar{\rho}_\lambda$, for all $\rho >$ $\bar{\rho}_\lambda$, such that $\lim_{\lambda\to 0}\frac{\partial L_N}{\partial \lambda}+\frac{\partial P}{\partial \lambda}\left(\frac{\partial L_M}{\partial P}+\frac{\partial L_N}{\partial P}\right)<0$ and $\lim_{\lambda\to 1}\frac{\partial \omega^*}{\partial \lambda}>0$

which implies that there is a correspondence of $\lambda(\theta)$, where the net effect of $\frac{\partial \omega}{\partial \lambda}|_{\lambda=\lambda(\theta)}=0$

Similarly,

$$\frac{\partial L_N}{\partial \theta}=(\rho-1)(1-\alpha)\left(\frac{\lambda}{1-\lambda}P_T^{1-\rho}\left(\frac{\omega}{\theta}\right)^{\rho-1}+1\right)^{-2}$$
$$\left(L+\frac{N}{\omega}(\mu d(z_H)+\cdots(1-\mu)d(z_L)\right)\left(\frac{\lambda}{1-\lambda}P_T^{1-\rho}\left(\frac{\omega}{\theta}\right)^{\rho-1}\frac{1}{\theta}\right)$$

As $\theta\to\frac{\omega}{P_T^*}$, $\frac{\partial L_N}{\partial \theta}\to\infty$ *while as* $\theta\to 0$, $\frac{\partial L_N}{\partial \theta}\to 0$

Therefore $\frac{\partial \omega}{\partial \theta}\left(\frac{\partial L_M}{\partial \omega}+\frac{\partial L_N}{\partial \omega}\right)<0 \ \textit{for all}\ \theta$

Since $\lim\limits_{\rho\to\infty}\frac{\partial L_N}{\partial \theta}\to\infty$, there exist an $\bar{\rho}_\theta$, for all $\rho >$ $\bar{\rho}_\theta$, such that

$$\lim_{\theta\to\frac{\omega}{P_T^*}}\frac{\partial L_N}{\partial \theta}+\frac{\partial \omega}{\partial \theta}\left(\frac{\partial L_M}{\partial \omega}+\frac{\partial L_N}{\partial \omega}\right)>0 \ \text{and}\ \lim_{\theta\to 0}\frac{\partial P^*}{\partial \theta}<0$$

This implies a correspondence of $\theta(\lambda)$, where the net effect of $\frac{\partial P}{\partial \theta}|_{\theta=\theta(\lambda)}=0$

Let $\hat{\rho}=\max\{\bar{\rho}_\lambda,\ \bar{\rho}_\theta\}$, for all $\rho >$ $\hat{\rho}$

The intersecting points of this correspondence would satisfy our requirement.

Proposition 2. *If $\rho \rightarrow \infty$ and a pair of (θ,λ) satisfies $\frac{\partial \omega^*}{\partial \lambda} = 0$ and $\frac{\partial P^*}{\partial \theta} = 0$, increases in θ and λ both increase the welfare of the economy, but the effect on productivity and labor in the manufacturing sector is opposite.*

Proof. Given the above $\hat{\rho}$, for all $\rho > \hat{\rho}$, there exists some point satisfied the condition chracterized by lemma 2.

Starting from the these (θ, λ), when θ increases by a small amount $d\theta$, $dP^* = \frac{\partial P^*}{\partial \theta} = 0$ and $d\omega^* \frac{\partial \omega^*}{\partial \theta} d\theta > 0$.

When λ increases by a small amount $d\lambda$, $d\omega^* = \frac{\partial \omega^*}{\partial \lambda} d\lambda = 0$ and $dP^* = \frac{\partial P^*}{\partial \lambda} d\lambda < 0$

Since the equilibrium μ is a function of (ω, P) and $\frac{\partial \mu}{\partial \omega} = \frac{1-\sigma}{\omega} < 0$ and $\frac{\partial \mu}{\partial P} = -\frac{1}{P} < 0$ μ is increasing as λ increases, and decreasing as θ increases.

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