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Theoretical approach to issues in developing countries: rural development, privatization, and wage inequality

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Chapter 1

Introduction

1.1 Research questions

World Economic and Social Survey 2017 reports that a larger number of developing economies experienced fast economic growth during the first years of the new millennium, especially some “emerging economies” such as China, India, Brazil. During this period, because of new technologies, coupled with trade liberalization, developing countries face new economic phenomena, which have never been seen in the process of developed countries. Many issues, about which have paid little concern in conventional development economics, appear. Such issues like poverty in the rural region, small-scale agricultural production, massive low-efficiency state-owned enterprises, poor property rights, bad institution system, etc. Among them, this dissertation theoretically investigates three issues in the process of economic development in developing countries, i.e, rural development under the background of rural-urban migration, vitalization of the urban economy with the privatization of state-owned enterprises(SOEs), and wage inequality between skilled and unskilled labor. In the following context, I will explain why such three issues matter.

First, I center the rural development in the context of the massive rural-urban migration. The agricultural sector is a key economic sector that produces essential food and other raw materials. Rural development or agricultural development not only relates to food security and poverty reduction but also acts as a driver for rural economic and social development through rural-urban linkages, such as rural-urban migration in particular. Rural labor enters into urban and provides cheap manpower to fuel a growing modern manufacturing sector. Take China and India, for example. In 1978, more than 80% of the Chinese population worked in agriculture; and in 2017, this figure was only 26.5%. From the Census of India 2011, rural migrants are nearly 400 million, comprising a third of India's population.

Such massive rural labor outflow brings several impacts on rural development. Considering its impact on agricultural output at first. Early literature contends that declining farm labor does not necessarily cause a fall in farm production in developing countries(Lewis, 1954). When a country passes the so-called Lewis turning point, when surplus labor is exhausted, a drop in the farm labor force in principle would harm agricultural output. However, the conclusion does not incorporate the situation that the agricultural sector could use other factors, such as capital, to substitute labor in order to keep agricultural output stable. In response to the shortage of labor and rising wage rate, farmers outsource some power-intensive stages of production, such as harvesting, to specialized mechanization service providers. Such a phenomenon has already existed in many developing countries, especially countries with a large population and small-scale agricultural production. Next, consider the subsequent phenomenon of internal migration: internal remittances. Due to the precarious living and working conditions, most migrants leave their family members, especially children, in the villages and remit sizable amounts of money(Li and Wang, 2015). The remittances sent by migrants play a significant role in rural development in developing countries. Internal remittances, comprising 20% to 50% of total family income in the receiving household, are crucial to paying for household expenses in China. In India, internal remittances financed over 30% of household consumption expenditure and 80% went to rural households(Tumbe, 2011). In addition, remittances are safety funds for relatively poor areas, as they are freer from political barriers and controls than other forms of aids in developing countries.

Second, I focus on the vitalization of the urban economy with the privatization of SOEs. Most of these SOEs locate in sectors such as transportation, telecommunications, power generation, finance, mining, manufacturing and other energy industries,most of which can be classified as the upstream industries(OECD, 2017). Such fact is more prominent in many developing countries, like China, Vietnam. And governments in developing countries could control or influence the whole economy through upstream SOEs, thus SOEs play a much larger role in the economies of developing countries than developed countries. Li et al. (2012) argue China has developed such a vertical structure around 2001. Under this structure, SOEs have monopolized key upstream industries, whereas downstream sectors have been liberalized and mostly open to private competition. Other developing countries,for instance, Zimbabwe and Ethiopia in Africa and Vietnam in Asia, the participation of SOEs in economic activity is substantial and they usually have monopoly status. Therefore, the performance of SOEs is crucially important to the whole economy.

Since SOEs hold a significant position, the productivity of SOEs could affect the whole economy. Many developing countries have identified the reform of SOEs as an essential step in the structural transformation. Several measures have implemented to speed up the process, such as opens state-owned enterprises to private capital, advancement in mixed-ownership. For example, The government of Vietnam plans to have only 150 wholly state-owned enterprises by 2020, from 526 in 2017, and 1,369 in 2011.

Third, I concentrate on wage inequality between skilled and unskilled labor. Economic development requires not only economic growth and but also the reduction of inequality. Currently, wage inequality is a concern for both developed and developing countries. While the dramatic rise in wage inequality over the past decades has been the topic of much research, its causes are still not perfectly understood.

Previously, many scholars believe that trade liberalization and international factor movement have contributed to widening inequality. Meanwhile, their effects on the wage gap have been analyzed extensively among theoretical papers. However, previous studies seldom consider the role of public infrastructure in the wage inequality. Nowadays, public infrastructure, such as legal and economic institutions, transportation systems, communications, is playing an increasing role in modern society, especially in many developing economies, without which economic growth development will be greatly affected.

Until recently, one line of research has paid attention to a change of domestic factors to explain wage inequality. In these studies, a variety of mechanisms are proposed to model impacts of a change in a domestic factor on wage gap such as public infrastructure provision, taxation on labor income, privatization, capital market distortion, skill-biased technical change. In this dissertation, I focus on the impact of control of manufacturing and agricultural pollution on wage inequality. Pollution,both from manufacturing and agricultural production, is one of the most severe challenges facing developing countries and exerts a negative effect on production and labor health. According to World Bank(2016a), pollution costs trillions of dollars a year and severely impedes development in many developing countries(China lost nearly 10% of its GDP, India 7.69% and Sri Lanka and Cambodia roughly 8% in 2013). Moreover, pollution also exposes a great threat to labor health, especially in developing countries. For example,pollution was responsible for 9 million premature deaths in 2015, and nearly all of these deaths (92%) took place in developing nations (Das and Horton, 2018).

To sum up, this dissertation tries to address current development issues by centering on the rural region, urban region and wage inequality. In particular, the dissertation picks up some specific key aspects to investigate such issues. Given those aspects could affect the development process significantly, several important policy implications are derived from the discussion in this study.

1.2 What we do

Chapter 2

Chapter 2 constructs a general equilibrium model with agricultural producer service sector and explores the impact of an inflow of capital and an increase in subsidy rate on agricultural output. In many developing countries, agricultural production is operated in small-scale land, which impedes the use of modern inputs by the agriculture directly. Agricultural producer service sector acts as a bridge to connect capital and rural region. And the agricultural sector uses the services as intermediate inputs to substitute labor in production.

Previous studies paid little attention to the agricultural producer service sector. Scholars in development economics considered that rural region has two distinctive sectors: traditional agriculture and modern agriculture. And they assume modern agriculture could employ capital directly while traditional agriculture only uses labor to production. However, under the background of small-scale agriculture,how to development of traditional agriculture or how to employ capital in traditional agriculture are ignored in previous papers. In contrast, the present analysis shows that capital could enter into agricultural production through agricultural producer service sector.

Furthermore, this chapter analyzes the impact of an inflow of capital and an increase in agricultural producer service subsidy rate on agricultural output. Since two exogenous changes reduce the fixed cost of agricultural producer service sector, however, their impacts on agricultural output are opposite because of their opposite impacts on manufacturing sector.

Chapter 3

Chapter 3 develops a three-sector general equilibrium model to examine the consequences of an increase in vocational training costs on internal remittances in a small open dual economy. Migrants' income, which is significantly affected by their human capital level, determines the capacity of remittances. Due to the backward education system in rural regions, migrants' human capital level is much lower than their counterparts in the urban. Thus, poor education migrants need training before entering the manufacturing sector.

Concerning internal remittances, scholars focus on how a change of internal remittances affects wage inequality and economy, and little theoretical research considers the determinant of internal remittances. This chapter uses indirect utility functions and endogenizes the internal remittances, and analyzes how an increase in vocational training cost of the manufacturing sector affects internal remittances.

Chapter 4

Chapter 4 concentrates on the privatization of SOEs in a vertical related market in developing economy by establishing a general equilibrium model. In reality, most of SOEs locates in upstream sectors and privatization occurs in upstream industries correspondingly.

Regarding this issue, most of the papers assume both public and private firms produce final goods and compete in the same market and employ game theory as a tool to analyze it. While the game theory approach is useful in realizing theoretical results, it is bound to be limited in the analysis, as it ignores factor markets. Generally, public firms experience an efficiency improvement in line with their level of privatization. After the improvement of efficiency, public firms reduce factor employment, which affects the cost of public firms and factor rewards in factor markets. Therefore, the privatization issue is in fact often addressed in situations where good markets and factor markets are interconnected.

Incorporating the vertical structure, this chapter constructs a three-sector general equilibrium model to investigate the impact of the privatization of a public upstream firm. The SOEs monopolize upstream industries and provides essential intermediate inputs to the downstream manufacturing sector. Final goods sectors are outputs from manufacturing and agricultural sector. In addition, assume once raising privatization level, the SOEs experience efficiency-enhancing effect. Under this framework, this chapter investigates the economic impacts of an increasing privatization level.

Chapter 5

Chapter 5 considers the impacts of international labor movement on wage inequality between skilled and unskilled labor by a dynamic treatment of the public intermediate input. Many scholars believe that trade liberalization and international factor movement have contributed to the widening inequality. Meanwhile, their effects on the wage gap have been analyzed extensively among theoretical papers. However, previous studies seldom consider the role of public infrastructure in wage inequality.

This chapter considers a small, open economy with three sectors: two private sectors, skill-using and unskill-using sector, and a public sector. The private sectors produce private final goods. While the public sector produces a public intermediate non-tradable good in Meade's (1952) 'unpaid factor' type, which can be accumulated, and its accumulated stock serves in the private production. After incorporating the public intermediate input into the model, the chapter obtains new conclusions.

Chapter 6

Chapter 6 focuses on pollution control both from manufacturing sector and agricultural sector. Pollution is one of the most severe challenges facing developing countries and exerts a negative effect on production and labor health. Facing the severe environmental problem, governments adopt certain policies to remedy negative externalities. Regarding manufacturing pollution, an environmental tax is a common preservation policy and has a substantial cost advantage over other instruments such as pollution control. As for solution of agricultural pollution, agricultural pollutants control is the most direct and effective approach for developing world.

This chapter establishes a three-sector general equilibrium model to analyze the impacts of manufacturing and agricultural pollution on wage inequality by considering pollution externalities both on production and labor health. Manufacturing sector generates pollution that affects agricultural production and labor health; while the agriculture employs the pollutant as a factor for production which only affects labor health. Labor have to spend time or money,i.e self-mitigation cost, to curb or prevent bad effects.

Chapter 7

Chapter 7 reviews the discussion and results obtained from the above chapters. Moreover, issues remaining for future research are proposed.

The main part of the dissertation consists of 5 chapters: from chapter 2 to chapter 6. Those five chapters could be divided into three parts. Chapter 2 and chapter 3 are classified as the rural development part. Chapter 4 belongs to the privatization part. Wage inequality part includes Chapter 5 and 6.

Chapter 2

Agricultural producer service and rural development in developing countries

This chapter considers agricultural producer service sector in developing countries. Due to small-scale production, capital cannot enter into agricultural production directly. And agricultural producer service sector acts as a bridge to connect capital and rural region. In the model, capital could mobile between manufacturing sector and agricultural producer service sector. Agricultural sector utilizes the output of agricultural service sector and unskilled labor to production. The main conclusion is that an inflow of capital raises the output of agricultural sector through more available agricultural producer services. However, an increase in subsidy rate of agricultural producer service decreases the output of agricultural sector.

2.1 Introduction

Growth in agriculture is central to development in developing countries. However, traditional agricultural systems cannot generate high labor productivity in agriculture; opportunities for rapid productivity growth become available only through advancement in science-based technology. Thus, modern intermediate inputs in agriculture, which refer to those factors that are provided outside the agricultural sector, are vital in agricultural development.

Restuccia et. al(2008) argue that expensive modern input is the direct barrier for adopting modern inputs. In many developing economies, small-scale agriculture worsens this issue. On the one hand, smallholders cannot purchase modern inputs(such as machines) due to the high cost. On the other hand, after smallholders buy such inputs, they face high average cost due to small-scale production. One way solve such problem is to develop the agricultural producer service sector. Specifically, agricultural producer service sector, as a substitute for individual farmers' investment, provides services to smallholder farmers; thus, smallholder farmers can also use modern inputs without paying the corresponding sunk costs. Meanwhile, firms in the agricultural producer service sector could provide services to large customers and greatly lower their unit cost of operation. In practices, many developing countries, especially countries with large smallholder farmers, such as China, Bangladesh, India, have developed such agricultural producer service sector to address the shortage of rural labor and raising the rural wage.

In literature, producer service associates with manufacturing sector as an intermediate input(Rivera-Batiz and Rivera-Batiz,1990; Eswaran and Kotwal,2002; Anwar,2008; Zhang,2012), and little research considers agricultural producer service. Recently, with the development of agricultural producer service in developing countries, scholars empirically analyze the impact of agricultural producer service on agricultural production. For example, Houssou et al(2013) assess whether specialized agricultural mechanization services can be a viable business model in Ghana; Yamauchi(2016) show farmers used more hired-in machines through machine service providers to response an increase in real wages in Indonesia rural areas. Zhang et al(2017) and Li et al(2017) consider the case of China; Khondoker et al(2017) examine the service provision model in Bangladesh. At the core of the model is the lead farmer, who makes the initial investment in agricultural machinery, and provides services to others on a fee-for-service basis. Considering the agricultural producer service develops rapidly in developing countries, it is necessary to investigate the role of agricultural producer service in agricultural development theoretically.

Development of agricultural producer service aims at rising agricultural productivity and realization of agricultural modernization. Scholars in development economics have broken through the traditional dual economy structure and considered that rural region has two distinctive sectors: traditional agriculture and modern agriculture. Different studies offer various insights to investigate the impacts of the development of modern agriculture, which can be classified into three theoretical strands. The first strand of literature (Chaudhuri,2007; Banerjee and Narayan, 2010; Li and Xu,2016) focuses on the effect of international factor mobility on skilled-unskilled wage inequality, unemployment, and social welfare by incorporating modern agriculture. The second strand of literature (Li and Shen,2012; Li et al,2013; Dong and Li, 2017) concentrates on the effect of development policies of modern agriculture, like wage subsidy, interest rate subsidy, on the economy. The third strand of literature (Li and Wu,2018) centers on the impact of the development of modern agriculture on the environment. Above research assume modern agriculture could employ capital directly while traditional agriculture only uses labor to production. However, under the background of small-scale agriculture, how to development of traditional agriculture or how to employ capital in traditional agriculture are ignored in previous papers.

In order to fill the existing theoretical gap, this chapter develops a static three-sector general equilibrium models with agricultural producer service sector to investigate the effects of an inflow of capital and an increase in the subsidy rate on agricultural development in developing countries. Due to the small-scale agriculture, capital cannot be directly employed by the agricultural sector. Agricultural producer service sector acts as a bridge to connect capital and rural region. In the model, capital mobiles between manufacturing and agricultural producer service sector. And the agricultural sector uses the services as intermediate inputs to substitute labor in production. The main conclusion is that an inflow of capital raises the output of agricultural sector through more available agricultural producer services. However, an increase in subsidy rate of agricultural producer service decreases the output of the agricultural sector.

It is worth mentioning that Murata (2002) also consider agricultural production uses producer service as intermediate inputs. Murata (2002) consider an economy with three sectors: urban intermediate goods sector, urban manufacturing sector and rural agricultural sector. The urban intermediate goods sector supplies varieties of differentiated intermediate goods to other sectors. Murata (2002) assume that manufacturing and agricultural sector use the same intermediate goods. However, the use of intermediate inputs in agricultural sector is vastly different from that in the manufacturing sector, especially in many developing countries. And in this chapter, I assume such agricultural intermediate inputs are sector-specific and highlight the role of the agricultural producer service sector in connecting capital and rural region.

The rest of the chapter is organized as follows. A general equilibrium model is established in Section 2.2 and investigate the effect of an inflow of capital and an increase in subsidy rate on agricultural output in Section 2.3. Concluding remarks are made in Section 2.4.

2.2 The model

Considering a small open developing economy composed of two regions: urban and rural area. The urban region consists of the manufacturing sector, while the rural region has two sectors: agricultural producer service sector and agricultural sector. The manufacturing sector (sector *M*) produces import-competing goods *M* by using skilled labor L_{SM}, unskilled labor L_{UM} and capital K_M. Agricultural producer service sector (sector S) utilizes capital and skilled labor to produce intermediate input for agricultural sector. Agricultural producer service sector provides services to facilitate agricultural production, such as agricultural materials distribution services, agricultural information services,agricultural technology extension services, agricultural machinery operation services. Agricultural sector (sector A) employs unskilled labor and agricultural producer service to production. The price of agricultural goods is set as numeraire.

Manufacturing sector has many competitive firms that produce goods with constant returns to scale technology, and the production function is $M = L_{SM}^{a} L_{UM}^{b} K_{M}^{1-a-b}$, where a and b are parameters in the range $(0,1)$. The cost minimization condition of sector M is:

$$\frac{1}{\Theta} w_S^a \overline{w}^b r^{1-a-b} = p_M \tag{2.1}$$

where w_S is skilled wage rate, $\overline{w}$ is rigid unskilled wage rate in the urban region due to labor union, r is the interest rate. p_M is the price of good M.

$\Theta = a^a b^b (1-a-b)^{1-a-b} > 0$. By Shephard's lemma, demands for skilled labor, unskilled labor and capital are $a\, w_S^{a-1} \overline{w}^b r^{1-a-b} M / \Theta$, $b\, w_S^a \overline{w}^{b-1} r^{1-a-b} M / \Theta$ and $(1-a-b)\, w_S^a \overline{w}^b r^{-a-b} M / \Theta$, respectively.

Agricultural producer service features with increasing returns to scale and the number of firms in this sector is n. A set of n of differentiated agricultural producer service firms competes within a monopolistically competitive market structure. The presence of internal economies of scale implies that each firm specializes in the production of a single variety. In this sector, every variety x_i is produced by the employment of capital and skilled labor. Assume each firm employs θ capital as the fixed cost, and skilled labor is the variable input, with the labor demand by each firm given by $L_{Si} = \beta x_i$, where β denotes the unit labor requirement. Total cost faced by each service firm is $TC_i = \theta r + \beta x_i w_S$.

Due to the shortage of labor and rising wage rate, agricultural sector hires the services from agricultural producer service sector to substitute labor in production.

Define $X = \left(\sum_{i=1}^{n} x_i^{\delta} \right)^{1/\delta}$ and $0 < \delta < 1$,as the index of differentiated intermediate goods in the CES type[1]. Here, I impose two assumptions about agricultural producer service. First, assume the market structure within services is one of Chamberlinian monopolistic competition (Dixit and Stiglitz, 1977). In this framework, the price elasticity of demand for a single service would be $1/(1-\delta)$. Second, I consider a symmetric way, $x_i = x_j = x$. Therefore, $X = n^{1/\delta} x$. As the value of δ goes to 1, the output of firms becomes perfect substitutes for each other, only the total output of agricultural producer service matters. On the other hand, as the δ declines towards 0, the importance of the firm's number becomes more important.

Use p_S to denote the price of a single service, and the equality of marginal cost to marginal revenue implied that

$$\delta p_S = \beta w_S \tag{2.2}$$

The agricultural good is produced by using unskilled labor with wage w and agricultural producer service under the constant-returns-to-scale technology in the rural area. The production function $A = \left[\gamma L_{UA}^{(\sigma-1)/\sigma} + (1-\gamma) X^{(\sigma-1)/\sigma} \right]^{\sigma/(\sigma-1)}$, where $\sigma > 1$ is the elasticity of substitution between unskilled labor and agricultural producer service, $\gamma \in (0,1)$ is the weight of unskilled labor. Under the condition that its market is perfectly competitive, we could obtain

$$\left[(1-\gamma)^{\sigma} (p_S n^{(\delta-1)/\delta})^{1-\sigma} + \gamma^{\sigma} w^{1-\sigma} \right]^{1/(1-\sigma)} = 1 \tag{2.3}$$

By Shephard's lemma, demands for labor and service are $\gamma^{\sigma} w^{-\sigma} A$ and $(1-\gamma)^{\sigma} p_S^{-\sigma} n^{(\delta-1)(1-\sigma)/\delta} A$, respectively.

The manufacturing sector faces an imperfect unskilled labor market because of a rigid high wage $\overline{w}$,which generates unemployment in the urban region.The two

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[1] In this chapter, I treat the agricultural producer service sector exists product differentiation, which is similar with the settings of producer service in manufacturing. Even though agricultural production does not need so many different types of specialized activities, the differentiation service in agricultural production also exhibits similar characteristics with that of manufacturing sector. If the market structure is completely competitive, the main conclusions are intact.

unskilled wage rates are related by the Harris-Todaro (1970) migration equilibrium condition where the expected urban wage equals the rural wage rate. Use $\lambda = L_{UU}/L_{UM}$ to denote the unemployment rate in the urban region. The unskilled labor market equilibrium condition is given by:

$$w(1+\lambda) = \bar{w} \tag{2.4}$$

The equilibrium conditions for skilled labor,unskilled labor, capital are:

$$a\, w_S^{a-1}\bar{w}^b r^{1-a-b} M/\Theta + nx\beta = L_S \tag{2.5}$$

$$(1+\lambda)b\, w_S^a \bar{w}^{b-1} r^{1-a-b} M/\Theta + \gamma^\sigma w^{-\sigma} A = L_U \tag{2.6}$$

$$(1-a-b)\, w_S^a \bar{w}^b r^{-a-b} M/\Theta + n\theta = K \tag{2.7}$$

$$(1-\gamma)^\sigma p_S^{-\sigma} n^{(\delta-1)(1-\sigma)/\delta} A = nx \tag{2.8}$$

where L_S, L_U,and K are the endowment of skilled labor, unskilled labor and capital in the economy.

In the long run, zero profit of sector S condition

$$p_S x(1-\delta) = \theta r(1-s) \tag{2.9}$$

where s is subsidy rate.

The description of the model has been completed. Eqs.(2.1)-(2.9) determine nine endogenous variables, i.e., w_S , w , r, τ , λ , n, x ,M, and A. The endowment of capital K is regarded as a variable affected by exogenous shocks, and a larger of K is interpreted as an inflow of capital. The subsidy rate s is a policy variable.

2.3 Comparative static analysis

Totally differentiate Eqs.(2.1)–(2.9), and obtain the following results in the matrix form

$$\begin{pmatrix} \theta_{AS} & \theta_{AU} & 0 & \theta_{AS}(1-1/\delta) & 0 \\ -\dfrac{1-a-b+a\lambda_{SS}}{1-a-b} & 0 & \lambda_{SM} & \lambda_{SS} & 0 \\ 0 & -\left[1+(\sigma-1)\lambda_{UA}\right] & (1+\lambda)\lambda_{UM} & 0 & \lambda_{UA} \\ \dfrac{a\lambda_{KM}}{1-a-b} & 0 & \lambda_{KM} & \lambda_{KS} & 0 \\ \dfrac{1-b}{1-a-b}-\sigma & 0 & 0 & \dfrac{(\delta-1)(1-\sigma)}{\delta}-1 & 1 \end{pmatrix} \begin{pmatrix} \hat{w}_S \\ \hat{w} \\ \hat{M} \\ \hat{n} \\ \hat{A} \end{pmatrix} = \begin{pmatrix} 0 \\ \lambda_{SS}\dfrac{s}{1-s}\hat{s} \\ 0 \\ \hat{K} \\ -\dfrac{s}{1-s}\hat{s} \end{pmatrix} \tag{2.10}$$

where " $\wedge$ " represents the rate of change(e.g., $\hat{w}_S = dw_S / w_S$), θ_{Ai} (*i*=*S*,*U*) is the distributive share of factor i in the agricultural sector (e.g. $\theta_{AU} = r^{\sigma} w^{1-\sigma}$), λ_{ij} (e.g. $i = S, U, K;\ j = M, S, A$) is the allocated share of factor i in the j th sector. To make the analysis tractable, assuming $\sigma > \max\{(1-b)/(1-a-b), \delta\theta_{AU} / (1-\delta)\theta_{AS}\}$, which means the elasticity of substitution between unskilled labor and agricultural producer service is relatively large. Also assume $\delta > \max\{(1-b)/(2-a-2b), (\sigma-1)/\sigma\}$, which means the external economies is not large in the agricultural producer services sector. Considering the economic reality, assume the share of skilled labor in agricultural producer service is small.

2.3.1 Impacts of an inflow of capital

First investigate the impacts of an inflow of capital on the output of manufacturing and agricultural producer services sector, which can be summarized by Lemma 2.1.

Lemma 2.1 *An inflow of capital brings an expansion of manufacturing sector and agricultural producer services sector.*
Proof: See Appendix 2.1.

An inflow of capital increases the endowment of capital in the economy and the interest rate falls. Manufacturing sector employs more capital and raises marginal productivity of skilled and unskilled labor employed in this sector. Since the price of *M* is constant, the value of marginal product of skilled and unskilled labor rise, which raises the demand for skilled and unskilled labor in the manufacturing sector. Because skilled labor market is perfectly competitive, skilled labor flows into the manufacturing sector. More inputs of three factors expand manufacturing sector and its output raises as a result of an inflow of capital. Regarding the agricultural producer services sector, this faces a lower fixed cost but a less availability of the variable input. A lower fixed cost increases the number of firms in this sector, while less amount of skilled labor reduces each firms output. Due to the rigid wage rate of unskilled labor, the expansion of manufacturing sector could hire unskilled labor at a constant wage rate and this sector could substitute skilled labor with unskilled labor, and the impacts of an inflow of capital on skilled wage rate and each firm′s output in the sector S are limit. Thus, the total output of sector S increases.

Next, I consider the impacts of an inflow of capital on the output of agricultural sector. An inflow of capital raises the demand for unskilled labor in the manufacturing sector and more unskilled labor will transfer to the urban region, which reduces the agricultural output. However, as the result in the Lemma 2.1, an increase in capital also promote the agricultural producer services sector and the output of this sector could substitute unskilled labor in production. Therefore, when rural labor transfers into the urban region, agricultural output may not reduce.

Proposition 2.1 *An inflow of capital will raise the output of agricultural sector through more available agricultural producer services.*
Proof: See Appendix 2.1.

2.3.2 Impacts of an increase in the subsidy rate

In this section, I first analyze the impacts of an increase in the subsidy rate of agricultural producer service on the output of manufacturing and agricultural producer services sector, which can be summarized by Lemma 2.2.

Lemma 2.2 *An increase in subsidy rate leads to an expansion of manufacturing sector and a reduction of agricultural producer services sector.*
Proof: See Appendix 2.2.

Intuitively, an increase in subsidy rate reduces the fixed cost of firms in the agricultural producer services sector and raises its output. When incorporating manufacturing and rural-urban migration,such a result is not stable. An increase in subsidy rate reduces the fixed cost and more firms exist in the agricultural producer services sector. Capital mobiles from manufacturing sector into agricultural producer services sector. An outflow of capital decreases the marginal productivity of skilled and unskilled labor employed in this sector. Since the price of M is constant, the value of marginal product of skilled and unskilled labor fall, which reduces the demand for skilled and unskilled labor in the manufacturing sector. More unskilled labor employs in the agricultural sector and decreases the demand for agricultural producer services, which decreases its price and each firm′s output. And the number of firms and sectoral output decrease at last. Capital and skilled labor move from agricultural producer services sector into manufacturing sector, which raises the marginal productivity of unskilled labor employed in this sector. Unskilled labor also transfers into the manufacturing sector and raises its output.

Next, I consider the impacts of an increase in subsidy rate on the output of agricultural sector. From Lemma 2.2, an increase in subsidy rate makes unskilled labor transfer into manufacturing sector and reduces the output of agricultural producer services sector. Therefore, an increase in subsidy rate reduces agricultural inputs and its output.

Proposition 2.2 *An increase in subsidy rate will decrease the agricultural sector.*

The policy aims to raise agricultural output, however, an opposite result appears. An inflow of capital and an increase in subsidy rate reduce the fixed cost of agricultural producer service. However, an inflow of capital enlarges the employment of manufacturing sector and promotes agricultural unskilled labor to transfer into manufacturing sector. While an increase in subsidy rate reduces the demand for unskilled labor in manufacturing sector initially and falls the demand for agricultural producer service.The agricultural sector uses relatively cheap unskilled labor to substitute agricultural producer service, which harms rural-urban migration. A decrease in demand for agricultural producer service makes capital and unskilled outflow into manufacturing sector and reduces agricultural output.

2.4.Conclusion

Under the background of small-scale agriculture, I consider the agricultural producer service sector in developing countries in this chapter. Due to small-scale production, capital cannot enter into agricultural production. And agricultural producer service sector acts as a bridge to connect capital and rural region. In the model, capital could mobile between manufacturing sector and agricultural producer service sector. Agricultural sector utilizes the output of agricultural service sector and unskilled labor to production. The main conclusion is that an inflow of capital raises the output of agricultural sector through more available agricultural producer services. However, an increase in subsidy rate of agricultural producer service decreases the output of agricultural sector.

Further research can possibly extend the analysis in the following two respects. Firstly, this chapter considers capital mobiles between manufacturing and agricultural service sector and agricultural service sector provides modern agricultural inputs in agricultural production. Since the equipment in agricultural producer service sector is output of manufacturing sector, new sector could be introduced into the model, which provides intermediate inputs to agricultural producer service. Secondly, due to the shortage of rural labor and the increasing wage rate, agricultural producer service develops. A static general equilibrium model cannot describe the dynamic process: along with the increasing wage rate and rural-urban migration, the agricultural producer service sector becomes larger and larger and substitutes more and more labor in agricultural production.

Appendix 2.1

Denote the determinant of the coefficient matrix of Eq. (10) as Δ,

$$\Delta=(\lambda_{SM}\lambda_{KS}-\lambda_{SS}\lambda_{KM})\left\{\theta\left[(1+\lambda)\lambda_{UM}+\sigma\lambda_{UA}\right]+\theta_{AU}\lambda_{UA}\left(\sigma-\frac{1-b}{1-a-b}\right)\right\}+$$
$$\theta_{AU}(1+\lambda)\lambda_{UM}\left[\lambda_{KS}\left(\lambda_{SM}+\lambda_{SS}\frac{1-b}{1-a-b}\right)+\lambda_{SS}\frac{a\lambda_{KM}}{1-a-b}\right]$$
$$+\left\{\theta_{AU}\lambda_{UA}\frac{(\delta-1)(1-\sigma)-\delta}{\delta}+\theta_{AS}\frac{1-\delta}{\delta}\left[(1+\lambda)\lambda_{UM}+\sigma\lambda_{UA}\right]\right\}\left[\lambda_{SM}\left(\lambda_{SM}+\lambda_{SS}\frac{1-b}{1-a-b}\right)+\lambda_{SM}\frac{a\lambda_{KM}}{1-a-b}\right]$$

Under the assumption, $\Delta>0$. Using the Cramer's rule to solve Eq. (10) with respect to $\hat{K}$, we get following results:

$$\Delta\frac{\hat{w}_S}{\hat{K}}=\theta_{AU}\left[\lambda_{SM}\lambda_{UA}\frac{(\delta-1)(1-\sigma)-\delta}{\delta}+\lambda_{SS}(1+\lambda)\lambda_{UM}\right]-\lambda_{SM}\theta_{AS}\frac{(\delta-1)}{\delta}\left[(1+\lambda)\lambda_{UM}+\sigma\lambda_{UA}\right]>0$$

$$\Delta\frac{\hat{w}}{\hat{K}}=\theta_{AS}\left\{\begin{array}{l}-\lambda_{SM}\lambda_{UA}\dfrac{(\delta-1)(1-\sigma)-\delta}{\delta}-\lambda_{SS}(1+\lambda)\lambda_{UM}+\\ \left(1-\dfrac{1}{\delta}\right)\left[\lambda_{SM}\lambda_{UA}\left(\dfrac{1-b}{1-a-b}-\sigma\right)-(1+\lambda)\lambda_{UM}\left(\lambda_{SM}+\lambda_{SS}\dfrac{1-b}{1-a-b}\right)\right]\end{array}\right\}>0$$

$$\Delta\frac{\hat{M}}{\hat{K}}=\left(1+\frac{a\lambda_{SS}}{1-a-b}\right)\frac{(1-\delta)}{\delta}\left[\theta_{AU}\lambda_{UA}(\sigma-1)+\theta_{AS}(1+\lambda)\lambda_{UM}+\theta_{AS}\sigma\lambda_{UA}\right],$$
$$-\lambda_{SM}\theta_{AU}\lambda_{UA}-\lambda_{SS}\left[\theta_{AS}(1+\lambda)\lambda_{UM}+\sigma\lambda_{UA}\right]$$

$$\Delta\frac{\hat{n}}{\hat{K}}=\lambda_{SM}\left[(1+\lambda)\lambda_{UM}+\sigma\lambda_{UA}\right]+\theta_{AU}\frac{1-b}{1-a-b}\left[\lambda_{SS}(1+\lambda)\lambda_{UM}-\lambda_{SM}\lambda_{UA}\right]>0$$

$$\Delta\frac{\hat{A}}{\hat{K}}=\left(1-\frac{a}{1-a-b}\frac{1-\delta}{\delta}\right)\left\{\lambda_{SM}\theta_{AS}\left[(1+\lambda)\lambda_{UM}+\sigma\lambda_{UA}\right]+(1+\lambda)\lambda_{UM}\theta_{AU}\lambda_{SS}\left(\sigma-1\right)\right\}$$

$$+\theta_{AU}(1+\lambda)\lambda_{UM}\left[1-\frac{\left(1-\delta\right)\left(\sigma-1\right)}{\delta}\right]>0$$

and

$$\Delta\frac{\hat{n}+\hat{x}}{\hat{K}}=\lambda_{SM}\left[(1+\lambda)\lambda_{UM}+\sigma\lambda_{UA}\right]-\lambda_{SM}\frac{1-b}{1-a-b}\frac{1-\delta}{\delta}\left[\theta_{AS}(1+\lambda)\lambda_{UM}+(\sigma-\theta_{AU})\lambda_{UA}\right]>0$$

Appendix 2.2

Using the Cramer's rule to solve Eq. (10) with respect to $\hat{s}$,

$$\Delta\frac{\hat{w}_S}{\hat{s}}=\frac{s}{1-s}\left\{\lambda_{KS}\theta_{AU}[\lambda_{SM}-(1+\lambda)\lambda_{UM}]+\lambda_{KM}\lambda_{SS}\frac{1-\delta}{\delta}\left[\lambda_{UA}(1-\sigma)-\theta_{AS}\right]\right\}$$

$$\Delta\frac{\hat{w}}{\hat{s}}=\frac{s}{1-s}\theta_{AS}\left\{(\lambda_{SS}-\lambda_{UA})\left[\lambda_{KS}+\lambda_{KM}\frac{1-\delta}{\delta}\frac{a}{1-a-b}\right]-\lambda_{KM}\lambda_{UA}\frac{1-\delta}{\delta}\right\}<0$$

$$\Delta\frac{\hat{M}}{\hat{s}}=\lambda_{KS}\frac{s}{1-s}\left\{\theta_{AS}\lambda_{SS}\left[(1+\lambda)\lambda_{UM}+\sigma\lambda_{UA}\right]+\theta_{AU}\lambda_{UA}\left(\lambda_{SM}+\sigma\lambda_{SS}\right)\right\}$$

$$+\lambda_{SS}\frac{s}{1-s}\frac{a\lambda_{KM}}{1-a-b}\frac{(1-\delta)}{\delta}\left[\lambda_{UA}\left(\sigma-1\right)+\theta_{AS}\right]>0$$

$$\Delta\frac{\hat{n}}{\hat{s}}=-\lambda_{KM}\frac{s}{1-s}\left\{\theta_{AS}\lambda_{SS}\left[(1+\lambda)\lambda_{UM}+\sigma\lambda_{UA}\right]+\theta_{AU}\left[\lambda_{SM}\lambda_{UA}+\frac{a}{1-a-b}(\lambda_{UA}-\lambda_{SS})+\sigma\lambda_{UA}\lambda_{SS}\right]\right\}<0$$

and

$$\Delta\frac{\hat{A}}{\hat{s}}=-\frac{s}{1-s}\left\{\begin{array}{l}\theta_{AS}\left[(1+\lambda)\lambda_{UM}+\sigma\lambda_{UA}\right]\left[\lambda_{SM}\lambda_{KS}+\lambda_{KM}\frac{1-\delta}{\delta}\left(1+\frac{a\lambda_{SM}}{1-a-b}\right)\right]+\\(1+\lambda)\lambda_{UM}\theta_{AU}\left[\left(\lambda_{SM}+\sigma\lambda_{SS}\right)\lambda_{KS}+\lambda_{SS}\frac{(1-\delta)(\sigma-1)}{\delta}\frac{a\lambda_{KM}}{1-a-b}\right]\end{array}\right\}<0$$

Chapter 3

Internal Remittances, Vocational Training Costs and Rural-Urban Migration in Developing Countries

This chapter develops a three-sector general equilibrium model to examine the consequences of an increase in vocational training costs on internal remittances in a small open dual economy. Using indirect utility functions, the chapter endogenizes the internal remittances. The theoretical analysis shows that an increase in vocational training cost of the manufacturing sector decreases internal remittances and the proportion of remittances in migrants' income. In addition, an increase in per capita training cost also contributes to expanding the informal sector and contracting the agricultural sector.

3.1 Introduction

Internal migration in general and rural-urban migration in particular are often viewed as the labor market adjustment to the inter-sectoral shift in importance from agriculture to manufacturing and services. This phenomenon has historically been a significant factor for economic structural changes in developed countries, while many developing countries are experiencing the same process currently, especially in countries with a large population. Take China and India for example. According to China's recent national statistics, rural migrants have increased from 229.78 million in 2009 to 281.71 million in 2016.[1]From the Census of India 2011, rural migrants are nearly 400 million, comprising a third of India's population. One of the most conspicuous effects of internal migration is the huge flow of remittances within the country.[2]There are no accurate statistics on the total amount of internal remittances, but a rough estimate can be made. Based on national statistics, the estimation for China shows that the internal remittances are near one trillion RMB (around 160 billion US dollars) in 2013 (Li and Wang, 2015). A survey conducted by National Sample Survey Organization shows around 58% of the domestic migrants send

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[1] National Bureau of Statistics of PRC, National Monitoring Survey Report of Rural-Urban Migrant Workers from 2009 to 2016

[2] Different with internal remittances ,external remittances or international remittances has captured lots of attention to development economists. The latest figure on external remittances is above US $441 billion, nearly three times the amount of official development assistance(World Bank, 2016b).

money home with an average remittance size of INR 13,000 (about 200 US dollars) in a year in India in 2008.[3] Moreover, internal remittances could transfer in various forms and actual internal remittances would probably be much larger than the estimated figure.[4]For example, the internal remittances market in India is dominated by the unorganized or informal channels of money transfer in 2008, which together accounted for 70.0% of the remittances.[5] The remittances sent by migrants play a significant role in rural development in developing countries. Internal remittances, comprising 20% to 50% of total family income in the receiving household, are crucial to paying for household expenses in China (Cheng and Xu, 2005). In India, internal remittances financed over 30% of household consumption expenditure and 80% went to rural households (Tumbe, 2011). In addition, remittances are safety funds for relatively poor areas, as they are freer from political barriers and controls than either products or other capital flows in developing countries.

Migrants' income, which is significantly affected by their human capital level, determines the capacity of remittances. Due to the backward education system in rural regions, migrants' human capital level is much lower than their counterparts in the urban. Thus, the poor education migrants have received and the low skills they possess have seriously hurdled their way into the urban manufacturing sector. Generally, offering basic education in regular schools before employment and developing skill through vocational training are main approaches for human capital accumulation. Thus, after transferring to an urban region, vocational training is the main approach to increase their human capital through "learning by doing." On the one hand, through vocational training, migrants could grasp industry-based and professional competencies to meet skill requirements in a short period, which bring better employment opportunities for them. On the other hand, industries could hire technical workers to handle new equipment. Therefore, government and firms make endeavors to overcome the shortcomings of the education system by offering

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[3] See http://catalog.ihsn.org/index.php/catalog/1907

[4] Even though the total amount of internal remittances is difficult to account, some scholar use survey data to analyze the impacts of internal remittances. McKay and Deshingkar(2014) examined secondary data from household surveys for six countries in Africa and Asia (Nigeria, Rwanda, South Africa,Uganda, Bangladesh and Vietnam), and showed the significance of internal remittances. And internal remittances flow to a larger number of receiving households, mainly in poor rural areas. Binci and Giannelli (2016) consider the impacts of internal and international remittances on child labor and schooling in Vietnam. Randazzo and Piracha (2018) consider remittances and household expenditure behavior in Senegal.

[5] See https://www.kenresearch.com/banking-financial-services-and-insurance/financial-services/india-domestic-remittance-market-research-report/474-93.html

vocational training.[6] Vocational training also incurs costs. In developed countries, these are borne jointly by firms, individuals and the state. While in developing countries, a larger proportion is born by the state and firms to stimulate the participation of eligible workers[7]. Under the background of industries upgrading and economic structural adjustment, it is obvious that the per capita cost of vocational training increases even though objective calculation of the costs of vocational training faces considerable difficulties. Consequently, firms with capable of workforce and modern equipment employ less workforce, particularly in labor-intensive sectors where capital substitutes for less skilled labor. At the aggregate level, this change also induces a changing demand for labor, demanding higher-quality labor rather than a higher number of employees.

In studies of the vocational training cost under the framework of internal migration, Djajic (1985) considered all individuals are born with identical ability and some choose to acquire skills which require finances while others remain unskilled. He examined the link between the minimum wage and unemployment in the context of an open-economy model. Samanta (2003) extended the Harris and Todaro model with the assumption that urban firms provide training to the workers and analyzed the economic effects of the training of urban sector employees. Li and Zhou (2013b) considered the situation where rural labor could enter into the producer services sector only by means of vocational training, and they investigated the environmental impacts of a change in training cost. However, the existing literature on training cost fails to consider the issue of internal remittances, and thus fails to investigate the effect of a change in training cost on internal remittances.

Massive remittances have motivated great interest in economists; however, most of the attention was paid to international remittances; internal remittances have received attention only recently and most papers on internal remittances concentrate

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[6] With the transformation and upgrading of China's industrial structure, the Chinese government released "Decision on Accelerating the Development of Modern Vocational Education" to promote the development of vocational education. According to the Decision, it is estimated that "by 2020, there will be 23.5 million students receiving secondary vocational education, 14.8 million students receiving vocational education at college level, and the number of students receiving vocational education at university level will also reach a certain scale. The number of practitioners receiving continuing education will hit 350 million." Government of Pakistan published The Vision 2025, which is a long-term strategic road map for the country's sustainable socioeconomic development, has six core objectives, all of which are closely linked to vocational training. Government of India set up the National Mission for Skills to create a larger skilled workforce and announced a centrally-sponsored program to upgrade all industrial training institutes (ITIs).

[7] In developing countries, the expensive training fee is beyond most workers' reach. In addition, a majority of workers hold that they should bear a fraction of the training fee.

on two aspects empirically: their determinants (Niimi et al,2009; Brauw and Mueller,2013) and effects (Adams, 2010; Mueller and Shariff, 2011; Adams, 2013). Nevertheless, theoretical research has been sparse in this field. Li and Zhou (2013a) investigated the impact exerted by a change in the remittances rate of the unskilled migrants on the wage inequality in the labor host region and found that an increase in their remittances rate decrease wage inequality in the labor host region. Li and Zhou (2015) considered a model that incorporates natural environment and remittances: urban manufacturing sector absorbs rural-urban migrants and generates pollution, and agricultural production depends on environmental factors. Under the model, they analyzed the short-term and long-term impacts of an increase in remittances of migrants on the environment with the model and arrived that the increase of migrant remittance can improve the environment in the short term but worsen the environment in the long run. Li and Wang (2015) considered the economic impact of migrants' remittances on the labor host regions from the short- and long-term perspectives and concluded that an increase in remittances will reduce the output of the informal sector and decrease urban residents' welfare in the short term, while it has opposite effects in the long term. Unfortunately, the existing literature treated internal remittances as an exogenous variable and analyzed their effects on economy and environment. Nevertheless, different from international remittances, which are largely determined without one economy, the internal remittances are determined within one economy and influenced by many factors of migrants. Training cost affects the employment of rural workers and their income, which further exerts an impact on internal remittances. However, the existing literature on internal remittances neglects to consider the issue of training cost in manufacturing, and thus fails to investigate the effect of a change in training cost on internal remittances.

In order to fill the current research gap, this chapter tries to integrate vocational training cost and internal remittances into a unified framework of labor migration. The economic intuition of this chapter can be briefly described as follows: an increase in per capita cost of vocational training in manufacturing sector will reduce the amount of employment, which further changes the employment of informal and agricultural sector. On the one hand, migrants' income and urban consumption also change consequently, which affects the capacity of internal remittances. On the other hand, rural income varies as a result of a change of employment in the agricultural sector. Rural income affects its utility, which further changes the remittances under the assumption that migrants remit for purely altruistic reasons. Combining the above two aspects, we can arrive at how vocational training cost exerts impacts on internal remittances in developing countries.

Thus, this chapter establishes a three-sector general equilibrium model and tries to analyze how a change of per capita vocational training cost affects internal remittances in developing countries. In the model, we find that an increase of per capita cost of vocational training will reduce the internal remittances and the proportion of remittances in migrants' income. In addition, an increase in per capita training cost also contributes to expanding the informal sector and contracting the agricultural sector. The rest of this chapter is organized as follows. The model is provided in Section 3.2. Section 3.3 examines the impacts of a change of per capita training cost on remittances. Section 3.4 makes some conclusions.

3.2 Theoretical model

The article considers a small, open, developing economy with three sectors: an urban formal manufacturing sector (sector 1), an urban informal sector (sector 2) and a rural agricultural sector (sector 3). The urban informal sector refers to the urban small-service sector. Products from the informal sector cannot transport and consumption is confined to local residents. Since such service products are rare in a rural area, the chapter assumes the informal sector provides domestic services to urban residents only[8]. The manufacturing sector and the agricultural sector produce traded goods, while the informal sector produces non-traded goods. Prefect competition is assumed to prevail in the economy. The manufacturing sector and the informal sector only use labor to produce goods, while the agricultural sector relies on labor and land. The wage of the urban manufacturer is inelastic, but wages of agriculture and informal sector are elastic.

In developing countries, the urban labor market is segmented between migrants and non-migrants, and there is little competition between them, and non-migrants have a huge advantage in the market (Knight et al, 1999;Meng and Zhang, 2001). To simplify the analysis, the chapter assumes that urban labor holds employment in the manufacturing sector constantly and only rural labor experiences the change of

[8] The informal sector is largely characterized by several qualities: easy entry, a lack of stable employer-employee relationships, a small scale of operations. Included in this sector are newsstand owners, street vendors, shoeshine boys, and so forth. See the theoretical studies of informal by Gupta(1997), Kar and Marjit (2001), etc.

employment in different sectors[9]. Since rural migrants' human capital level lags behind urban counterparts, the manufacturing sector would invest in the employees' skills to meet the requirements. We assume the training cost of each labor is h in the manufacturing, and firms in manufacturing bear the cost of vocational training alone.[10] $q(h)$ expresses the efficiency of each migrant after vocational training, that is, the minimum per capita human capital level needed by the manufacturing sector. $q(h)$ satisfies the conditions $q(0) = 1, q'(h) > 0$ and $q''(h) < 0$. Production functions for each sector are:

$$X_1 = F^1(\overline{L}_1, q(h)L_1)$$

$$X_2 = F^2(\overline{L}_2 + L_2)$$

$$X_3 = k(\beta)F^3(L_3, T)$$

where F^i (i = 1, 2, 3) means the production function of the three sectors, all are strictly quasi-concave, linearly homogeneous function. Note, urban labor and transferred migrants are not perfect substitution in the manufacturing sector. $\overline{L}_i (i = 1,2)$ is employment of urban citizens in sector i. $L_i (i = 1,2,3)$ is the rural labor employed in sector i. T is land employed in the agricultural sector. β is the remittances sent by migrants. Assume that remittances have a positive effect on agricultural production, use k to denote the impact. And $k(\beta)$ has the property that: $k(0) = 1$, $k'(\beta) > 0$, $k''(\beta) = 0$.

Profit maximization of three sector yields:

$$q(h) p_1 F_L^1(\overline{L}_1, q(h)L_1) = h + \overline{w} \tag{3.1}$$

$$p_2 F_L^2(\overline{L}_2 + L_2) = w_2 \tag{3.2}$$

$$k(\beta) F_L^3(L_3, T) = w_3 \tag{3.3}$$

where $F_L^i = \partial F^i / \partial L_i > 0 (i = 1,2,3)$ are the marginal products of labor in respective sectors. $\overline{w}$ is the wage level of the manufacturing sector, while w_2 and w_3 refer to the wage levels of informal and agricultural sectors. In the model, the price of agricultural goods is assumed as 1, and $p_i (i = 1,2)$ is the price of the goods in sector i relative to that of agricultural goods.

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[9] Note that urban labors in the manufacturing and informal sector are different and they hold their employment due to their priority in the labor market.

[10] In general, firms and the government mainly bear the training cost in developing countries. Government pays the cost by tax revenue. Here, to simply the analysis, we assume firms offer necessary funds for the training alone.

Rural labor market-clearing condition could be shown as follows:

$$L_1 + L_2 + L_3 = L_R \tag{3.4}$$

where L_R is rural labor endowment. The rural labor allocation mechanism in sectors yields:

$$w_3 = \frac{L_1}{L_1 + L_2}\bar{w} + \frac{L_2}{L_1 + L_2} w_2 \tag{3.5}$$

where $L_1/(L_1 + L_2)$ and $L_2/(L_1 + L_2)$ are the probability of migrants to be employed by the manufacturing sector and informal sector, respectively.

The following considers the consumption. There are three types of labor: urban labor, rural migrants and rural labor. The representative labor who is an urban citizen has utility function $U^U(D_1^U, D_2^U, D_3^U) = \alpha_1^U \ln D_1^U + \alpha_2^U \ln D_2^U + \alpha_3^U \ln D_3^U$, where D_1^U, D_2^U and D_3^U denote the consumption of goods of the manufacturing sector, informal sector and agricultural sector, respectively; α_1^U, α_2^U and α_3^U are all positive parameters, and $\alpha_1^U + \alpha_2^U + \alpha_3^U = 1$. Income of urban labor y_U is expressed by $y_U \equiv p_1 X_1 + p_2 X_2 - L_1(h + \bar{w}) - w_2 L_2$, which means income deducts the training cost and migrants' income[11]. By solving utility maximization problem, subject to the budget constraint: $p_1 D_1^U + p_2 D_2^U + D_3^U = y_U$, we have indirect utility $V^U(p_1, p_2, 1, y_U) = \sum_{i=1}^{3} \alpha_i^U \ln \alpha_i^U + \ln y_U - \alpha_1^U \ln p_1 - \alpha_2^U \ln p_2$. The representative labor who is a rural migrant has utility function $U^T(D_1^T, D_2^T, D_3^T) = \alpha_1^T \ln D_1^T + \alpha_2^T \ln D_2^T + \alpha_3^T \ln D_3^T$, where D_1^T, D_2^T and D_3^T denote the consumption of goods of the manufacturing sector, informal sector and agricultural sector, respectively; α_1^T, α_2^T and α_3^T are all positive parameters, and $\alpha_1^T + \alpha_2^T + \alpha_3^T = 1$. Disposable income of migrants y_T is expressed by $y_T \equiv \bar{w} L_1 + w_2 L_2 - \beta$, which means income subtracts the internal remittances. From budget constraint $p_1 D_1^T + p_2 D_2^T + D_3^T = y_T$, we can arrive the corresponding indirect utility of migrants $V^T(p_1, p_2, 1, y_T) = \sum_{i=1}^{3} \alpha_i^T \ln \alpha_i^T + \ln y_T - \alpha_1^T \ln p_1 - \alpha_2^T \ln p_2$. The

[11] The revenue of urban labor is $y_U \equiv \bar{L}_1 \bar{w} + w_2 \bar{L}_2$. Using production function of manufacturing and informal sector, $p_1 X_1 = \bar{L}_1 \bar{w} + (h + \bar{w}) L_1$ and $p_2 X_2 = w_2 \bar{L}_2 + w_2 L_2$. Thus,we can find that $y_U \equiv p_1 X_1 + p_2 X_2 - L_1(h + \bar{w}) - w_2 L_2$.

representative labor who is a rural labor has utility function $U^A(D_1^A, D_3^A) = \alpha_1^A \ln D_1^A + \alpha_3^A \ln D_3^A$, where D_1^A and D_3^A denote the consumption of goods of the manufacturing sector and agricultural sector. α_1^A and α_3^A are positive parameters, and $\alpha_1^A + \alpha_3^A = 1$. Disposable income of rural labor is $y_A \equiv kF^3$ and budget constraint is $p_1 D_1^A + D_3^A = y_A$. The indirect utility is $V^A(p_1, 1, y_A) = \alpha_1^A \ln \alpha_1^A + \alpha_3^A \ln \alpha_3^A + \ln y_A - \alpha_1^A \ln p_1$.

As to the consumption of informal goods, urban labor and rural migrants spend α_2^U and α_2^T parts of disposable income on consumption of informal sector goods, respectively. Informal goods market-clearing condition can be demonstrated by:

$$p_2 X_2 = D_2^U + D_2^T = \alpha_2^U y_U + \alpha_2^T y_T \tag{3.6}$$

Remittances affect labor's income and utility, therefore, the flow of remittances changes the utility of migrants and rural labors.The chapter assumes that migrants remit for purely altruistic reasons in order to increase the utility of rural household by providing additional assistance. Consequently, the welfare of migrants consists of two parts: their own utility and their rural household's utility.The weight of own utility is $\theta (0 < \theta < 1)$, while the weight of rural household is $1-\theta$.Thus, the welfare of migrants V^{TR} is the weighted average of two items: $V^{TR} = \theta V^T + (1-\theta)V^A$. Migrants choose an amount of remittances to maximize their welfare and derives,

$$\frac{\theta}{L_1 \overline{w} + L_2 w_2 - \beta} = \frac{(1-\theta)k'}{k} \tag{3.7}$$

The theoretical model thus consists of seven equations: (3.1)–(3.7). Endogenous variables are determined: L_1, L_2, L_3, w_2, w_3, p_2 and β.

3.3 Comparative statics

This section focuses on the economic effects of an increase in per capita vocational training cost on internal remittances based on the established model. Total differentiation of equations (3.1) to (3.7), and reorganize these equations into the following matrix notation[12],

$$\begin{pmatrix} -kF_{LL}^3 & 0 & -1 & k'F_L^3 \\ w_3 - w_2 & -L_2 & L_1 + L_2 & 0 \\ (1-\alpha_2^T)w_2 & \Omega_0 & 0 & \alpha_2^T \\ (1-\theta)w_2 & (1-\theta)L_2 & 0 & -1 \end{pmatrix} \begin{pmatrix} dL_2 \\ dw_2 \\ dw_3 \\ d\beta \end{pmatrix} = \begin{pmatrix} \Omega_2 kF_{LL}^3 \\ \Omega_2(\overline{w} - w_3) \\ \Omega_1 \\ -(1-\theta)\overline{w}\Omega_2 \end{pmatrix} dh \tag{3.8}$$

where $F_{LL}^3 = \partial^2 F^3 / \partial L_3^2 < 0$, $\Omega_0 = (1-\alpha_2^U)\overline{L}_2 + (1-\alpha_2^T)L_2 > 0$, $\Omega_1 = \alpha_2^T \overline{w}\Omega_2 + \alpha_2^U L_1(p_1 q' F_L^1 - 1)$, and $\Omega_2 = [1 - p_1 q'(F_L^1 + qF_{LL}^1 L_1)]/q^2 p_1 F_{LL}^1$. Before we make the analysis, we need to determine the sign of Ω_1 and Ω_2, which are related with the training cost elasticity of *q*. Denote $\varepsilon_h = hq'/q$ as training cost elasticity of *q*.

Assumption: $\varepsilon_h < h/(h+\overline{w})$ holds.

From the assumption, we have $\Omega_1 < 0$ and $\Omega_2 < 0$. The determinant of the coefficient matrix of the equation(3.8) is denoted as Δ,

$$\Delta = \overline{L}_2(1-\alpha_2^U)\left\{w_3 - w_2 + (L_1+L_2)[k'F_L^3 w_2(1-\theta) - kF_{LL}^3]\right\} + L_2(1-\alpha_2^T\theta)[w_3 - kF_{LL}^3(L_1+L_2)] > 0$$

Next, we consider an increase in the per capita training cost on employment of rural labor among three sectors. From equation(3.1), we obtain that an increase in the per capita training cost will reduce the employment of migrants in the manufacturing sector. However, the distribution of the reduced workforce between informal and agricultural sector is unclear. We use Lemma 3.1 to describe the impacts of an increase in per capita training cost on employment of rural labor in the informal and agricultural sector.

Lemma 3.1 An increase in per capita training cost reduces agricultural employment and increases employment of migrants in the informal sector if $\dfrac{\overline{w}L_1 + w_2 L_2}{\beta}(1-\theta) > \dfrac{1}{\varepsilon_\beta}$,

where $\varepsilon_\beta = k'\beta/k$ denotes remittances elasticity of agriculture production.

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[12] The model can be decomposed. Totally differentiate equation(1), we can get the relationship between *h* and L_1; from equation(2), we get the relationship between p_2 and w_2. Since L_1 is determined in equation(1), from equation(4), we can get the relationship between L_2 and L_3. Put three results of total differentiation in equation(1),(2) and (4) into the other four differentiation results, we can obtain equation(8).

Proof

From equation(3.1) and (3.5), we obtain $\frac{dL_1}{dh}+\frac{dL_2}{dh}=-\frac{dL_3}{dh}$ and $\frac{dL_1}{dh}=\Omega_2$. Using Cramer's rule in equation(3.8),

$$\frac{dL_2}{dh}=\left\{\begin{array}{l}\Omega_2[(1-\alpha_2^U)\overline{L}_2+L_2(1-\alpha_2^T\theta)]\left\{\overline{w}-w_3+(L_1+L_2)[kF_{LL}^3-(1-\theta)\overline{w}k'F_L^3]\right\} \\ -L_2[(1-\theta)k'F_L^3(L_1+L_2)-1][\theta\overline{w}\Omega_2+\alpha_2^U L_1(p_1q'F_L^1-1)]\end{array}\right\}\Big/\Delta$$

Thus, we have

$$\frac{dL_3}{dh}=[(1-\theta)k'F_L^3(L_1+L_2)-1]\left[(\overline{w}-w_2)\Omega_2\Omega_0+w_2L_2\Omega_2-\alpha_2^U(L_1+\overline{L}_1)L_2\right]\Big/\Delta$$

If $\frac{\overline{w}L_1+w_2L_2}{\beta}(1-\theta)>\frac{1}{\varepsilon_\beta}$, we have $(1-\theta)k'F_L^3(L_1+L_2)>1$ and further we get $\frac{dL_2}{dh}>0$ and $\frac{dL_3}{dh}<0$.

The condition in the Lemma 1 $\frac{\overline{w}L_1+w_2L_2}{\beta}(1-\theta)>\frac{1}{\varepsilon_\beta}$ is made from the mathematical point of view, which may satisfy the real-world situation. In developing countries with the backward agricultural sector, agriculture is a lack of funds and a marginal increase in funds promotes agricultural production in a relatively large magnitude, thus the elasticity is likely greater than 1 and the right side of the inequality is likely lower than 1. To the left side of inequality, migrants send parts of their income back and $\left(\overline{w}L_1+w_2L_2\right)/\beta>1$;since migrants have much connection between rural household,$1-\theta$ may much larger than 0.[13]Therefore, the left side of inequality may be larger than 1. From the discussion, it is reasonable to hold that the condition has wide representation in the real-world situation.

Next, we consider an increase in the per capita training cost on other economic variables. We show the result by solving equation (3.8),

$$\frac{dw_2}{dh}=\left\{\begin{array}{l}[w_3-w_2-kF_{LL}^3(L_1+L_2)+(1-\theta)w_2k'F_L^3(L_1+L_2)][\alpha_2^U L_1(p_1q'F_L^1-1)+ \\ \Omega_2w_2(1-\alpha_2^T)+\Omega_2\theta\overline{w}\alpha_2^T]-w_2(1-\alpha_2^T\theta)\Omega_2(\overline{w}-w_2)[1-(1-\theta)k'F_L^3(L_1+L_2)]\end{array}\right\}\Big/\Delta<0$$

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[13] Since rural-urban migrants are mostly employed in dirty, dangerous and poorly paid occupations, most of them leave their family members, especially children, in rural areas. From the National Monitoring Survey Report of Rural-Urban Migrant Workers in 2015,only 21% of the rural–urban migration was family migration. In such situations, migrants spent on consumption prudently and remitted sizable percentages of their income. Also from the Report in 2015, rural-urban migrants' average income was 3359 yuan per month, and their average monthly expenditure only 1012 yuan.

$$\frac{dw_3}{dh} = -k'F_L^3(1-\theta)w_3[\Omega_0\Omega_2(w_2-\overline{w}) - \Omega_1 L_2 - L_2(1-\alpha_2^T)w_2\Omega_2]$$
$$-kF_{LL}^3\left\{-L_2[\alpha_2^U L_1(p_1 q' F_L^1 - 1) + w_2\Omega_2 + \theta\alpha_2^T\Omega_2(\overline{w}-w_2)] - \Omega_2(\overline{w}-w_2)[\Omega_0 + (1-\theta)L_2\alpha_2^T]\right\} < 0$$

and

$$\frac{d\beta}{dh} = -(1-\theta)[w_3 - kF_{LL}^3(L_1+L_2)]\left[\Omega_2\Omega_0(w_2-\overline{w}) - \Omega_1 L_2 - w_2(1-\alpha_2^T)L_2\Omega_2\right]/\Delta < 0$$

From above results, we further obtain $dp_2/dh < 0$ from equation(3.2). An increase in the per capita training cost will change the income and the consumption of migrants, which affect the proportion of remittances in migrants' income. In view of the results, we can establish the following results:

$$\frac{dy_T}{dh} = \left(\begin{array}{l}[w_3 - kF_{LL}^3(L_1+L_2)][\Omega_2\overline{w}L_2(1-\alpha_2^T) + \Omega_2(\overline{w}-w_2)\overline{L}_2(1-\alpha_2^U) + \Omega_1 L_2 \\ +(1-\theta)\Omega_2\overline{w}\Omega_0(\overline{w}-w_2) + (1-\theta)\Omega_1 L_2 + (1-\theta)(1-\alpha_2^T)w_2\Omega_2 L_2]\end{array}\right)\Big/\Delta < 0$$

and

$$\frac{d\left(\beta/(\overline{w}L_1 + w_2L_2)\right)}{dh} =$$
$$\frac{[kF_{LL}^3(L_1+L_2) - w_3]\left\{\begin{array}{l}(1-\theta)(\overline{w}L_1 + w_2L_2)[\Omega_2\Omega_0(w_2-\overline{w}) - \Omega_1 L_2 - (1-\alpha_2^T)w_2\Omega_2 L_2] + \\ \beta[\Omega_2\overline{w}L_2(1-\alpha_2^T) + \Omega_2(\overline{w}-w_2)\overline{L}_2(1-\alpha_2^U) + \Omega_1 L_2]\end{array}\right\}}{\Delta(\overline{w}L_1 + w_2L_2)^2} < 0$$

From above results, we get

Proposition 3.1: *In our assumed economy, an increase in the per capita training cost generates the following impacts:*

(1) A reduction in internal remittances and migrants' urban consumption;

(2) A decrease in the proportion of remittances in migrants' income.

An increase in the per capita training cost increases the cost of the manufacturing sector and reduces employment correspondingly. Reduced workforce flows into the informal sector, which also attracts agricultural employees. Therefore, an increase in the per capita training cost also promotes rural-urban migration. However, the more migrants work in the lower-wage informal sector while fewer migrants are employed in the high-wage manufacturing sector, brings down total migrants' income. Meanwhile, the expansion of the informal sector brings down its price and stimulates its consumption. Since the income of urban labor is constant, migrants' increase the consumption of informal goods at a lower price. A decreased total income and an increased informal consumption reduce the capacity of remittances, which lowers the proportion of remittances in migrants' income at last.

The change of employment and remittances also leads to the fluctuation of output. The informal sector expands with more employment while the agricultural sector experiences a loss with fewer remittances and workers. From the results of equation(3.8), we obtain

$$\frac{dX_2}{dh} = F_L^2 \frac{dL_2}{dh} > 0$$

and

$$\frac{dX_3}{dh} = k'F^3 \frac{d\beta}{dh} + kF_L^3 \frac{dL_3}{dh} < 0$$

We use Proposition 3.2 to summarize the impacts of an increase in per capita training cost on output in the informal and the agricultural sectors.

Proposition 3.2 An increase in per capita training cost contributes to an expanding informal sector and a contracting agricultural sector.

When the manufacturing sector faces structural adjustments and increases its training cost, rural-urban migrants experience unemployment in the manufacturing sector. Migrants who are in unemployment prefer to stay in the urban region, i.e., self-employment in the informal sector instead of returning to the agriculture. In this situation, the low-end informal sector expands. One theoretical explanation for this phenomenon is that migrants view informal sector employment as a temporary staging post for a way to gain formal sector employment (Johnson, 1971; Fields,1975; Mazumdar,1975). This hypothesis is supported by some economic reality (International Labour Office, 1972) and empirical research (Meng,2001;Junankar and Shonchoy, 2013). This conclusion is also supported by China's economic facts. According to the National Monitoring Survey Report of Rural-Urban Migrant Workers from 2008 to 2016 in China, 37.2% and 33.8% of migrants employed in the manufacturing (excluding construction industry) and tertiary industry in 2008, respectively; however, when China faced industry upgrading and increased its training cost, the manufacturing sector dropped the employment of migrants while an increasing number of migrants employed in low-end tertiary rather than agricultural sector, and the figures were 30.2% and 46.7% in 2016, respectively. At the same time, the number of migrants increased from the Survey Report. Ceteris paribus, the agricultural sector experiences a loss. In reality, the output of the agricultural sector may not fall because of the inflow of capital to substitute the transferred labor. Here, our model confines to the short term and does not consider the mobility of capital.

3.4 Concluding remarks

Based on the new phenomena of manufacturing in developing countries, the article analyzes theoretically impacts of an increase in per capita training cost on internal remittances. We find that an increase in per capita training cost in the manufacturing sector reduces internal remittances and the proportion of remittances in migrants' income. In addition, an increase in per capita training cost also contributes to expanding the informal sector and contracting the agricultural sector. Since similar analyses have been sparse, the main contents of this chapter provide new perspectives to the best of our knowledge. Several important policy implications are derived from the findings in this study.

First, since the remittances have a positive impact on agricultural production, the government could put more financial resources into rural areas, such as provision of infrastructure, reduction of pollution, improvement of government service, to minimize negative impacts generated by a reduction of remittances. Second, reducing the per capita training cost would raise the employment of migrants and remittances in the urban area, and promote agricultural output and add agricultural wage in the rural area. Increment in the human capital level of the rural is an effective solution to drop the training cost. However, rural people could hardly afford the investment of human capital. The government should play a significant role, making policies to broaden access to basic education, strengthen the technical and vocational training programs, improve school-industry partnerships, in effectively enhancing the human capital level of the rural. Third, many rural migrants will face unemployment when manufacturing increases its training cost and the informal sector provides jobs to them in the urban regions. Programs, such as provision of training, facilitation of micro-finance, reduction the cost of establishment and operation of a business(including simplified registration and licensing procedures, favorable tax conditions), legal protection, should be designed and implemented to promote the development of informal sector and ease the negative impacts resulted from an increase in training cost.

Chapter 4

Privatization in vertical related market in developing economy: a general equilibrium approach

In this chapter, a three-sector general equilibrium model is built to investigate the impacts of deepening privatization of an upstream state-owned enterprise in the developing economy. The public firm, facing privatization, owns a monopolistic position in upstream market and offers an essential intermediate input for downstream manufacturing sector. After the privatization, the public firm improves its efficiency. We conclude the efficiency-enhancing effect is crucial for determining the impacts of privatization and provides a new perspective for considering the privatization issue. Deepening privatization lowers (raises) price of the intermediate input and increases its output if the efficiency-enhancing effect is relatively large (small). When the effect is moderate, an increase in the privatization level could raise the output of manufacturing and agricultural and social welfare.

4.1 Introduction

Due to the momentum of economic liberalization, the world has experienced a massive shift toward the privatization of state-owned enterprises (SOEs) since the 1980s, especially in transition and developing economies[1]. During this privatization momentum, new private firms entered a market monopolized by SOEs. This type of market is recognized as a "mixed oligopoly," where both public and private firms produce final goods and compete in the same market (De Fraja and Delbono, 1989). Following this framework, many attempts have been made by scholars to analyze the impact of the partial privatization of SOEs (Matsumura,1998; Fujiwara, 2007; Matsumura and Shimizu, 2010; Wang and Chen, 2011; Han and Ogawa, 2012; Xu et al., 2017). Most existing literature assumes that SOEs and non-SOEs compete in the same market and provide their goods directly to consumers. However, such structure may not be applicable to economic reality. International Labour Office (1999) lists over 100 countries engaged in privatizing SOEs of which the bulk occurs in upstream industries. OECD (2017) reported that 51% of all SOEs by value and 70% by employment in OECD countries and four developing countries (Argentina, Brazil, China, India and Saudi Arabia) are in sectors such as transportation,

[1] Most of this privatization occurred in Europe, Central and East Asia, and Latin America, while the scale of privatization in Africa and South Asia is rather small. For more stylized facts, see Estrin and Pelletier (2018).

telecommunications, power generation, finance, mining, manufacturing and other energy industries-most of which can be classified as the upstream industries. A vertical structure has developed between SOEs and non-SOEs, where SOEs monopolize key upstream industries, whereas downstream industries are mostly open to private competition[2].

This vertical structure has recently received much attention, and some scholars have explored the impact of the privatization of upstream SOEs. Chang and Ryu (2015) investigated the optimal privatization policy of the public firms in vertically related markets where an upstream public firm competes with a foreign firm and supplies an intermediate input to downstream private firms. This optimal policy depends on several factors: the market share, the initial public ownership level of public firm, and the number of both domestic and foreign downstream firms. Additionally, they concluded that complete privatization is never optimal. When the upstream market is monopolized by a domestic public firm, full nationalization is optimal. Chang and Ryu (2016) studied an export rivalry model under a vertical structure similar to that of Chang and Ryu's (2015) work and obtained the optimal privatization level under a new market structure. One key implication of their conclusions is that the ownership share of the upstream firm can play the role of a disguised export subsidy. Wu et al. (2016) examined the welfare implications of privatization in a mixed oligopoly and vertically related markets. In the vertical markets, an upstream foreign monopolist sells an intermediate input to public and private firms located downstream within the domestic market. Without foreign ownership in the downstream private firms, the optimal policy toward the public firm is complete privatization. With foreign ownership, complete privatization can never be socially optimal.

Previous literature, however, has focused on the partial impact of privatization in vertically related markets and employed game theory as a tool to analyze this issue. While the game theory approach is useful in realizing theoretical results, it is bound to be limited in the analysis, as it ignores factor markets. When considering factor markets and employing a general-equilibrium approach, we can "offset or even

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[2] For partial privatization transition economies, Li et al. (2012) introduced this structure in China, which was formed around 2001. Additionally, the participation of SOEs in economic activity in many developing countries is substantial and they usually have monopoly status, for instance, Zimbabwe and Ethiopia in Africa and Vietnam in Asia.

reverse sensible partial equilibrium conclusions" (Acemoglu, 2010). Generally, public firms experience an efficiency improvement in line with their level of privatization (Gupta, 2005). After the improvement of efficiency, public firms reduce factor employment, which affects the cost of public firms and factor rewards in factor markets. Therefore, the privatization issue is in fact often addressed in situations where good markets and factor markets are interconnected.

There are few existing studies that have explored partial privatization from a general equilibrium approach. An example is Beladi and Chao (2006a), who investigated the impact of partial privatization on unemployment and social welfare in both the short and the long term. Chao and Yu (2006) used an international mixed oligopoly model to determine the effect of partial privatization on optimum tariffs and concluded that partial privatization raises the optimal tariff rate. Ghosh and Sen (2012) studied the privatization issue within a general equilibrium model and concluded that privatization raises the returns to capital, increases the tariff revenue, and lowers wage rates. Chao et al. (2016) and Pi and Zhang (2018) considered the impact of privatization on skilled-unskilled wage inequality from different aspects. However, these studies were based on a horizontal market structure in which private and public firms produce and compete only in a final goods market.

To fill the current research gap, this study constructs a three-sector general equilibrium model to investigate the impact of the privatization of a public upstream firm. Compared with existing studies, our study provides a new perspective. When we incorporate the efficiency-enhancing effect of the public firm, we observe that deepening privatization of a public upstream firm may not raise its price if the this effect is relatively large. To the best of our knowledge, this conclusion is new to this field of study. The economic intuition behind these results is as follows: an increase in the privatization level of a public firm leads it to focus more on its profit, but also increases its efficiency. The efficiency improvement leads to the public firm employing less labor for unit production, which reduces the wage rate. A reduction in wage rate and the efficiency improvement, in turn, decrease the marginal cost of the public firm. If the efficiency-enhancing effect is relatively large, the impact of the profit seeking on its price offsets by a decline in the marginal cost.

Chang and Ryu (2015, 2016) also considered a scenario in which an upstream public firm has a monopoly position in the upstream market. In their study, they assumed that one unit of the final product requires one unit of the intermediate product and an increase in the privatization level does not affect the public firm's efficiency. They concluded that the optimal privatization policy is the full nationalization of the upstream public firm. Within the framework of Chang and Ryu's work, if the current model does not incorporate the impact of an increase in privatization on the factor market, we can also determine that the optimal privatization policy is full nationalization of the upstream public firm. However, if we incorporate the impact of a change in privatization level on the factor market, a trade-off occurs between agriculture and manufacturing sector: an increase in the privatization level increases agricultural output and reduces manufacturing output. And optimal policy dictates either full nationalization or full privatization of an upstream public firm. Additionally, if we incorporate the impact of a change in privatization level on a public firm's efficiency, we obtain results that are dependent on the efficiency-enhancing effect. Therefore, this study utilizes Chang and Ryu's (2015, 2016) structure to extend the scope and adjusts the model to be more relevant to economic reality.

The rest of the chapter is organized as follows. A general equilibrium model is established in Section 4.2. Comparative results are showed in Section 4.3. Some discussion is in Section 4.4. Concluding remarks are made in Section 4.5.

4.2 The Model

We consider a developing economy with urban and rural region. In the rural region, private firms in agricultural sector produce agricultural good *X* under perfect competition. Within the urban region, there is a vertical structure with an upstream public firm, which is facing partial privatization, producing intermediate input *Z* and the downstream manufacturing sector producing a consumption good *Y*. Consumers demand for final good *X* and *Y*. Following Chao et al (2018), assume the utility function is a quasi-linear: $U = X + aY - Y^2/2$, where a is sufficiently large and represents the scale of market. The budget constraint is: $I = X + qY$, where I is total income, price of the good *X* is normalized to be unity and q is the relative price of good *Y*. Solving the utility maximization problem, we get the inverse demand for good $Y, q = q(Y) = a - Y$, with $q'(Y) = -1 < 0$.

The agricultural good is produced by using labor and land with wage w and rental rate τ under the constant-returns-to-scale technology in the rural area. The corresponding unit cost function is denoted by $w^{\alpha}\tau^{1-\alpha}$, where α is parameter in the range $(0,1)$. Under the condition that its market is perfectly competitive, we could obtain

$$w^{\alpha}\tau^{1-\alpha} = 1 \tag{4.1}$$

By Shephard's lemma, demands for labor and land are $\alpha X/w$ and $(1-\alpha)X/\tau$, respectively.

As for the urban region, downstream manufacturing sector *Y* is perfectly competitive with constant returns to scale and firms in this sector are pricing-taking in both output and input markets. The manufacturing sector uses labor and intermediate good Z as inputs and the production function is $Y = L_y^{1-\beta}Z^{\beta}$, where is L_y labor input and β is parameter in the range $(0,1)$. To make the after analysis tractable, we assume the role of intermediate input in manufacturing production β is relatively enough. Considering the economic reality, upstream SOEs play strategically significant roles in the developing economy by offering essential intermediate input, thus the assumption here is acceptable. From the production function, unit cost in the manufacturing sector *c* is given by $c = Aw^{1-\beta}p^{\beta}$, where *p* is the price of intermediate input and $A = \frac{1}{1-\beta}\left(\frac{1-\beta}{\beta}\right)^{\beta} > 0$. Since the manufacturing sector is price taking, it produces where price *q* equals unit cost *c*. From the unit cost function of manufacturing sector, we have

$$p = \left(\frac{a-Y}{A}\right)^{\frac{1}{\beta}} w^{\frac{\beta-1}{\beta}} \tag{4.2}$$

The equation (4.2) shows the amount that the downstream manufacturing sector will pay for its intermediate input as a function of its output price and wage rate. At output level, the manufacturing sector's demand for labor and intermediate input are given by $L_y = (1-\beta)(a-Y)Y/w$ and $Z = \beta(a-Y)Y/p$, respectively.

The upstream firm produces good Z with a technology which uses labor alone and has increasing returns to scale. Assume that the technology has fixed labor input *f* and marginal labor input *b* per unit output. The profit π, therefore takes the form, $\pi = pZ - w(f + bZ)$. Since the upstream is a public (partially privatized) firm, it cares not only in its profit, but also is welfare generated. The welfare is: $W = \pi + CS$, where

$CS = aY - Y^2/2 - q(Y)Y = Y^2/2$ denotes consumers' surplus from good *Y*. The objective of the upstream firm is to maximize a weighted average of its profit and welfare, $\theta\pi + (1-\theta)W$, where θ is parameter in the range $[0,1]$. θ represents the degree of private ownership: the more the private-owned, the larger the value of θ. Assume that once the upstream firm is (partial) privatized, its efficiency is improved in the variable cost. We thereby assume that $b = b(\theta)$, where $b'(\theta) < 0$, $b''(\theta) > 0$. We regard $-b'(\theta) > 0$ as the efficiency-enhancing effect if θ raises. The upstream firm chooses the output to maximize the objective and first order condition is:

$$p\left(1 - \frac{Y\theta}{a-Y}\right) = wb \tag{4.3}$$

The left term expresses marginal benefits of producing good *Z* and the right side is the marginal cost. When $\theta = 0$ ($\theta > 0$) ,the upstream firm is fully state-owned (partial privatized), and price is equal (larger) than the marginal cost. As expected, deepening privatization of upstream firm increases its price when such change does not affect the reward of labor and its efficiency.

The equilibrium condition for labor, land and intermediate input are:

$$\alpha X/w + (1-\beta)(a-Y)Y/w + Zb + f = L \tag{4.4}$$

$$(1-\alpha)X/\tau = T \tag{4.5}$$

$$(a-Y)\beta Y/p = Z \tag{4.6}$$

where *L* and *T* are the endowment of labor and land in the economy.

So far, the construction of the model has completed. There are six equations, from (4.1) to (4.6), determining six endogenous variables, namely w, τ, X, Y, Z, p.

4.3 Comparative Results

This section examines the impact of the deepening of privatization (an increase in θ) on the output of two final sectors and on social welfare.

First, we consider the agricultural sector. The agricultural sector minimizes its cost according to (1), and by completely differentiating equation (4.1), we have:

$$\hat{\tau} = -\frac{\alpha}{1-\alpha}\hat{w} \tag{4.7}$$

where the notation "^" above a variable denotes the relative change in the variable. The zero profit in agriculture makes τ and w change in opposite directions.

The rent of land is determined by equation (4.5). By completely differentiating equation (4.5) and by using equation (4.7), we have:

$$\hat{X} = \hat{\tau} = -\frac{\alpha}{1-\alpha}\hat{w} \tag{4.8}$$

From equation (4.8), a change in w causes τ and X to shift in the same direction. An increase in the wage rate will reduce the labor demand in this sector, which lowers the marginal productivity of the land and its output.

Next, we investigate the urban region. By completely differentiating equations (4.2) and (4.6), we obtain

$$\hat{p} - \left(1 - \frac{1}{\beta}\right)\hat{w} + \frac{Y}{\beta(a-Y)}\hat{Y} = 0 \tag{4.9}$$

and

$$\frac{a-2Y}{a-Y}\hat{Y} - \hat{p} - \hat{Z} = 0 \tag{4.10}$$

Where $a - 2Y > 0$ under the assumption that the market scale is sufficiently large. Obviously, a more expensive intermediate input decreases manufacturing output from (4.9) and more provision for Z raises it from (4.10).

Next, we consider the impact of the partial privatization of an upstream public firm. Such effects can be derived from equations (4.3) and (4.4). Using equation (4.8) and completely differentiating equations (4.3) and (4.4) gives us

$$\hat{p} - \hat{w} - \frac{a\theta Y}{(a-Y)(a-Y-\theta Y)}\hat{Y} = \left(\frac{Y\theta}{(a-Y-\theta Y)} + \varepsilon_\theta\right)\hat{\theta} \tag{4.11}$$

and

$$-\left(\frac{\lambda_{LX}}{1-\alpha} + \lambda_{LY}\right)\hat{w} + \lambda_{LY}\frac{a-2Y}{a-Y}\hat{Y} + \lambda_{LV}\hat{Z} = -\lambda_{LV}\varepsilon_\theta\hat{\theta} \tag{4.12}$$

where λ_{LX} (λ_{LY}) represents the allocative share of labor in the production of product X(Y) and λ_{LV} represents the allocative share of labor in the variable cost of production of product Z. $\varepsilon_\theta = \theta b'/b < 0$ expresses the marginal labor input elasticity of privatization. If the absolute value of ε_θ is large, then the efficiency-enhancing effect will be significant and the marginal labor input will decrease by a relatively large margin as a result of privatization. Conversely, if the absolute value of ε_θ is small, the effect will be weak and the deepening privatization has a negligible impact on the marginal labor input. From equation (4.11), the deepening privatization of an upstream public firm may not increase its price if the efficiency-enhancing effect is relatively large. Equation (4.12) states that the deepening privatization also leads to a reduction in a public firm's costs by lowering its wage rate.

To conduct a comparative static analysis of the impacts of privatization on the economy, rewriting equations (4.9) to (4.12) into the matrix forms

$$\begin{pmatrix} 1 & -\left(1-\frac{1}{\beta}\right) & \frac{Y}{\beta(a-Y)} & 0 \\ 1 & -1 & \frac{a\theta Y}{(a-Y)(a-Y-\theta Y)} & 0 \\ 0 & -\left(\frac{\lambda_{LX}}{1-\alpha}+\lambda_{LY}\right) & \frac{\lambda_{LY}(a-2Y)}{a-Y} & \lambda_{LV} \\ -1 & 0 & \frac{a-2Y}{a-Y} & -1 \end{pmatrix} \begin{pmatrix} \hat{p} \\ \hat{w} \\ \hat{Y} \\ \hat{Z} \end{pmatrix} = \begin{pmatrix} 0 \\ \frac{Y\theta}{a-Y\theta-Y}+\varepsilon_{\theta} \\ -\lambda_{LV}\varepsilon_{\theta} \\ 0 \end{pmatrix} \hat{\theta} \qquad (4.13)$$

Denote the value of determinant of the coefficient matrix of equation (4.13) as Δ, and we have

$$\Delta = \frac{1}{a-Y}\left\{\frac{1}{\beta}\left[(\lambda_{LY}+\lambda_{LV})(a-2Y)-\frac{a\theta Y\lambda_{LV}}{a-Y-\theta Y}\right]+\left(\frac{Y}{\beta}+\frac{a\theta Y\lambda_{LV}}{a-Y-\theta Y}\right)\left(\frac{\lambda_{LX}}{1-\alpha}+\lambda_{LY}+\lambda_{LV}\right)\right\}>0\,.$$

Deepening privatization will affect the price of both intermediate input and output directly, which further changes factors' price and the output of the final sectors indirectly. We use a Lemma 4.1 proposition to summarize how the price of intermediate input and output will change after the privatization of an upstream public firm.

Lemma 4.1: *To develop an economy with a manufacturing sector and an upstream public firm that is facing privatization in an urban region, the deepening privatization decreases (or increases) its price and increases (or decreases) its output if the efficiency-enhancing effect is relatively large (or small).*

Proof: See Appendix 4.1

The economic intuition provided by Lemma 4.1 can be expressed as follows: The transition from a pure public firm to a partially privatized firm corresponds to the change of its objective, which leads the firm to focus more on its profit. To achieve this, the firm will reduce its output and raise the price of its product, as can be seen in most previous studies. With less provision for intermediate input, the downstream manufacturing sector also decreases its output, which in turn decreases employment in two sectors and therefore reduces the wage rate. When incorporating the impact of privatization on public firms' efficiency, an increase in the privatization level will generate another effect; the efficiency-enhancing effect. Concerning this effect, privatization will reduce employment in the unit production of an upstream firm, which decreases the wage rate in labor market. Therefore, the upstream firm faces a lower marginal labor input, wage rate, and marginal cost after privatization. Furthermore, if the effect is relatively large (or small), which means a large (or small) reduction of marginal labor input, an increase in the privatization level reduces its marginal cost significantly (or insignificantly). Following equation (3), its price consequently decreases (or increases) and its output increases (or decreases).

Next, we investigate how the deepening privatization of a public firm exerts an impact on two final sectors, which are described by Propositions 4.1 and 4.2.

Proposition 4.1: *In the established model, an increase in the privatization level expands (or shrinks) the output of the manufacturing sector if the efficiency-enhancing effect is relatively large (or small).*

Proof: See Appendix 4.1

The intuition of Proposition 4.1 is similar to that of Lemma 4.1. When the efficiency-enhancing effect is relatively large (or small), an increase in the privatization level of a public firm increases (or decreases) its output and reduces its price, which, in turn, expands (or shrinks) the output of the manufacturing sector. Note that the threshold of the efficiency-enhancing effect in Proposition 4.1 is less than that of Lemma 4.1. An increase in the privatization level affects not only the price of intermediate input, but also the wage rate. If the efficiency-enhancing effect is relatively large, privatization also reduces the wage rate, which promotes the expansion of the manufacturing sector. If the efficiency-enhancing effect is relatively small, the provision of intermediate input and wage rate are reduced. Considering that intermediate input plays a strategically significant role in production, the reduction of intermediate input outweighs the increase in employment and the manufacturing sector's output is reduced.

Proposition 4.2: *In the established model, an increase in the privatization level increases (or decreases) the output of the agricultural sector if the efficiency-enhancing effect is relatively small (or large enough).*

Proof: See Appendix 4.1

Concerning the impact of a privatization level increase on agricultural output, the result depends on its impact on the wage rate, see equation (4.8). Since the land factor is specific to the agricultural sector, a lower wage rate leads to this sector employing more labor to increase its output. As can be seen in the Appendix, the threshold of efficiency-enhancing effect in Proposition 4.2 is larger than that of both Lemma 4.1 and Proposition 4.1. When the efficiency-enhancing effect is less than the threshold in Proposition 4.2, an increase in privatization may either increase or decrease the output of sectors *Y* and Z. If the efficiency-enhancing effect is less than the threshold in the Proposition 4.1, an increase in privatization shrinks the output of sectors *Y* and *Z*. Additionally, more labor are employed in the agricultural sector, which consequently increases (or reduces) its output. If the efficiency-enhancing effect is larger than the threshold in Proposition 4.1 but less than that of Proposition 4.2, it indicates that privatization expands sectors *Y* and *Z*. Forthwith, we need to explain the expansion of the three sectors concerning the given labor endowment. Privatization improves the efficiency of an upstream firm, which leads to a reduction in its marginal labor input, wage rate, and marginal cost. Under the pricing rule, its price also decreases, but to a larger degree than that of the wage rate. Therefore, the manufacturing sector faces a comparatively cheaper intermediate input than that of labor, which will limit the demand for labor. Furthermore, the reduction of employment will be dominant and the equilibrium wage rate will reduce. If the efficiency-enhancing effect is large enough, it means that the output of sector Z increases markedly and the manufacturing sector faces a much lower price of intermediate input. Consequently, the marginal product labor also increase and the demand for labor in the manufacturing sector rises by a relatively large margin. In this situation, the increase in employment—in both sectors *Y* and *Z*—will be dominant and the output of the agricultural sector decreases.

Next, we consider the impact of privatization on social welfare. We first establish the social welfare criterion, which is the basis for evaluating privatization. Following Beladi and Chao (2006a), the social welfare of the economy is expressed by the utility $U = X + aY - Y^2/2$. When we completely differentiate this utility and substitute the results from the Appendix 4.1, we get

$$\frac{\hat{U}}{\hat{\theta}} = \frac{I\theta}{U\Delta}\left\{\frac{X}{I}\frac{\alpha}{1-\alpha}\frac{\Psi_4\left(1+b'\psi_4/b\right)}{(a-Y)(a-Y-\theta Y)} + \frac{qY}{I}\left[\frac{\lambda_{LY}Y}{\beta(a-Y-\theta Y)} - \Psi_3\left(\frac{b'}{b} + \frac{Y}{a-Y-\theta Y}\right)\right]\right\}$$

Since the symbols in the above equation are ambiguous, we consider the following three cases: (a) if $-b'/b$ is small enough, the symbol $\hat{U}/\hat{\theta}$ is ambiguous, depending on the value of X/I and qY/I. If X/I is relatively larger (or smaller) than qY/I, then $\hat{U}/\hat{\theta} > 0$ ($\hat{U}/\hat{\theta} < 0$); (b) If $\frac{Y}{a-Y-\theta Y} < -\frac{b'}{b} < \frac{1}{\psi_4}$, then $\hat{U}/\hat{\theta} > 0$;

and (c) if $-\frac{b'}{b} > \frac{1}{\psi_4}$, the symbol also depends on the value of X/I and qY/I. If qY/I is relatively larger (or smaller) than X/I, then $\hat{U}/\hat{\theta} > 0$ ($\hat{U}/\hat{\theta} < 0$).

Proposition 4.3: *The impact of deepening privatization on social welfare depends on the magnitude of the efficiency-enhancing effect. If the effect is moderate, an increase in privatization of an upstream firm raises social welfare unambiguously.*

Suppose that the efficiency-enhancing effect is small enough. A small increase in the privatization level will decrease the output of the intermediate sector and will reduce the equilibrium wage rate. More labor will be employed in the agricultural sector, causing agricultural output to increase. The expansion of the agricultural sector and the contraction of the manufacturing sector has an indeterminate effect on social welfare. If the share of the manufacturing sector is relatively large, full nationalization is the optimal policy. If the share of the agricultural sector is large enough, complete privatization is the optimal policy. Lastly, the partial privatization of an upstream firm is never optimal.

Next, we consider a moderate efficiency-enhancing effect. A rise in the privatization level reduces the labor cost of an upstream firm. The manufacturing sector expands its output, which demands more labor, increasing the wage rate. When the efficiency-enhancing effect is moderate, a rise in privatization reduces the price of intermediate input less severely, resulting in a smaller increase in the demand for labor in the manufacturing sector. Therefore, the demand for labor in the manufacturing sector increases slightly, bringing down the wage rate, as discussed in the explanation of Proposition 4.2. The agricultural sector employs more labor to increase its output. In this case, an increase in privatization increases the output of the two final sectors simultaneously. Consequently, deepening privatization increases social welfare.

When the effect is large enough, a rise in privatization expands the output of manufacturing sector more noticeably, resulting in a larger increase in the demand for labor. As a result, the equilibrium wage rate rises. More labor are employed in the urban region, shrinking the output of the agricultural sector. The impact of deepening privatization on social welfare depends on the income share of the manufacturing sector and the agricultural sector. If the manufacturing share is relatively large, further (diminishing) privatization is the optimal choice.

4.4 Discussion of the theoretical model

For developed economies in the 1980s and 1990s, the main purpose of privatization was usually to improve SOEs' performance and efficiency, to reduce government intervention, and to introduce competition in monopolized sectors (Vickers and Yarrow, 1988). Many developing economies had similar motivations (Van der Walle, 1989).As Megginson and Sutter (2006) note, researchers face numerous methodological problems when they analyze the economic effects of privatization. In particular, data availability and consistency, especially in developing countries, and sample selection bias, represent key issues. In theory, once privatization, the firm will raise its price to seek more profit; meanwhile, its cost also decreases due to efficiency improvement, which may reduce its price. Thus, a rise in privatization level will not always increase it price. Such a mechanism has been empirically examined by Konings et al. (2005).

The magnitude of efficiency-enhancing effect plays a key role in this chapter. Estrin and Pelletier (2018) summarized the evidence concerning the effects of privatization on efficiency in developing countries in three sectors: banking, telecommunications, and utilities. The results showed that privatization improves firm performance in banking, while there was not a significant improvement in utilities. They also showed that privatization alone does not automatically yield economic benefit and that many factors have been found to influence successful privatization. Therefore, the effect of privatization on efficiency improvement can be either large or small. Next, we consider privatization in China to clarify the applicability of our theoretical model.

China's SOEs are inefficiently managed and their profitability was deteriorating until the middle of the 1990s, as demonstrated by many indicators. For example, even though no SOEs have closed down, the share of SOEs' net industrial output decreased from more than 80% in 1978 to approximately 58.7% in 1993. In the 1990s, the average rate of profit has declined to almost zero. Bai et al. (2006) stated that there is an approximately 30% labor surplus in China's SOEs, and they have accumulated a large amount of debt. To reduce the government burden, they drastically restructured the SOEs in the late 1990s, privatizing some and shutting down others. From 1995 to

2002, over 40 million jobs in the government sector were cut and the number of jobs in the urban government sector fell from 59% to 32% of total urban employment.

Following this wave of privatization, the government privatized or closed down most small and medium-sized SOEs, while the upstream markets—where competition was severely restricted through regulation—were still monopolized by SOEs. The massive expansion of non-SOEs contributed to China's rapid industrialization, which also increased the demand for intermediate inputs from SOEs. Within this structure, even without any productivity improvement, the upstream SOEs could benefit from the growth of non-SOEs (Li et al., 2012). However, this rent extraction mechanism could not last long. When the demand for non-SOEs decreases, the inefficient SOEs could face difficulties and the government would have to undertake a reform of SOEs to restructure the economy. Several important sectors—like the railway, coal, and steel sectors—have faced the privatization process and mass layoffs in SOEs[3].

An example is the China Railway Corporation (CRC). The company—which was created after the Ministry of Railways was dissolved in 2013—completely reformed its corporate structure at the end of 2017. When the CRC was established, people afraid of a higher price due to the privatization. After six years, this concern does not happen. After its marketization, the CRC developed a few solutions to improve profitability, which included the display of the mass advertisement in trains and stations, market regulation price, land sales, and improving asset securities. The CRC also took steps to reduce its cost by dismissing 8.1% of their employees.

4.5. Concluding remarks

The study explores the impact on the economy of the partial privatization of a public upstream firm through the general equilibrium approach. We concluded that the efficiency-enhancing effect of privatization is crucial for determining the impact of privatization and offer a new perspective for considering the privatization issue. We also found that deepening privatization lowers (or raises) its price and increases the output of the manufacturing sector if the efficiency-enhancing effect is relatively large (or small). When the effect is moderate, an increase in the privatization level could increase the output of both the manufacturing and the agricultural sectors through the efficiency improvement of a public firm.

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[3] Reuters reported that China aims to lay off 5-6 million state workers between 2017 and 2019.

To conclude our study, we propose possible directions for future research. First, for the purposes of this study, we assume that all market sectors employ homogeneous labor and that there is no employment in the economy. However, the upstream public sector holds a monopoly position and unskilled labor cannot be employed in this sector. To solve this problem, we can introduce heterogeneous labor—skilled and unskilled—into the model. Second, many developing countries experience massive rural labor migration and urban region often have high unemployment. For this situation, we can incorporate a rural labor migration mechanism and unemployment into the model, which may lead to different conclusions. Third, foreign competition is not considered in this study. In future, we can introduce a foreign private firm in the upstream market to compete with the public firm.

Appendix 4.1

By employing the Cramer's rule to solve equation (4.13), and we get the following results:

$$\frac{\hat{p}}{\hat{\theta}}=\frac{\theta\Psi_1 Y}{\Delta\beta(a-Y)(a-Y-\theta Y)}\left(1+\frac{b'}{b}\psi_1\right)$$

$$\frac{\hat{Z}}{\hat{\theta}}=-\frac{\theta\Psi_2 Y}{(a-Y)(a-Y-\theta Y)\Delta}\left(1+\frac{b'}{b}\psi_2\right)$$

$$\frac{\hat{Y}}{\hat{\theta}}=\frac{\theta}{\Delta}\left[\frac{Y(\lambda_{LV}-\beta\Psi_3)}{(a-Y-\theta Y)\beta}-\frac{b'}{b}\Psi_3\right]=\frac{\theta}{\Delta}\left[\frac{\lambda_{LV}Y}{(a-Y-\theta Y)\beta}-\Psi_3\left(\frac{b'}{b}+\frac{Y}{a-Y-\theta Y}\right)\right]$$

and

$$\frac{\hat{w}}{\hat{\theta}}=-\frac{\theta\Psi_4}{\Delta(a-Y)(a-Y-\theta Y)}\left(1+\frac{b'}{b}\psi_4\right)$$

where $\Psi_1=(1-\beta)(\lambda_{LY}+\lambda_{LV})(a-2Y)+Y\left(\frac{\lambda_{LX}}{1-\alpha}+\lambda_{LY}\right)>0$,

$$\psi_1=\frac{\Psi_1(a-Y-\theta Y)+Y\left[(a-Y)(1-\theta)+\theta(\beta a-2Y)\right]}{\Psi_1 Y}>0,$$

$$\Psi_2=\left(\frac{Y}{\beta}+a-2Y\right)\left(\frac{\lambda_{LX}}{1-\alpha}+\lambda_{LY}\right)-\lambda_{LV}(a-2Y)\left(1-\frac{1}{\beta}\right)>0,$$

$$\psi_2=\frac{\beta\Psi_2\left(a-Y-\theta Y\right)+\lambda_{LV}[\left(a-Y\right)(a-Y-\theta Y)-a\theta Y(1-\beta)]}{\beta\Psi_2 Y}>0$$

$$\Psi_3=\lambda_{LY}+\lambda_{LV}+\frac{\lambda_{LX}}{1-\alpha}>0,\ \Psi_4=Y\left(\lambda_{LV}\frac{Y}{\beta}+\left(a-2Y\right)\left(\lambda_{LY}+\lambda_{LV}\right)\right)>0$$

and $\psi_4 = \dfrac{\left[(a-2Y)(a-Y-\theta Y)(\lambda_{LY}+\lambda_{LV})-a\theta Y\lambda_{LV}\right]}{\Psi_4} > 0$. In addition, we can easily get $\dfrac{1}{\psi_1} < \dfrac{Y}{a-Y-\theta Y} < \dfrac{1}{\psi_4}$.

Therefore, if $-\dfrac{b'}{b} > \dfrac{1}{\psi_1}$, then $\dfrac{\hat{p}}{\hat{\theta}} < 0$; if $-\dfrac{b'}{b} > \dfrac{1}{\psi_2}$, then $\dfrac{\hat{Z}}{\hat{\theta}} > 0$; if $-\dfrac{b'}{b} > \dfrac{Y}{a-Y-\theta Y}$, then $\dfrac{\hat{Y}}{\hat{\theta}} > 0$; if $-\dfrac{b'}{b} < \dfrac{1}{\psi_4}$, then $\dfrac{\hat{w}}{\hat{\theta}} < 0$ and $\dfrac{\hat{X}}{\hat{\theta}} > 0$; if $-\dfrac{b'}{b} > \dfrac{1}{\psi_4}$, then $\dfrac{\hat{w}}{\hat{\theta}} > 0$ and $\dfrac{\hat{X}}{\hat{\theta}} < 0$.

Chapter 5

International labor movement, Public intermediate input and Wage inequality: a dynamic approach

This chapter incorporates the public intermediate input in a dynamic model with two final private sectors and a public sector and investigates impacts of an inflow of skilled and unskilled labor on wage inequality. The public intermediate input can be accumulated and its accumulated stock serves as a public input for private production. From the analysis, in the steady state equilibrium, an increase in the skilled and unskilled labor endowment raise the stock of public intermediate input. And an inflow of skilled labor reduces the wage of skilled labor and raises the wage of unskilled labor, and an inflow of unskilled labor increases both the wages of skilled and unskilled labor. Concerning their impacts on the wage inequality, an inflow of skilled labor decreases the wage inequality while the result of an inflow of unskilled labor on wage inequality is ambiguous. If the production elasticity of the public intermediate input stock in the skill-using sector is small enough, an inflow of unskilled labor narrows down wage inequality.

5.1 Introduction

The rising wage inequality between skilled and unskilled labor is a concern for both developed and developing countries. Many scholars believe that trade liberalization and international factor movement have contributed to the widening inequality such as Leamer(1996), Feenstra and Hanson (1996), Beyer et al. (1999), Reenen(2011), Afonso (2012). Meanwhile, their effects on wage gap have been analyzed extensively among theoretical papers. Marjit and Kar (2005) analyzed how an outflow of skilled and unskilled labor affect wage inequality in a dual economy and the results depend on the capital intensities in the skilled labor-using sector and unskilled labor-using sector. Marjit and Kar (2005) analysis has been extended by incorporating domestic labor migration from various perspectives, as in Beladi et al. (2008), Chaudhuri(2008), Gupta and Dutta (2010), Pan and Zhou (2013), Li and Xu(2016). Beladi et al. (2008) considered a model with unemployment and impacts of international factor movement on wage inequality crucially depend on the difference in intersectoral factor intensities. Chaudhuri(2008) included unemployment and unionized wage rate of unskilled labor and showed that the results of international factor movement on wage inequality may not necessarily depend on the difference in the factor intensity. Gupta and Dutta(2010) introduced a non-traded final good sector and endogenous formation of skilled labor in a general model and found that the international factor movement on wage inequality depends on factor intensity ranking between two skilled labor sectors. Pan and Zhou (2013) established a model by accommodating environmental pollution which affects agricultural production and impacts of factors movement on wage inequality depend on the negative impact of pollution on agricultural production. Li and Xu (2016) investigated how international factor movements affect wage inequality with the existence of a modern agricultural sector, and found that a decrease in the endowment of unskilled labor certainly decreases the wage inequality and the result that skilled labor movement has on wage inequality is dependent on the factor intensity between the urban and modern agricultural sector.

However, previous studies seldom consider the role of public infrastructure in the wage inequality. Nowadays, public infrastructure, such as legal and economic institutions, transportation systems, communications, is playing an increasing role in a modern society, without which economic growth development will be greatly affected. The importance of public infrastructure for economic growth stems from its effect on private production. Following Meade's(1952) classification of public infrastructure, there are two types: "creation of atmosphere" and "unpaid factors". In the "creation of atmosphere" type, public infrastructure is fully available to every firm, such as free information about technology. In the "unpaid factors" type, public infrastructure, such as highways, bridges and communication facilities, can be viewed as public intermediate input in the production process of private industry. The private production function exhibits constant returns to scale with respect to public intermediate input and primary inputs (labor and capital). However, unlike private inputs, the public intermediate input needs enormous funds for construction, maintenance, operations and overall development, and usually is provided by the government and financed by taxation. Though private industries pay the cost ultimately, their payments do not affect the quantity of the public intermediate input directly and such input is essentially an unpaid input from the private industries' perspective.

The importance of public infrastructure arouses the great interest of many economic theorists, especially in international trade theory. Such studies include

McMillan (1978), Manning and McMillan (1979), Tawada and Abe (1984), Tawada and Okamoto (1983), Abe (1990), Suga and Tawada (2007), Yanase and Tawada (2012). Previous papers dealing with public infrastructure are confined mostly to a static framework or “creation of atmosphere” type. Exceptional a paper is Yanase and Tawada (2017), which consider the stock effects of an “unpaid factors” type public intermediate good in a dynamic open economy with two consumption final goods, one public intermediate good, and one primary factor (labor), and shows a country’s trade pattern and whether a country gains or loses after the opening. However, existing studies dealing with the public intermediate input seldom consider wage inequality issue. Since the public intermediate input affects productivity and wages of private sectors at different levels, therefore, it is necessary to investigate how international factor movement influences the wage inequality with the presence of the public intermediate input.

In order to fill the theoretical research gap, this chapter makes an analysis of how an inflow of skilled and unskilled labor affects wage inequality by a dynamic treatment of the public intermediate input. When incorporating the public intermediate input into the model, the chapter obtains new conclusions. From the analysis, in the steady state equilibrium, an inflow of skilled labor reduces the wage of skilled labor and raises the wage of unskilled labor, and an inflow of unskilled labor increases both the wage of skilled and unskilled labor. With regards to their impact on the wage inequality, an inflow of skilled labor decreases the wage inequality while the result of an inflow of unskilled labor on wage inequality is ambiguous. If the production elasticity of the public intermediate input stock in the skill-using sector is small enough, an inflow of unskilled labor narrows down wage inequality.

It is worth mentioning that Pi and Zhou (2012,2014) also analyze the impacts generated by a movement of international factors on the wage inequality with the consideration of public infrastructure. The main differences between this chapter and Pi and Zhou (2012,2014) are reflected mainly in the treatment of public intermediate input. The chapter uses a dynamic analysis and incorporates the stock effect of public intermediate input, while Pi and Zhou (2012,2014) considered the static framework. In reality, however, many public intermediate inputs have the characteristics of durability or capital and dynamic analysis is closer to the reality of the economy. To my knowledge, there is no dynamic theoretical model analysis focusing on wage inequality with the stock effect of public intermediate input of an “unpaid factor” type.

In addition, the results of international factor movement on the wage of skilled and unskilled labor in Pi and Zhou (2012,2014) also depend on the factor intensities. However, this chapter shows that an inflow of skilled labor reduces the wage of skilled labor and raises the wage of unskilled labor, and an inflow of unskilled labor increases both wages of skilled and unskilled labor. These results are new in this field.

Another point worthy of mention is that the chapter employs the framework of Yanase and Tawada (2017) to embed the public intermediate input. Yanase and Tawada (2017) considers an economy with two private sectors and one public sector to address international trade issues. Both private and public sectors utilize one primary factor labor which is homogeneous. With homogeneous labor input and public intermediate input, Yanase and Tawada (2017) arrives that the production frontier of the economy is strictly concave to the origin and a smaller (larger) labor endowment country tends to become an exporter of a good whose productivity is more (less) sensitive to the public intermediate input. In our case where labor is heterogeneous, the skill-using sector uses skilled labor and unskill-using sector and public sector only use unskilled labor for production, the chapter investigates impacts of an inflow of skilled and unskilled labor factor on wage inequality. Since the skilled labor is specific to the skill-using sector, an inflow of skilled and unskilled labor bring the unskilled labor transfer between unskilled and public sector, which contributes to changing wages of skilled and unskilled labor consequently. For example, an inflow of skilled labor leads to an increase in the demand for the public intermediate input, which expands the public sector and attracts unskilled labor from the unskill-using sector. Both an inflow of skilled labor and movement of unskilled labor affect the skilled wage. As for wage of unskilled labor, besides the movement of unskilled labor between unskilled and public sector, the more stock of public intermediate input also brings to the change of unskilled wage. Such a movement of unskilled labor is crucial to the analysis; however, in Yanase and Tawada (2017), because labor is homogeneous and labor could move freely among three sectors, such mechanism does not exist.

The remainder of this chapter is organized as follows. The model is described in Section 5.2 and conduct a static analysis in Section 5.3. In Section 5.4, consider the dynamic analysis. Concluding remarks are made in Section 5.5.

5.2 The model

The article considers a small, open economy with three sectors: two private sectors, skill-using and unskill-using sector, and a public sector. The private sectors produce private final goods. While the public sector produces a public intermediate non-tradable good in Meade's (1952) 'unpaid factor' type, which can be accumulated, and its accumulated stock serves in the private production. Assume two final goods are tradable and, hence, their prices are given internationally.

As for two private sectors, we adopt a specific-factor model related to Marjit and Kar (2005) where skill-using sector employs skilled labor and the public intermediate input to produce the high-skill product while unskill-using sector uses unskilled labor and the public intermediate input to produce low-skill good. Skilled labor is specific to the skill-using sector and unskilled labor can not enter into it. The production functions for two private sectors are assumed to be linearly homogeneous with two respective factors and to taken the Cobb-Douglas form:

$$Y_S = R^{\alpha_S} L_S^{1-\alpha_S}, 0 < \alpha_S < 1 \qquad (5.1)$$

and

$$Y_U = R^{\alpha_U} L_U^{1-\alpha_U}, 0 < \alpha_U < 1 \qquad (5.2)$$

where Y_S (Y_U)the output of skill-using sector (unskill-using sector), R is the stock of the public intermediate input, and L_S (L_U) is the employment of skilled (unskilled) labor in the skill-using(unskill-using) sector. From two production functions, α_S and α_U are the production elasticity of the public intermediate input stock in the skill-using and unskill-using sector, respectively. Assume the public intermediate input stock serves more significantly in the skill-using sector than in that of the unskill-using sector, and impose the following assumption:

Assumption. For all $R > 0$, $\alpha_S > \alpha_U$.

According to Pi and Zhou(2014), assume the public intermediate input is produced by the aid of unskilled labor only and its production function is a linear function for simplicity's sake and expressed as $Y_R = L_{UR}$, where L_{UR} is the employment of public sector. Following Yanase and Tawada(2012,2017), the accumulation of the public intermediate good is described in the following dynamic equation:

$$\dot{R} = Y_R - \beta R \qquad (5.3)$$

where β is the depreciation rate of the stock of the public intermediate input.

At each moment in time, the market-clearing conditions of the skilled and unskilled labor could be shown as follows:

$$L_S = \overline{L}_S \qquad (5.4)$$

and

$$L_U + L_{UR} = \overline{L}_U \qquad (5.5)$$

where $\overline{L}_S$ and $\overline{L}_U$ are the skilled and unskilled labor endowment, respectively.

Nest consider the behavior of a representative household whose lifetime utility is

$$U = \int_0^{\infty} e^{-\rho t}[\alpha \ln C_S + (1-\alpha)\ln C_U]dt \qquad (5.6)$$

where C_S and C_U are the consumption good of skill-using and unskill-using sector, ρ is the rate of time preference, and $0 < \alpha < 1$ is a parameter.

With no international borrowing or lending, balance of payment implies

$$pY_S + Y_U = pC_S + C_U \qquad (5.7)$$

where p is the world price good of skill-using sector relative to that of unskill-using sector and is assumed to be given and constant over time under a small open economy assumption.

The social planner determines $\{L_S, L_U, L_{UR}, C_S, C_U\}_0^{\infty}$ to maximize a representative household's lifetime utility (5.6) subject to the constraints(5.1), (5.2),(5.3), (5.4),(5.5) and (5.7).

5.3 Static analysis

In this section, we consider the stock of the public intermediate input is constant. Given the stock of the public intermediate input R and its shadow price θ, the static results can be obtained by solving a social planner's dynamic optimization problem. The current-value Hamiltonian function is described as:

$$\begin{aligned} H &= \alpha \ln C_S + (1-\alpha)\ln C_U + \theta(L_{UR} - \beta R) \\ &+ \pi(pR^{\alpha_S} L_S^{1-\alpha_S} + R^{\alpha_U} L_U^{1-\alpha_U} - pC_S - C_U) + \lambda_S(\overline{L}_S - L_S) + \lambda_U(\overline{L}_U - L_U - L_{UR}) \end{aligned}$$

where π is the multiplier associated with income constraint, λ_S and λ_U are the multipliers associated with the full employment constraint of skilled and unskilled labor, respectively.

Solving the current-value Hamiltonian function,

$$yC_S = \alpha Y_S, (1-y)C_U = (1-\alpha)Y_U, \tag{5.8}$$

$$\frac{(1-\alpha_S)y}{L_S} = \lambda_S, \tag{5.9}$$

$$\frac{(1-\alpha_U)(1-y)}{L_U} = \theta = \lambda_U, \tag{5.10}$$

where $y = pY_S/(pY_S + Y_U)$ is the share of skill-using sector in national income. Equation(5.8) describes the optimal consumption of two private good. Equation(5.10) indicates the optimal allocation of unskilled labor between the unskill-using sector and public sector.

The static model thus consists of six equations: (5.1),(5.2),(5.4),(5.5),(5.10) and $y = pY_S/(pY_S + Y_U)$.Six endogenous variables, $Y_S, Y_U, L_U, L_S, L_{UR}, y$, are determined as a function of the state variable R,co-state variable θ, and parameters $\bar{L}_S, \bar{L}_U$ and p. Following Yanase and Tawada (2017), denote these equilibrium solutions as temporary equilibrium[1]. Once Y_S, Y_U, and y are determined, C_S and C_U are determined from (5.8). Totally differentiating the system, we have the following Lemma 5.1.

Lemma 5.1. The equilibrium solutions of $y(R,\theta;\bar{L}_S,\bar{L}_U,p)$, $Y_S(R,\theta;\bar{L}_S,\bar{L}_U,p)$, $Y_U(R,\theta;\bar{L}_S,\bar{L}_U,p)$ and $L_{UR}(R,\theta;\bar{L}_S,\bar{L}_U,p)$ have the following properties

(a)Under the Assumption, $\partial y/\partial R > 0$, $\partial L_{UR}/\partial R > 0$. As for output, $\partial Y_S/\partial R > 0$, while the sign of $\partial Y_U/\partial R$ is ambiguous, depending on the value of α_S and α_U.

(b) $\partial y/\partial \theta > 0$, $\partial Y_U/\partial \theta < 0$, $\partial L_{UR}/\partial \theta > 0$

(c) $\partial y/\partial \bar{L}_S > 0$, $\partial Y_S/\partial \bar{L}_S > 0$, $\partial Y_U/\partial \bar{L}_S < 0$, $\partial L_{UR}/\partial \bar{L}_S > 0$

(d) $\partial y/\partial \bar{L}_U = 0$, $\partial Y_U/\partial \bar{L}_U = 0$, $\partial L_{UR}/\partial \bar{L}_U = 1$

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[1] Here, the equilibrium is the one derived for a given level of the stock of the public infrastructure R, which is given constant at each moment in time.

Proof See Appendix 5.1

The economic intuition behind Lemma 5.1 is as follows. Concerning (a), an increase in the stock of public intermediate input has a positive impact on the outputs of both two private sectors; meanwhile, unskilled labor flows from the unskill-using sector to the public sector to increase the stock of public intermediate input, which has a negative impact on the production of unskill-using sector. If the difference in production elasticity of the public intermediate input stock between the two sectors is not very large, the positive effect outweighs the negative effect on output and $\partial Y_U / \partial R > 0$. However, if α_S is much larger than α_U, which means the unskill-using sector benefits little from more provision of public intermediate input, the negative effect dominates the change and $\partial Y_U / \partial R < 0$. Though an increase in *R* has a positive effect on output of private sectors, the skill-using sector gains more than that of unskill-using sector under the Assumption, $\partial y / \partial R > 0$. Given the production function of public intermediate input, one unit of unskilled labor could produce one unit of public intermediate input, and an increase in *R* needs more employment of public sector and $\partial L_{UR} / \partial R > 0$. As for (b), a rise in θ promotes the production of public intermediate input, thus $\partial L_{UR} / \partial \theta > 0$. Meanwhile, unskilled labor flows into the public sector and unskill-using sector experiences a lose in output because of $0 < \alpha_U < 1$, and drops the share of unskill-using sector in national income, and $\partial y / \partial \theta > 0$. Regarding (c), adding the endowment of skilled labor will expand the skill-using sector and increase the demand of public intermediate input. the unskill-using sector drops its output because of the outflow of unskilled labor. Finally,(d) describes the effects of an increase in the endowment of unskilled labor. Since the contribution of one additional of unskilled labor employed in the public sector is greater than that allocated in the unskill-using sector, increased unskilled labor is wholly absorbed by the public sector and has no impacts on private output.

It should be noted that even though the chapter employs the framework of Yanase and Tawada(2017), the main results are different. Since the labor is homogenous in the Yanase and Tawada(2017), there is no distinction between skilled and unskilled labor. An increase in the labor endowment enlarges the output of both two private sectors, as shown in Lemma 4 of the Yanase and Tawada(2017). However, in the established model, an increase in skilled labor enlarges the output of skill-using sector and shrinks the output of unskill-using sector; an inflow of unskilled labor has no impact on output of private sectors in the short term.

Next, consider the wage inequality between skilled and unskilled labor. The wage of skilled labor w_S and wage of unskilled labor w are expressed as $w_S = (1-\alpha_S) pY_S / L_S$ and $w = (1-\alpha_U) Y_U / L_U$, respectively.

Proposition 5.1. In the temporary equilibrium, an inflow of skilled labor decreases the wage inequality while an inflow of unskilled labor has no effect on it.

Proof. Using the results in the Appendix A.1, we can get

$$\frac{dw_S}{d\bar{L}_S} = (1-\alpha_S) p \frac{\bar{L}_S\, \partial Y_S / \partial \bar{L}_S - Y_S}{\bar{L}_S^{\,2}} = -\frac{\alpha_S (1-\alpha_S) pY_S}{\bar{L}_S^{\,2}} < 0$$

and

$$\frac{dw}{d\bar{L}_S} = (1-\alpha_U) \frac{L_U\, \partial Y_U / \partial \bar{L}_S - Y_U\, \partial L_U / \partial \bar{L}_S}{L_U^{\,2}} = (1-\alpha_U) \frac{L_U\, \partial Y_U / \partial \bar{L}_S + Y_U\, \partial L_{UR} / \partial \bar{L}_S}{L_U^{\,2}} > 0$$

The impact of a change of skilled labor endowment on the skilled-unskilled wage inequality can be expressed as:

$$\frac{d(w_S - w)}{d\bar{L}_S} < 0$$

Similarly, we have $dw_S / d\bar{L}_U = 0$, $dw / d\bar{L}_U = 0$ and $d(w_S - w) / d\bar{L}_U = 0$.

The economic intuition behind Proposition 5.1 can be explained as follows. An inflow of skilled labor will raise the supply of skilled labor in the economic system, and as a result, its wage will fall. However, from the Lemma 5.1, a larger endowment of skilled labor augments the public sector and move unskilled labor from the unskill-using sector to the public sector, which decreases the employment of unskilled labor in unskill-using sector and increases its marginal product and its wage. Thus, an inflow of skilled labor reduces wage inequality. An inflow of unskilled labor has no impact on skilled wage since the stock of public intermediate input is constant. An inflow of unskilled labor increases unskilled labor supply; however, the increased unskilled labor wholly locates in the public sector to produce the intermediate input and has no impacts on private output in the short term. Therefore, the wages of skilled labor and unskilled labor stay the same.

5.4 Dynamic analysis

In this section, the public intermediate input be accumulated by the production of public sector and the its stock changes. The dynamic results are characterized by the following adjoint equation and the transversality condition:

$$\dot{\theta} = (\rho + \beta)\theta - \frac{\alpha_S y + \alpha_U (1-y)}{R} \tag{5.11}$$

$$\lim_{t\to\infty} e^{-\rho t}\theta(t)R(t) = 0 \tag{5.12}$$

In the (5.11), the first term of the right-hand side, $(\rho+\beta)\theta$, is the sum of the intertemporal cost($\rho\theta$) and the replacement cost of depreciated public intermediate input($\beta\theta$). The second term, $[\alpha_S y + \alpha_U (1-y)]/R$, is the sum of two private sectors' marginal revenue product (in GDP term) of public intermediate input. And the left-hand side, $\dot{\theta}$, is the gain (or loss if negative) of the public intermediate input. Rewrite the (5.11) as $\dot{\theta} + [\alpha_S y + \alpha_U (1-y)]/R = (\rho+\beta)\theta$, which states that the optimal allocation of public intermediate input balances benefits and cost. The dynamic equilibrium (5.11) can be satisfied under the competitive decentralized economy by incorporating the Lindahl pricing rule for financing the cost of public good (See Appendix 5.2).

Using the results in section 3 and substituting them into (5.3) and (5.11),

$$\dot{R} = Y_R(R, \theta; \overline{L}_S, \overline{L}_U, p) - \beta R \tag{5.13}$$

and

$$\dot{\theta} = (\rho+\beta)\theta - \frac{\alpha_S y(R,\theta;\overline{L}_S,\overline{L}_U,p) + \alpha_U (1 - y(R,\theta;\overline{L}_S,\overline{L}_U,p))}{R} \tag{5.14}$$

The dynamic path is characterized by $\{R(t), \theta(t)\}_0^\infty$ satisfying (5.11) and (5.12). Denote $\overline{z}$ as a steady state solution for a variable *z*, and ($\overline{R}, \overline{\theta}$) is a solution for $\dot{R} = \dot{\theta} = 0$. In light of (5.13) and (5.14), conditions for steady-state equilibrium are given by:

$$L_{UR} \equiv Y_R(R, \theta; \overline{L}_S, \overline{L}_U, p) = \beta R \tag{5.15}$$

and

$$(\rho+\beta)\theta=\frac{\alpha_S y(R,\theta;\bar{L}_S,\bar{L}_U,p)+\alpha_U(1-y(R,\theta;\bar{L}_S,\bar{L}_U,p))}{R} \tag{5.16}$$

The solutions of the dynamic model can be arrived by solving the (5.1), (5.2), (5.4), (5.5), (5.10), $y=pY_S/(pY_S+Y_U)$, (5.15) and (5.16). Using (5.4), (5.5) and (5.15), the production function of skill-using and unskill-using sector can be written as

$$Y_S=\left(\frac{L_{UR}}{\beta}\right)^{\alpha_S}\bar{L}_S^{\,1-\alpha_S},\quad Y_U=\left(\frac{L_{UR}}{\beta}\right)^{\alpha_U}\left(\bar{L}_U-L_{UR}\right)^{1-\alpha_U}. \tag{5.17}$$

Substituting (5.17) into $y=pY_S/(pY_S+Y_U)$,

$$\frac{1-y}{y}=\left(\frac{L_{UR}}{\beta}\right)^{\alpha_U-\alpha_S}\frac{(\bar{L}_U-L_{UR})^{1-\alpha_U}}{p\bar{L}_S^{1-\alpha_S}} \tag{5.18}$$

which implicitly determines y as a function of L_{UR}. Denote this as $y=\xi(L_{UR})$, which has $\lim_{L_{UR}\to 0}\xi(L_{UR})=0$ and $\lim_{L_{UR}\to\bar{L}_U}\xi(L_{UR})=1$ and $\xi'(L_{UR})>0$ under the Assumption. Using (5.5), (5.10) and (5.16), we can get

$$y=1-\frac{\beta\alpha_S(\bar{L}_U-L_{UR})}{(\rho+\beta)(1-\alpha_U)L_{UR}+\beta(\alpha_S-\alpha_U)(\bar{L}_U-L_{UR})} \tag{5.19}$$

From (5.19), we get $y=\varsigma(L_{UR})$, and $\lim_{L_{UR}\to 0}\varsigma(L_{UR})=-\alpha_U/(\alpha_S-\alpha_U)<0$, $\lim_{L_{UR}\to\bar{L}_U}\varsigma(L_{UR})=1$ and $\varsigma'(L_{UR})>0$. Thus, the system can be reduced to (5.18) and (5.19). Moreover, we can get $\xi'(L_{UR})<\varsigma'(L_{UR})$. Therefore, there exists a unique pair of steady-state solutions $(L_{UR},y)\in(0,\bar{L}_U)\times(0,1)$. C_S and C_U can be obtained once we get these solutions through (5.8).

Next, we consider the stability of the steady state. Linearizing the dynamic system (5.13) and (5.14) around the steady state, we have

$$\begin{pmatrix}\dot{R}\\ \dot{\theta}\end{pmatrix}=\begin{pmatrix}\partial L_{UR}/\partial R-\beta & \partial L_{UR}/\partial\theta\\ \frac{\alpha_S y+(1-y)\alpha_U}{R^2}-(\alpha_S-\alpha_U)\frac{\partial y}{\partial R} & \rho+\beta-\frac{(\alpha_S-\alpha_U)}{R}\frac{\partial y}{\partial\theta}\end{pmatrix}\begin{pmatrix}R-\bar{R}\\ \theta-\bar{\theta}\end{pmatrix} \tag{5.20}$$

The determinant of the Jacobian matrix in (5.20) is denoted as J, and substituting the results in Appendix 5.1, we get

$$J=-\frac{y(1-\alpha_S)L_U(\alpha_S-\alpha_U)+\alpha_U L_{UR}[1-y(1-\alpha_S)]+\alpha_U L_U}{\theta R^2[1-y(1-\alpha_U)]}<0$$

which indicates that the characteristic roots are of opposite signs. Therefore, the steady state is a local saddle point.

The steady-state solution depends on the endowment of skilled and unskilled labor. Next, we examine how a change of skilled and unskilled labor endowment affect the steady-state stock of public intermediate input and its shadow price. We use Lemma 5.2 to express the impacts.

Lemma 5.2. An inflow of the skilled and unskilled labor raise the stock of public intermediate input and drop its shadow price in the steady state equilibrium.
Proof See Appendix 5.3

A larger endowment of unskilled labor brings more unskilled labor to produce the public intermediate input and results in a greater stock of public intermediate input. Here, it should be noted that even though skilled labor is not an input in the production of public intermediate input, a higher skilled labor endowment also contributes to more stock of public intermediate input. From the Lemma 5.1, an inflow of skilled labor moves unskilled labor from the unskill-using sector to public sector, which leads to more production of public sector and larger amount of stock of public intermediate input.

Now we proceed to the analysis of wage inequality in the steady state equilibrium. Different with the static case where the stock of public intermediate input is constant, in the steady state equilibrium, an increase in the endowment of skilled and unskilled labor can affect the stock of public intermediate input and its shadow price, which impact the wages indirectly. First, examine the impact of an inflow of skilled labor,

$$\frac{dw_S}{d\bar{L}_S}=\frac{\alpha_S(1-\alpha_S)p}{\bar{L}_S^{\,2}}\left(\frac{\bar{L}_S}{R}\frac{\partial\bar{R}}{\partial\bar{L}_S}-1\right)=\frac{\alpha_S(1-\alpha_S)p}{\bar{L}_S^{\,2}}\frac{\alpha_U\bar{L}_U[1-y(1-\alpha_S)]}{\theta R^2 J[1-y(1-\alpha_U)]}<0$$

and

$$\frac{dw}{d\bar{L}_S}=\frac{\alpha_U(1-\alpha_U)Y_U}{L_U[1-y(1-\alpha_U)]}\left[\frac{y(1-\alpha_S)}{\bar{L}_S}+\frac{1-y(1-\alpha_S)}{R}\frac{\partial\bar{R}}{\partial\bar{L}_S}+\frac{1}{\theta}\frac{\partial\bar{\theta}}{\partial\bar{L}_S}\right]>0$$

Thus, we can get $d(w_S - w)/d\bar{L}_S < 0$. Considering the impact of an inflow of unskilled labor,

$$\frac{dw_S}{d\bar{L}_U} = \frac{\alpha_S(1-\alpha_S)pY_S}{\bar{L}_S R}\frac{\partial \bar{R}}{\partial \bar{L}_U}$$

$$= \frac{\alpha_S(1-\alpha_S)pY_S}{\bar{L}_S}\frac{\alpha_U[1-y(1-\alpha_S)]}{y(1-\alpha_S)L_U(\alpha_S-\alpha_U)+\alpha_U L_{UR}[1-y(1-\alpha_S)]+\alpha_U L_U} > 0,$$

$$\frac{dw}{d\bar{L}_U} = \frac{(1-\alpha_U)Y_U}{L_U^2}\left[1+\frac{\alpha_U L_U[1-y(1-\alpha_S)]}{R[1-y(1-\alpha_U)]}\frac{\partial \bar{R}}{\partial \bar{L}_U}+\frac{\alpha_U L_U}{\theta[1-y(1-\alpha_U)]}\frac{\partial \bar{\theta}}{\partial \bar{L}_U}\right]$$

$$= \frac{(1-\alpha_U)Y_U}{L_U^2}\frac{(1-\alpha_S)yL_U(\alpha_S-\alpha_U)+\alpha_U L_{UR}[1-y(1-\alpha_S)]+\alpha_U L_U[1-\alpha_S y(1-\alpha_S)]}{y(1-\alpha_S)L_U(\alpha_S-\alpha_U)+\alpha_U L_{UR}[1-y(1-\alpha_S)]+\alpha_U L_U} > 0$$

and

$$\frac{d(w_S-w)}{d\bar{L}_U} = \frac{\alpha_U(\alpha_S w_S - w)-(w_S-w)\alpha_S\alpha_U y(1-\alpha_S)-yw(1-\alpha_S)(\alpha_S-\alpha_U)-w\alpha_U(1-y+y\alpha_S)L_{UR}/L_U}{y(1-\alpha_S)L_U(\alpha_S-\alpha_U)+\alpha_U L_{UR}[1-y(1-\alpha_S)]+\alpha_U L_U}$$

the sign of which is ambiguous, depending on the value of α_S. Note that α_S is the production elasticity of the public intermediate input stock in the skill-using sector, if α_S is small enough, $d(w_S - w)/d\bar{L}_U < 0$.

Proposition 5.2. *In the steady state, an inflow of skilled labor decreases the wage inequality while the impact of an inflow of unskilled labor on wage inequality is ambiguous. If the production elasticity of the public intermediate input stock in the skill-using sector is small enough, an inflow of unskilled labor narrows down wage inequality.*

We will explain the economic mechanism behind Proposition 5.2. An increase in skilled labor endowment raises the stock of public intermediate input which will generate the positive effect for wage of skilled and unskilled labor, as well as the negative effect for skilled labor wage. Under the model, the negative effect dominates the interaction and wage of skilled labor drops as a result of an increase in the supply of skilled labor. As for wage of unskilled labor, from the Lemma 5.1, an inflow of skilled labor raises the demand for unskilled labor. Because of the positive effect of the stock of public intermediate input and increased demand, the wage of unskilled labor rises. Thus, the wage inequality reduces as a result of an inflow of skilled labor.

An inflow of unskilled labor increases skilled wage because of the higher stock of public intermediate input from the Lemma 5.2. Concerning the wage of unskilled labor, a larger endowment of unskilled labor has two effects on its wage: productivity effect due to the stock of public intermediate input and the supply effect. However, the latter effect exerts no impact on its wage. According to the Lemma 5.1, the increased unskilled labor wholly absorbed by the public sector and the wage of unskilled labor increases as a result of an inflow of unskilled labor. As for its impact on the wage inequality, the direction is ambiguous since an inflow of unskilled labor raises the wages of both skilled and unskilled labor. If the production elasticity of the public intermediate input stock in the skill-using sector is small enough, implying that the public intermediate input stock serves little significantly in the skill-using sector, the impact of an inflow of unskilled labor on skilled wage will not be too large compared to that of unskilled labor, and wage inequality will narrow down.

5.5 Concluding remarks

Traditionally, an inflow of skilled labor will reduce the wage inequality while an inflow of unskilled will widen it. Previous papers largely ignore the role of public intermediate input in wage inequality. This chapter incorporates the public intermediate input in "unpaid factor" type and investigates the impact of an inflow of skilled and unskilled labor on wage inequality by establishing a model with two private sectors and one public sector. The public intermediate input can be accumulated and its accumulated stock serves as a public good for private production. From the analysis, in the steady state equilibrium, an increase in the skilled and unskilled labor endowment raise the stock of public intermediate input. And an inflow of skilled labor reduces the wage of skilled labor and raises wage of unskilled labor, and an inflow of unskilled labor increases both wages of skilled and unskilled labor. Concerning their impacts on the wage inequality, an inflow of skilled labor decreases the wage inequality while the result of an inflow of unskilled labor on the wage inequality is ambiguous. If the production elasticity of the public intermediate input stock in the skill-using sector is small enough, an inflow of unskilled labor narrows down wage inequality. Since the public intermediate input is playing an increasing role in both developing and developed countries, the findings of this chapter have revealed a possibility that the conventional emigration policy of unskilled labor may not succeed in altering the wage inequality, especially for developed countries with well developed public infrastructure. According to the results, the governments of such countries should be indifferent to such an influx of unskilled labor. However, for developing countries with deficient public infrastructure, governments should not only pay attention to brain drain but also take appropriate measures to retain unskilled labor.

To our knowledge, this chapter is the first to analyze in an integrated framework the role of international labor movement on the wage of skilled and unskilled labor and wage inequality by a dynamic treatment of the public intermediate input. Admittedly, our model has some limitations and special in some of its assumptions. For example, the chapter assumes that the production elasticity of the public intermediate input stock in the skill-using sector is larger than that in the unskill-using sector, which is an empirical question. However, little empirical studies have tested the elasticity of public intermediate input stock in skill-using and unskill-using sector. Another limitation is the production function of the public sector and assumes its production function is a linear function. In general, the production function is assumed to be strictly concave and satisfies Inada conditions. However, the general production function makes the analysis much more complicated, especially in the dynamic analysis. Using the linear function, we can clarify some economic mechanisms that explain why an inflow of skilled and unskilled labor can bring the movement of unskilled labor between unskill-using sector and public sector and change the wage of skilled and unskilled labor.

We can possibly extend our analysis in the following three respects. Firstly, this chapter considers the impacts of international factor movement on wage inequality with the presence of a public intermediate input. As mention in the introduction section, many scholars hold that international goods trade may also contribute to the rising wage inequality. Then, how international trade affects wage inequality is one direction for future research. Secondly, in the model, all private firms can use the stock of public intermediate input commonly for production without arising congestion issue. In reality, the contribution of stock of public intermediate input (such as transportation and communication system, water supply and irrigation, etc.) to private sectors is subject to congestion. We can introduce the congestion issue by assuming that contribution of public intermediate input is decreasing in the use of private factors. Thirdly, existing theoretical papers on public intermediate input have adopted the full-employment framework and ignored the problem of unemployment, particularly that of unskilled labor. An inflow of unskilled labor may significantly affect the overall employment, wages, and skilled–unskilled wage inequality. Therefore, such an embeddedness may bring about some new insights that are different from the traditional literature.

Appendix

Appendix 5.1 Proof of Lemma 5.1

Totally differentiating the production function of skill-using sectors,

$$dY_S = \frac{(1-\alpha_S)Y_S}{L_S} d\bar{L}_S + \frac{\alpha_S Y_S}{R} dR \tag{A-1}$$

Totally differentiating $y = pY_S/(pY_S + Y_U)$ and substituting (A-1), and obtain

$$\frac{1}{Y_U} dY_U + \frac{1}{y(1-y)} dy = \frac{(1-\alpha_S)}{L_S} d\bar{L}_S + \frac{\alpha_S}{R} dR \tag{A-2}$$

Using (5.10), the (5.5) can be written as $(1-\alpha_U)(1-y) + \theta L_{UR} = \theta \bar{L}_U$ .Totally differentiating this equation, and get

$$-\frac{(1-\alpha_U)}{\theta} dy + dL_{UR} = \frac{\bar{L}_U - L_{UR}}{\theta} d\theta + d\bar{L}_U \tag{A-3}$$

Using (5.10), the (5.2) can be written as $Y_U = R^{\alpha_U} \left[(1-\alpha_U)(1-y)\theta^{-1} \right]^{1-\alpha_U}$ .Totally differentiating this equation, and get

$$\frac{1}{Y_U} dY_U + \frac{1-\alpha_U}{1-y} dy = \frac{\alpha_U}{R} dR - \frac{1-\alpha_U}{\theta} d\theta \tag{A-4}$$

From (A-2) and (A-4), get

$$dY_U = -\frac{yY_U(1-\alpha_S)(1-\alpha_U)}{[1-y(1-\alpha_U)]\bar{L}_S} d\bar{L}_S - \frac{Y_U[y\alpha_S(1-\alpha_U)-\alpha_U]}{[1-y(1-\alpha_U)]R} dR - \frac{Y_U(1-\alpha_U)}{[1-y(1-\alpha_U)]\theta} d\theta \tag{A-5}$$

$$dy = \frac{y(1-\alpha_S)(1-y)}{[1-y(1-\alpha_U)]\bar{L}_S} d\bar{L}_S + \frac{y(\alpha_S-\alpha_U)(1-y)}{[1-y(1-\alpha_U)]R} dR + \frac{y(1-y)(1-\alpha_U)}{[1-y(1-\alpha_U)]\theta} d\theta \tag{A-6}$$

$$dL_{UR} = \frac{yL_U(1-\alpha_S)}{[1-y(1-\alpha_U)]\bar{L}_S} d\bar{L}_S + \frac{yL_U(\alpha_S-\alpha_U)}{[1-y(1-\alpha_U)]R} dR + \frac{L_U}{[1-y(1-\alpha_U)]\theta} d\theta + d\bar{L}_U \tag{A-7}$$

From (A-5), the sign of $\partial Y_U / \partial R$ is ambiguous, depending the value of α_S and α_U. If the difference in production elasticity of the public intermediate input stock between the two sectors is not very large, $\partial Y_U / \partial R > 0$.

Appendix 5.2 Decentralized equilibrium result

Consider a competitive economy with two private sectors and one public sector. Assume the government finances the cost of public intermediate good, wL_{UR}, by Lindahl pricing rule $t_S pY_S + t_U Y_U$, where $t_i (i = S, U)$ is the production tax rate imposed in *i* sector. Assume that the (instantaneous) utility function of a representative household is in Cobb-Douglas type $U(C_S, C_U) = \gamma \ln C_S + (1-\gamma)\ln C_U$. The household's income, I ,consists of profits, $\Pi_S = (1-t_S)pY_S - w_S L_S$ and $\Pi_U = (1-t_U)Y_U - wL_U$,and wage reward $w_S L_S + w(L_U + L_{UR})$. Thus, $I = pY_S + Y_U$. Under the budget constraint, the optimal consumption amount is obtained as $C_S = \gamma I / p$ and $C_U = (1-\gamma)I$. Profit maximization conditions for two private sectors are $(1-t_S)(1-\alpha_S)pY_S/L_S = w_S$ and $(1-t_U)(1-\alpha_U)Y_U/L_U = w$.

So far, public sector's budget constraint $wL_{UR} = t_S pY_S + t_U Y_U$, two private sectors' profit maximization conditions, (5.1), (5.2), (5.4), (5.5) jointly determine the equilibrium values for $w, w_S, Y_S, Y_U, L_S, L_U, L_{UR}$,for given R in temproary equilibrium model, t_S and t_U are policy variables. After solving the model and obtaining the results of Y_S and Y_U, C_S and C_U could be arrived correspondingly. From C_S and C_U, the indirect utility is $v(p, I) = \ln I - \gamma \ln p + \Omega$, where $\Omega = \gamma \ln \gamma + (1-\gamma)\ln(1-\gamma)$.

The government chooses the tax time path t_S and t_U in order to maximize the discounted sum of the utility $\int_0^\infty e^{-\rho t}[\ln(pY_S + Y_U) - \gamma \ln p + \Omega]dt$ subject to the (5.3). The current-value Hamiltonian function is described as:

$$H^A = \ln(pY_S + Y_U) - \gamma \ln p + \Omega + \Gamma(L_{UR} - \beta R)$$
$$+ w\left[\bar{L}_U - \left(\frac{Y_U}{R^{\alpha_U}}\right)^{\frac{1}{1-\alpha_U}} - L_{UR}\right] + w_S\left[\bar{L}_S - \left(\frac{Y_S}{R^{\alpha_S}}\right)^{\frac{1}{1-\alpha_S}}\right]$$

where Γ is the shadow price of public intermediate input. Solving the H^A, the optimal tax should satisfy $t_S = t_U = 1 - 1/(pY_S + Y_U)$. The adjoint equation is $\dot{\Gamma} = (\rho+\beta)\Gamma - \left[y\alpha_S + (1-y)\alpha_U\right]/R$. Setting $\Gamma = \theta$, the adjoint equation is identical to (5.11), and the centralized equilibrium results can be satisfied under decentralized competitive economy with the Lindahl rule for the provision of public intermediate input.

Appendix 5.3 Proof of Lemma 5.2

Denote the right-hand side of (5.13) as $\Phi(R,\theta;\bar{L}_S,\bar{L}_U,p) = Y_R - \beta R$ and that of (5.14) as $\Psi(R,\theta;\bar{L}_S,\bar{L}_U,p) = (\rho+\beta)\theta - [\alpha_S y + \alpha_U(1-y)]/R$. Totally differentiating the steady state conditions,

$$\begin{pmatrix} \partial L_{UR}/\partial R - \beta & \partial L_{UR}/\partial\theta \\ \dfrac{\alpha_S y + (1-y)\alpha_U}{R^2} - \dfrac{(\alpha_S - \alpha_U)}{R}\dfrac{\partial y}{\partial R} & \rho + \beta - \dfrac{(\alpha_S - \alpha_U)}{R}\dfrac{\partial y}{\partial\theta} \end{pmatrix}\begin{pmatrix} d\bar{R} \\ d\bar{\theta} \end{pmatrix} = -\begin{pmatrix} \partial L_{UR}/\partial\bar{L}_S \\ -\dfrac{(\alpha_S-\alpha_U)}{R}\dfrac{\partial y}{\partial\bar{L}_S} \end{pmatrix} d\bar{L}_S - \begin{pmatrix} 1 \\ 0 \end{pmatrix} d\bar{L}_U \tag{A-8}$$

Solving (A-8), we have

$$d\bar{R} = -\frac{\left(\rho+\beta-\dfrac{\alpha_S-\alpha_U}{R}\dfrac{\partial y}{\partial\theta}\right)\dfrac{\partial L_{UR}}{\partial\bar{L}_S} + \dfrac{(\alpha_S-\alpha_U)}{R}\dfrac{\partial L_{UR}}{\partial\theta}\dfrac{\partial y}{\partial\bar{L}_S}}{J} d\bar{L}_S - \frac{\left(\rho+\beta-\dfrac{\alpha_S-\alpha_U}{R}\dfrac{\partial y}{\partial\theta}\right)}{J} d\bar{L}_U \tag{A-9}$$

and

$$d\bar{\theta} = \frac{\left(\dfrac{\partial L_{UR}}{\partial R}-\beta\right)\dfrac{(\alpha_S-\alpha_U)}{R}\dfrac{\partial y}{\partial\bar{L}_S} + \dfrac{\partial L_{UR}}{\partial\bar{L}_S}\left[\dfrac{\alpha_S y + (1-y)\alpha_U}{R^2} - \dfrac{(\alpha_S-\alpha_U)}{R}\dfrac{\partial y}{\partial R}\right]}{J} d\bar{L}_S + \frac{\dfrac{\alpha_S y + (1-y)\alpha_U}{R^2} - \dfrac{(\alpha_S-\alpha_U)}{R}\dfrac{\partial y}{\partial R}}{J} d\bar{L}_U \tag{A-10}$$

From (A-9), we get $d\bar{R}/d\bar{L}_S > 0$ and $d\bar{R}/d\bar{L}_U > 0$, $d\bar{\theta}/d\bar{L}_S < 0$ and $d\bar{\theta}/d\bar{L}_U < 0$.

Chapter 6

Manufacturing and agricultural pollution, private mitigation and wage inequality in the presence of pollution externalities

This chapter incorporates manufacturing and agricultural pollution into a three-sector general equilibrium model with pollution externalities both on agricultural production and labor health. Manufacturing generates pollution that affects agricultural production and health; while agriculture employs the pollutant as a factor for production which only affects health. Under the framework, we investigate impacts of environmental protection policies and a rise in self-mitigation cost of skilled and unskilled labor on wage inequality. A larger environmental tax expands wage gap if partial elasticity of substitution between labor and dirty input in urban unskilled sector is small enough. More restrictive agricultural pollutants control narrows down the wage gap. The impact of an increase in self-mitigation cost of skilled labor on wage inequality is ambiguous, depending on the factors substitution in agriculture and the elasticity of manufacturing pollution on agricultural production; while a larger self-mitigation cost of unskilled labor brings down wage gap.

6.1 Introduction

Pollution is one of the most severe challenges facing developing countries. In the last few years development economists have engaged in a discussion over possible effects of environmental policies on environment and whole economy[1]. They assumed that only manufacturing production causes emission of pollution. The harmful substances emitted pollute water and soil for agricultural use through atmosphere, rivers and other media, exerting negative effects on agriculture. Perhaps one of the most serious limitations of such theoretical works is that it ignores that agricultural practices also generate in-negligible pollution and bring a massive impact on developing world. Pollution by agricultural practices has come up ever since the demand for food has increased. To increase the yield of farms,farmers have to resort to additional chemical

[1] For theoretical papers, see Copeland and Taylor(1999), Beladi and Chao (2006b), Kondoh and Yabuuchi (2012), Nakamura (2013), Li and Zhou(2015).

fertilizers, pesticides, weedicides, nutrient-laden feed and many such practices which changed the way farming was done traditionally. Take China for example. In 2010, government released results of national pollution census and agriculture was a bigger source of water pollution in China than manufacturing.

Pollution, both from manufacturing and agriculture, exerts a negative effect on production and labor health. According to World Bank(2016a), pollution costs trillions of dollars a year and severely impedes development in many developing countries(China lost nearly 10% of its GDP, India 7.69% and Sri Lanka and Cambodia roughly 8% in 2013). Moreover, pollution also exposes a great threat to labor health, especially in developing countries[2]. Facing the severe environmental problem, governments adopt certain policies to remedy negative externalities. Regarding manufacturing pollution, an environmental tax is a common preservation policy and has a substantial cost advantage over other instruments such as pollution control. Its effects are also explored by many scholars from different perspectives (Williams,2002; Daitoh,2008; Yanase,2010; Kuo et al ,2018). As for solution of agricultural pollution, Ahodo and Svatonova (2014) discussed the advantages and disadvantages of economic instruments to mitigate agricultural pollution in developed countries. However, with the undeveloped market, agricultural pollutants control is the most direct and effective approach for developing world. Some developing countries launched a program to replace chemical fertilizes with organic alternatives to curb agricultural pollutants[3].

Environmental protection(a rise in environmental tax and more restrictive agricultural pollutants control) and a greater negative effect of pollution on health (an increase in the cost of self-mitigation to prevent or cure the bad effect) affect domestic employment and wage in developing countries, and exert an impact on inequality between skilled and unskilled labor consequently. Academics have already investigated this issue and focused on international factor mobility to explain it (Marjit and Kar, 2005; Beladi et al, 2008; Chaudhuri, 2008). Until recently, one line of research has paid attention to domestic factors to explain it. In these studies, a variety of mechanisms are proposed to model impacts of a change in a domestic factor

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[2] Pollution was responsible for 9 million premature deaths in 2015, and nearly all of these deaths (92%) took place in developing nations (Das and Horton, 2018).

[3] For example, China's Ministry of Agriculture(MOA) released an action plan that key growing areas for fruit, greenhouse vegetables and tea should cut chemical fertiliser and pesticideuse by 2020 (MOA,2015a;MOA,2015b).

on wage gap such as public infrastructure provision(Pi and Zhou,2012),,taxation on labor income (Anwar and Sun, 2015), privatization(Chao et al, 2016),capital market distortion(Pi and Chen, 2016), skill-biased technical change (Behar, 2016), pollution control(Pi and Zhang,2017). However, on the one hand, existing literature on wage inequality neglects to consider the issue of the environmental tax and agricultural pollutants control, and thus fails to analyzes effects of environmental tax and agricultural pollutants control on wage gap. On the other hand, previous studies on bad externalities of pollution in developing countries focus on bad effects on agricultural production (Kondoh and Yabuuchi,2012; Pi and Zhang, 2017;Li and Wu, 2018) and pay little attention to its effect on labor health. When health is affected by pollution and labor's productivity reduces which drops the total available labor in the market, wages are also affected. Thus, the role of the private self-mitigation effort in determining wage gap has largely ignored.

In order to fill current research gap and address issues mentioned above, this chapter establishes a three-sector general equilibrium model to investigate impacts of an increase in environmental tax and self-mitigation cost and more restrictive agricultural pollutants control on wage inequality. Manufacturing sector generates pollution that affects agricultural production and labor health; while the agriculture employs the pollutant as a factor for production which only affects labor health. Labor have to spend time or money,i.e self-mitigation cost, to curb or prevent bad effects. We find that a larger environmental tax expands wage gap if partial elasticity of substitution between unskilled labor and dirty input in unskilled sector is small enough. More restrictive agricultural pollutants control narrows down it. The impact of a greater self-mitigation cost of skilled labor on wage inequality is ambiguous, depending on factors substitution in the agriculture and the elasticity of manufacturing pollution on agricultural production; while a larger self-mitigation cost of unskilled labor brings down wage gap.

The rest is organized as follows: we establish a theoretical model in Section 6.2. Section 6.3 investigates effects of environmental protection policies and a larger of self-mitigation cost on wage inequality. Concluding remarks are made in Section 6.4.

6.2. The model

Consider a small open economy that composes of three sectors: an urban skilled sector, an urban unskilled sector and an agriculture sector. The skilled sector(sector 1) uses skilled labor L_{S1} and capital K_1 to produce an exportable good X_1, while unskilled sector (sector 2) uses unskilled labor L_{U2}, capital K_2 and dirty input *D* to produce an import-competing good X_2 [4]. Production in unskilled sector generates pollution *E* and damages environment. The agriculture (sector 3) employs unskilled labor L_{U3} and pollutant factor *T* to produce X_3. Furthermore assume that agricultural production depends on *E*: a smaller *E* brings more agricultural output. Skilled labor, dirty input and pollutant factor are specific to the skilled sector, unskilled sector and agriculture, respectively. Capital moves freely between skilled and unskilled sector; however, unskilled labor moves imperfectly between unskilled sector and agriculture due to the rigid downward wage in unskilled sector. Since skilled labor is a shortage in developing countries, urban unemployment only exists among unskilled labor and the movement of unskilled labor from agriculture to unskilled sector satisfies Harris-Todaro equilibrium condition(Harris and Todaro, 1970). The production functions are $X_1 = F^1(L_{S1}, K_1)$, $X_2 = F^2(L_{U2}, K_2, D)$, and $X_3 = g(E)F^3(L_{U3}, T)$, where three functions satisfy neoclassical properties (i.e., strict quasi-concavity and linear homogeneity); *g*(*E*) expresses the impact of *E* on the agriculture, and $g'(E) < 0$, $g''(E) > 0$, $g(0) = 1$, and $0 < g(E) < 1$.

For simplicity, assume the dirty input market does not exist. To control externality of the dirty input, government levies a corrective tax ρ of per unit of the dirty input. All the goods and factor markets,except unskilled labor market, are perfectly competitive. The cost minimization conditions are described as:

$$p_1 = a_{S1}w_S + a_{K1}r \tag{6.1}$$

$$p_2 = a_{U2}\overline{w}_U + a_{K2}r + a_{D2}\rho \tag{6.2}$$

$$g(E) = a_{U3}w_U + a_{T3}\tau \tag{6.3}$$

where p_1 and p_2 are good prices of skilled and unskilled sector relative to that of agriculture, respectively, and p_1 and p_2 are assumed to be given and constant. $a_{ij}(i = S, U, K, D; j = 1, 2)$ represents that factor *i* used in producing one unit of good in

[4] Here, the model treats the dirty input as an input in the production of the unskilled sector. The similar setting could refer to Daitoh(2008), Pi and Zhang (2017), and Kuo et al, (2017) .

j th sector. $a_{i3}(i=U,T)$ represents factor i used in producing one unit of goods (without pollution effect) in agriculture (e.g., $a_{U3}=L_{U3}/F^3$). w_S is elastic skilled wage . $\overline{w}_U$ is fixed unskilled wage in the unskilled sector. w_U is fully elastic wage in agriculture. r is interest rate. ρ is tax per capita and represents price of dirty input. τ indicates price of the agricultural pollutants.

Use $\lambda = L_{UU}/(a_{U1}X_1 + a_{U2}X_2)$ to denote unemployment rate in urban region. The unskilled labor market equilibrium condition is given by

$$w_U\left(1+\lambda\right)=\overline{w}_U \tag{6.4}$$

The unskilled sector and agricultural pollutants generate manufacturing pollution and agricultural pollution, respectively[5]. Assume manufacturing pollution is generated during the production process of unskilled sector and δ expresses units of pollution generated by one unit of production, and $0<\delta<1$, while agricultural pollution is the amount of the pollutant factor T[6]. Thus, manufacturing pollution $E=\delta X_2$. As previous mentioned, pollution discussed in this chapter affects skilled and unskilled labor health, either causing labor to spend time sick or by reducing its productivity. Such kinds of impacts shift part labor away from productive activities, leading to a reduction in the available labor. Following Williams(2002), assume the pollution affects labor health, resulting in either reducing the amount or productivity of total labor. More specific, the pollution (E+T) drops $t_S(E+T)$ and $t_U(E+T)$ amounts of skilled and unskilled labor away from skilled and unskilled labor market, respectively. $t_i(i=S,U)$ is the per capital effect of pollution on i type labor, and $t_i>0$. $t_i(i=S,U)$ determines the effect of pollution on i type labor and also indicates the private cost to avoid bad effects of pollution. In the following, we call t_i is the self-mitigation cost of i type labor. A greater value of t_i means a larger effect of pollution on health and labor must spend a larger cost to keep health. Market-clearing conditions yield:

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[5] The reason is that the unskilled sector, like steel,printing, plastic material, chemical, is usually an emission intensive sector in developing countries and uses dirty inputs to production. The agricultural pollution is mainly generated from synthetic organic chemicals, which also contributes to the agricultural output.

[6] Concerning pollution in the theoretical literature, there are two methods associated with the generation of pollution broadly. The first regards factor inputs generate pollution in the production process, and pollution equals the dirty input (Daitoh,2008; Pi and Zhang, 2017; Kuo et al, 2017). The second approach views the generation of pollution as by-products during the production process(Tawada and Sun,2010; Li and Zhou, 2015). Here, we treat the agricultural pollution as an input-generation type while the manufacturing pollution is a by-products type.

$$a_{S1}X_1 = L_S - t_S(E+T) \tag{6.5}$$

$$(1+\lambda)a_{U2}X_2 + a_{U3}F^3 = L_U - t_U(E+T) \tag{6.6}$$

$$a_{K1}X_1 + a_{K2}X_2 = K \tag{6.7}$$

$$a_{T3}F^3 = T \tag{6.8}$$

where L_S, L_U, K, T are the endowment of skilled labor, unskilled labor, capital and agricultural pollutants, respectively.

So far, the theoretical model has been established. Eight endogenous variables, w_S, w_U, r, τ, λ, X_1, X_2 and X_3, are determined by (6.1)–(6.8), ρ, T, t_S and t_U are policy variables. Other variables are exogenous.

6.3 Comparative Analysis

6.3.1 Environmental protection and wage inequality

We first investigate the impacts of environmental protection policies(an increase in ρ and a decrease in T) on the output of skilled and unskilled sector, which can be summarized by Lemma 6.1.

Lemma 6.1 *Suppose the share of exited skilled labor is not large. A larger environmental tax rate and more restrictive agricultural pollutants control bring a reduction of unskilled output and an expansion of skilled output.*

Proof. The system could decompose into two sub-systems.Eq(6.1),(6.2),(6.5),(6.7), constitute a sub-system which determines w_S, r, X_1 ,and X_2. Totally differentiating (6.1),(6.2),(6.5),(6.7):

$$\frac{\hat{w}_S}{\hat{\rho}} = \frac{\theta_{K1}\theta_{D2}}{\theta_{S1}\theta_{K2}} > 0, \tag{6.9}$$

$$\frac{\hat{r}}{\hat{\rho}} = -\frac{\theta_{D2}}{\theta_{K2}} < 0, \tag{6.10}$$

$$\hat{X}_1 = \frac{\left(\lambda_{K2}\Omega_1 - \lambda_{s2}\Omega_2\right)\hat{\rho} - \lambda_{s3}\lambda_{K2}\hat{T} - \lambda_{ts}\lambda_{K2}\hat{t}_S}{\Delta_1} \tag{6.11}$$

and

$$\hat{X}_2 = \frac{\left(\lambda_{S1}\Omega_2 - \lambda_{K1}\Omega_1\right)\hat{\rho} + \lambda_{K1}\lambda_{s3}\hat{T} + \lambda_{ts}\lambda_{K1}\hat{t}_S}{\Delta_1} \tag{6.12}$$

where "$\wedge$" represents the rate of change(e.g., $\hat{w}_S = dw_S / w_S$), $\Delta_1 = \lambda_{K2}\lambda_{S1} - \lambda_{K1}\lambda_{s2}$,

$\Omega_1 = \left(S^1_{SK} - S^1_{SS}\theta_{K1}/\theta_{S1}\right)\lambda_{S1}\theta_{D2}/\theta_{K2} > 0$,

$\Omega_2 = \left(\lambda_{K1}S^1_{KK} + \lambda_{K2}S^2_{KK}\right)\theta_{D2}/\theta_{K2} - \lambda_{K2}S^2_{KD} - \lambda_{K1}S^1_{KS}\theta_{K1}\theta_{D2}/\left(\theta_{K2}\theta_{S1}\right) < 0$. θ_{ij} (i=S,U,K,D; j=1,2) is the distributive share of factor i in the j th sector (e.g. $\theta_{S1} = a_{S1}w_S / p_1$), λ_{ij} is the allocated share of factor i in the j th sector (e.g. $\lambda_{U2} = a_{U2}X_2 / L_U$).

$\lambda_{ts} = t_S(E+T)/L_S$ is share of total exited skilled labor, $\lambda_{s2} = t_S E/L_S$ ($\lambda_{s3} = t_S T/L_S$) is share of exited skilled labor due to manufacturing(agricultural) pollution. S^h_{ij} (i, j=S,U,K,D,T; h=1,2,3) is the partial elasticity of substitution between factors i and j in hth sector (e.g, $S^1_{SK} = \dfrac{\partial a_{S1}}{\partial r}\dfrac{r}{a_{S1}}$), $S^h_{ij} > 0 (i \neq j)$ and $S^h_{ii} < 0$.

The sign of Δ_1 is ambiguous. Here, we impose an inequality $\lambda_{S1}/\lambda_{K1} > \lambda_{ts}/\lambda_{K2}$. Note that λ_{ts} is the share of total exited skilled labor.Consider the economic reality, λ_{ts} is relatively small and allocated share of capital in unskilled sector is larger than that of skilled sector, and this inequality is easily satisfied in the real economy. Thus, $\Delta_1 > 0$.

From (6.11) and (6.12), we have $\hat{X}_1/\hat{\rho} > 0$, $\hat{X}_2/\hat{\rho} < 0$, $\hat{X}_1/\hat{T} < 0$, and $\hat{X}_2/\hat{T} > 0$.

■

The economic explanation of the Lemma 6.1 is as follows. An increase in environmental tax drops dirty input, which lowers the employment of capital and unskilled labor in the unskilled sector. The output of unskilled sector and manufacturing pollution reduce. Meanwhile, an inflow of capital and an enlargement of skilled labor due to a smaller *E* expand the skilled sector. A reduction of agricultural pollutants improves health condition of skilled and unskilled labor. Skilled sector has more available skilled labor and enlarges its employment, which attracts capital movement from unskilled into skilled sector. Though more available unskilled labor exists in the market, the employment of unskilled sector is unchanged due to the rigid wage. Since capital moves out of unskilled sector, its output drops consequently.

Next consider the wage gap. In accordance with the denotation of skilled-unskilled wage inequality in Beladi et al. (2008), Li and Xu(2016) and Pi and

Zhang (2017) , use skilled labor wage and average wage of unskilled labor, as well as their relative change to address the issue. Combing with (6.4) and (6.6), average unskilled wage is w_U .[7] Totally differentiating (6.3),(6.4),(6.6)and (6.8), and substituting (6.9),(6.10),(6.11),and (6.12),

$$\begin{pmatrix} 0 & \theta_{U3} & \theta_{T3} \\ 1 & S_{TU}^3 & S_{TT}^3 \\ \lambda_{U3} & \lambda_{U3}S_{UU}^3 - \lambda_{U2}^* & \lambda_{U3}S_{UT}^3 \end{pmatrix} \begin{pmatrix} \hat{X}_3 \\ \hat{w}_U \\ \hat{\tau} \end{pmatrix} =$$

$$\begin{pmatrix} \varepsilon\Psi_1 \\ \varepsilon\Psi_1 \\ \Omega_4 \end{pmatrix} \hat{\rho} + \Psi_2 \begin{pmatrix} \varepsilon \\ \varepsilon \\ -\Omega_3 \end{pmatrix} \hat{t}_S + \begin{pmatrix} \varepsilon\Psi_3 \\ 1+\varepsilon\Psi_3 \\ -(\Omega_3\Psi_3 + \lambda_{tu3}) \end{pmatrix} \hat{T} + \begin{pmatrix} 0 \\ 0 \\ -\lambda_{tu} \end{pmatrix} \hat{t}_U \tag{6.13}$$

where $\theta_{U3} = a_{U3}w_U / g(E)$, $\theta_{T3} = a_{T3}\tau / g(E)$, $\varepsilon = g'E/g < 0$ captures the negative impact of pollution on agriculture. $\lambda_{U2}^* = (1+\lambda)\lambda_{U2}$, $\lambda_{tu} = t_U(E+T)/L_U$ is the share of total exited unskilled labor, $\lambda_{tu2} = t_U E/L_U$ ($\lambda_{tu3} = t_U T/L_U$) is share of exited unskilled labor due to manufacturing(agricultural) pollution. Moreover,

$\Psi_1 = (\lambda_{S1}\Omega_2 - \lambda_{K1}\Omega_1)/\Delta_1 < 0$, $\Psi_2 = \lambda_{ts}\lambda_{K1}/\Delta_1 > 0$, $\Psi_3 = \lambda_{K1}\lambda_{s3}/\Delta_1 > 0$,

$\Omega_3 = \lambda_{U2}^*(\varepsilon+1) - \varepsilon(1-\lambda_{tu}) + \lambda_{tu2} > 0$, $\Omega_4 = \lambda_{U2}^*\left(\theta_{D2}S_{UK}^2/\theta_{K2} - S_{UD}^2\right) - \Omega_3\Psi_1$.

Define the determinant of matrix in (6.13) as Δ_2 and

$$\Delta_2 = \theta_{T3}(\lambda_{U3}S_{UU}^3 - \lambda_{U2}^* - \lambda_{U3}S_{TU}^3) - \theta_{U3}\lambda_{U3}(S_{UT}^3 - S_{TT}^3) < 0$$

By Cramer's rule,

$$\frac{\hat{w}_U}{\hat{\rho}} = \frac{\theta_{T3}\Omega_4 - \varepsilon\lambda_{U3}\Psi_1(\theta_{T3} + S_{UT}^3 - S_{TT}^3)}{\Delta_2} \tag{6.14}$$

and

$$\frac{\hat{w}_U}{\hat{T}} = \frac{\varepsilon\Psi_3(\lambda_{U3}S_{UU}^3 - \lambda_{U2}^* - \lambda_{U3}S_{TU}^3) + \theta_{U3}(\Omega_3\Psi_3 + \varepsilon\lambda_{U3}\Psi_3 + \lambda_{U3} + \lambda_{tu3})}{\Delta_2} < 0 \tag{6.15}$$

Using (6.9) and (6.14), the effect of an increase in environmental tax on wage gap can be expressed as:

$$\frac{\hat{w}_S - \hat{w}_U}{\hat{\rho}} = \frac{\theta_{K1}\theta_{D2}}{\theta_{S1}\theta_{K2}} - \frac{\theta_{T3}\Omega_4 - \varepsilon\lambda_{U3}\Psi_1(\theta_{T3} + S_{UT}^3 - S_{TT}^3)}{\Delta_2}$$

$$= \frac{\theta_{K1}\theta_{D2}}{\theta_{S1}\theta_{K2}} - \frac{\theta_{T3}\theta_{D2}\lambda_{U2}^*S_{UK}^2}{\Delta_2\theta_{K2}} + \frac{\Psi_1[\varepsilon\lambda_{U3}(S_{UT}^3 - S_{TT}^3) + \theta_{T3}(\lambda_{U2}^* + \lambda_{tu2})]}{\Delta_2} + \frac{\theta_{T3}\lambda_{U2}^*S_{UD}^2}{\Delta_2}$$

[7] We only consider the wage of skilled and unskilled labor in the market and do not include the dropped skilled and unskilled labor.

Suppose that S_{UD}^{2*} solves $\left(\hat{w}_S - \hat{w}_U\right)/\hat{\rho} = 0$. If $S_{UD}^{2} \in (S_{UD}^{2*}, +\infty)$, then $\left(\hat{w}_S - \hat{w}_U\right)/\hat{\rho} < 0$; and if $S_{UD}^{2} \in (0, S_{UD}^{2*})$, then $\left(\hat{w}_S - \hat{w}_U\right)/\hat{\rho} > 0$.

The above results are summarized as Proposition 6.1:

Proposition 6.1 *A larger environmental tax expands the wage gap if the partial elasticity of substitution between labor and dirty input in urban unskilled sector is small enough. However, the wage inequality can be reduced if the elasticity of substitution is large enough.*

An increase in environmental tax raises the shadow price of dirty input. As a result, the employment of dirty input drops which decreases the marginal productivity of capital employed in the unskilled sector. Consequently, the demand for capital also decreases in this sector, which leads to a decrease of interest rate in the economic system. The unskilled sector experiences a reduction in its output. Due to a smaller of manufacturing pollution, more available skilled labor drops its wage.While an inflow of capital increases the marginal productivity of skilled labor and raises its wage. Consider the share of exited skilled labor is not large, the latter impact is dominant and skilled wage increases finally. The unskilled wage is determined by two aspects:demand for unskilled labor in the unskilled sector and the positive impact of reduced manufacturing pollution on agricultural output. The latter has a positive effect on unskilled wage unambiguously. While the change of former is more complicatedly. On the one hand, less dirty input and capital decrease the marginal productivity of unskilled labor in this sector and lead to a reduction in the demand for unskilled labor. On the other hand, substitution unskilled labor with relatively expensive dirty input occurs. If the partial elasticity of substitution between labor and dirty input in the unskilled sector is relatively large and the substitution will be relatively easy, then this sector will employ more unskilled labor.And the increase of the demand for unskilled labor will be dominant. Less unskilled labor will be employed in agriculture, which raises the status quo unskilled wage. If the partial elasticity of substitution is relatively small and the decrease of demand for unskilled labor will be dominant, and more unskilled labor will be located in agriculture and drops the status quo unskilled wage . When the wage gap is taken into consideration, the logic of the partial elasticity of substitution is very similar. If $S_{UD}^2 \in (S_{UD}^{2*}, +\infty)$ ($S_{UD}^2 \in (0, S_{UD}^{2*})$),wage gap will be reduced (expanded) .

Since a change in T does not affect skilled wage, the effect of more restrictive agricultural pollutants control on wage gap is:

$$\frac{\hat{w}_S - \hat{w}_U}{\hat{T}} = \frac{\varepsilon \Psi_3 (\lambda_{U3} S_{UU}^3 - \lambda_{U2}^* - \lambda_{U3} S_{TU}^3) + \theta_{U3}(\Omega_3 \Psi_3 + \varepsilon \lambda_{U3} \Psi_3 + \lambda_{U3} + \lambda_{tu3})}{\Delta_2} > 0$$

Proposition 6.2 is established to show how more restrictive agricultural pollutants control influences wage inequality.

Proposition 6.2 *More restrictive agricultural pollutants control narrow down the wage inequality.*

More restrictive agricultural pollutants control makes more skilled labor available and increases the marginal productivity of capital employed in skilled sector. Capital moves from the unskilled sector to skilled sector and reduces interest rate initially. Due to the unskilled fixed wage , unskilled sector uses relatively cheap capital to substitute unskilled labor until the interest rate equals to its previous equilibrium value. With the constant interest rate, the skilled wage is also invariant. However, more restrictive agricultural pollutants control exerts an impact on the unskilled wage in three aspects: more available unskilled labor, decreases the demand for unskilled labor in agriculture, reduces manufacturing pollution. A reduction of agricultural pollutants implies the improvement of labor health, and more unskilled labor is available. Less agricultural pollutants bring down the marginal productivity of unskilled labor employed in agriculture and drop the demand for unskilled labor consequently. The constriction of unskilled sector reduces the manufacturing pollution and improves labor health. Reduction of manufacturing pollution has all of these effects as well as a further reduction in the demand for unskilled in agriculture. All of aspects reduce unskilled wage and wage gap expands.

6.3.2 Self-mitigation cost of skilled and unskilled labor and wage inequality

In this part, we first investigate the impacts of a greater of self-mitigation cost on the output of skilled and unskilled sector. From (6.11) and (6.12), $\hat{X}_1/\hat{t}_S < 0$, $\hat{X}_2/\hat{t}_S > 0$, $\hat{X}_1/\hat{t}_U = 0$ and $\hat{X}_2/\hat{t}_U = 0$. These resulted can be summarized by Lemma 6.2.

Lemma 6.2 *Suppose the share of exited skilled labor is not large. A greater of self-mitigation cost of skilled labor drops the output of skilled sector and raises that of unskilled sector. However, a change of self-mitigation cost of skilled labor exerts no effect on output of both sectors.*

A greater of self-mitigation cost of skilled labor reduces the amount of available skilled labor and shrinks its employment in the skilled sector. The less available skilled labor decreases the marginal productivity of capital in this sector and the capital outflows from the skilled sector. As a consequence, the output of skilled sector drops and that of unskilled sector rises. A greater of self-mitigation cost of unskilled labor also reduces the amount of available unskilled labor. Since the wage of unskilled sector is rigid, less amount of unskilled labor does not affect the employment of unskilled labor and capital in the unskilled sector, and the output of unskilled sector does not change. With constant employment of skilled labor and capital in the skilled sector, the output of that sector is also invariant.

Next consider the impacts of a greater of self-mitigation cost on wage inequality. From (6.13),

$$\frac{\hat{w}_U}{\hat{t}_S} = -\frac{\Psi_2\left[\varepsilon\lambda_{U3}(S_{UT}^3 + S_{TT}^3 + \theta_{T3}) + \theta_{T3}\Omega_3\right]}{\Delta_2} \tag{6.16}$$

and

$$\frac{\hat{w}_U}{\hat{t}_U} = -\frac{\lambda_{tu}\theta_{T3}}{\Delta_2} > 0 \tag{6.17}$$

Since a change of self-mitigation cost of both skilled and unskilled labor does not affect the skilled wage, the effect of an increase in self-mitigation cost on wage gap:

$$\frac{\hat{w}_S - \hat{w}_U}{\hat{t}_S} = \frac{\Psi_2\left[\varepsilon\lambda_{U3}(S_{UT}^3 - S_{TU}^3 + \theta_{T3}) + \theta_{T3}\Omega_3\right]}{\Delta_2}$$
$$= \frac{\Psi_2\left[\varepsilon\lambda_{U3}(S_{UT}^3 - S_{TU}^3) + \theta_{T3}(\lambda_{U2}^* + \lambda_{tu2})\right]}{\Delta_2}$$

and

$$\frac{\hat{w}_S - \hat{w}_U}{\hat{t}_U} = \frac{\lambda_{tu}\theta_{T3}}{\Delta_2} < 0$$

If $S_{UT}^3 < S_{TU}^3$, $(\hat{w}_S - \hat{w}_U)/\hat{t}_S < 0$. If $S_{UT}^3 > S_{TU}^3$, then the sign of $(\hat{w}_S - \hat{w}_U)/\hat{t}_S$ relies on S_{UT}^3 and ε. If the partial elasticity of substitution between labor and agricultural pollutants is large enough or the elasticity of manufacturing pollution on agricultural production is small enough, $(\hat{w}_S - \hat{w}_U)/\hat{t}_S > 0$.

Summarized above results, we get Proposition 6.3 and 6.4.

Proposition 6.3 *If the self-mitigation cost of skilled labor is increased, the wage inequality will be narrowed down if the partial elasticity of substitution between labor and agricultural pollutants is smaller than the partial elasticity of substitution between agricultural pollutants and labor. However, the wage inequality may be expanded in the opposite situation when the partial elasticity of substitution between labor and agricultural pollutants is large enough or the elasticity of manufacturing pollution on agricultural production is small enough.*

Less skilled labor exists as a result of an increase in the self-mitigation cost of skilled labor, reducing the employment of skilled labor in the skilled sector. Consequently, the marginal productivity of capital employed in the unskilled sector decreases and the demand for capital also reduces in this sector, which leads to a decrease of the interest rate initially. The unskilled sector employs more relatively cheap capital to substitute relatively expensive unskilled labor and increases its demand for capital until the interest rate equals to its previous equilibrium value. A larger self-mitigation cost of skilled labor will not change the interest rate as well as the skilled wage at last. Capital moves from the skilled sector to the unskilled sector, expanding the demand for unskilled labor in the unskilled sector. Rural unskilled labor migrates out of agriculture into the unskilled sector. With more capital and labor, the unskilled sector raises its output which brings a greater manufacturing pollution. The marginal productivity of agricultural pollutants drops as a result of the movement of agricultural unskilled labor, bringing down its reward. Thus, the agricultural faces the relatively cheap agricultural pollutants and the relatively expensive unskilled labor and factors substitution occurs. When the partial elasticity of substitution between labor and agricultural pollutants is smaller than the partial elasticity of substitution between agricultural pollutants and labor, which implies unskilled labor is harder to substitute than pollutants, unskilled wage rises regardless of the magnitude of manufacturing pollution on agricultural production. In the opposite situation, the unskilled wage reduces in two situations. When the partial elasticity of substitution between labor and agricultural pollutants is large enough, then pollutants is harder to substitute than unskilled labor, a reduction of price of pollutants leads to a large decrease in demand for unskilled labor and unskilled wage decreases; when the negative externality of manufacturing pollution on agricultural production is small enough, an increase in manufacturing pollution exerts a large negative impact on agricultural production and drop the unskilled wage. In these two situations, wage gap will expand.

Proposition 6.4 *A larger self-mitigation cost of unskilled labor brings down wage gap.*

When the self-mitigation cost of unskilled labor increases, less amount of unskilled labor exists in the market. Due to the rigid wage rate in the unskilled sector, a larger of self-mitigation cost of unskilled labor does not affect the variables of urban two sectors. Since agricultural wage is elastic, less supply of unskilled labor raises the marginal productivity of unskilled labor in the agriculture as well as its wage, narrowing down the wage gap.

6.4 Concluding remarks

Currently, developing countries face severe pollution problems generated by not only the manufacturing sector but also agricultural production. The deterioration of environment poses a negative externalities on both agricultural production and labor health. The government and private have made their efforts to reduce the bad externalities of pollution and such efforts affect the employment and wage rate, and skilled and unskilled wage consequently.

This chapter establishes a three-sector general equilibrium model to investigate the impacts of environmental protection policies and an increase in the self-mitigation cost on wage inequality. In the theoretical model, urban unskilled sector generates manufacturing pollution that affects agricultural production and labor health; while the agriculture employs pollutants as a factor for production which only affects labor health. Labor have to spend time or money,i.e self-mitigation cost, to curb or prevent the bad effect both from manufacturing and agricultural pollution. When agricultural pollution is incorporated, we find that a larger environmental tax expands the wage gap if the partial elasticity of substitution between labor and dirty input in the unskilled sector is small enough. More restrictive agricultural pollutants control narrows down the wage inequality. The impact of an increase in the self-mitigation cost of skilled labor on wage inequality is ambiguous, depending on the factors substitution in the agriculture and the elasticity of manufacturing pollution on agricultural production; while a larger self-mitigation cost of unskilled labor brings down wage gap.

Chapter 7

Conclusion

This dissertation theoretically analyzes three issues in developing economy: rural development, privatization of SOEs and wage inequality between skilled labor and unskilled labor. This chapter reviews the results and discussions from these three parts and proposes certain aspects remaining for a future investigation.

Part 1: Rural Development

This part centers on rural development in the context of rural-urban migration. Chapter 2 considers the agricultural sector employs service,from agricultural producer service sector, to substitute labor. Chapter 3 investigates the subsequent phenomenon of migration: internal remittances.

In chapter 2, I incorporate the agricultural producer service sector in a three-sector general equilibrium model and explore the impact of an inflow of capital and an increase in subsidy rate on agricultural output. The main conclusion is that an inflow of capital raises the output of agricultural sector through more available agricultural producer services. However, an increase in the subsidy rate of agricultural producer service decreases the output of agricultural sector. The conclusions suggest that agricultural supporting policies alone could not achieve expected result and policymakers should also pay attention to other policies to pull rural labor into urban region.

Chapter 3 integrates vocational training cost and internal remittances into a unified framework of labor migration and analyzes how a change of per capita vocational training cost affects internal remittances in developing countries. An increase of per capita cost of vocational training reduces the internal remittances and the proportion of remittances in migrants' income. In addition, an increase in per capita training cost also contributes to expanding the informal sector and contracting the agricultural sector.

This part proposes the agricultural producer service sector acts as a bridge to connect small-scale agriculture and capital. Since the agricultural producer service sector uses modern intermediate inputs for production, one possible direction of the extension could analyze it from rural-urban interdependence perspective. And agricultural producer service sector acts as a bridge to connect urban and rural region.

Urban region offers modern agricultural input to rural region, and rural region supplies labor to urban region and promotes urban development.

Part 2: Privatization

This part explores the impact on the economy of the partial privatization of a public upstream firm through the general equilibrium approach. The public firm, facing privatization, owns a monopolistic position in the upstream market and offers an essential intermediate input for the downstream manufacturing sector. After the privatization, the public firm improves its efficiency. From the discussion, the efficiency-enhancing effect is crucial for determining the impacts of privatization and provides a new perspective for considering the privatization issue. Deepening privatization lowers (raises) price of the intermediate input and increases its output if the efficiency-enhancing effect is relatively large (small). When the effect is moderate, an increase in the privatization level could raise the output of manufacturing and agricultural and social welfare.

This part considers one important characteristic of SOEs, i.e, they locate the upstream industries. However, the analysis pays little attention to another significant aspect of SOEs: they provide necessary intermediate inputs to firms and final consumption goods to individuals at the same time. Such SOEs like, energy, telecommunication, transportation, public utilities, banking. One possible extension could consider SOEs provide same goods with same price or different prices to firms and individuals, and investigate the impacts of an increasing privatization level.

Part 3: Wage inequality between skilled and unskilled labor

In this part, chapter 5 examines wage inequality from external factors perspective, i.e, international labor movement; While chapter 6 conducts analysis from the internal aspect, i.e., pollution control.

Chapter 5 incorporates the public intermediate input in a dynamic model with two final private sectors and a public sector and investigates impacts of an inflow of skilled and unskilled labor on wage inequality. The public intermediate input can be accumulated and its accumulated stock serves as a public input for private production. From the analysis, in the steady state equilibrium, an increase in the skilled and unskilled labor endowment raise the stock of public intermediate input. And an inflow of skilled labor reduces the wage of skilled labor and raises the wage of unskilled labor, and an inflow of unskilled labor increases both the wages of skilled and unskilled labor. Concerning their impacts on the wage inequality, an inflow of skilled labor decreases the wage inequality while the result of an inflow of unskilled labor on wage inequality is ambiguous. If the production elasticity of the public intermediate input stock in the skill-using sector is small enough, an inflow of unskilled labor narrows down wage inequality.

Chapter 6 incorporates manufacturing and agricultural pollution into a three-sector general equilibrium model with pollution externalities both on agricultural production and labor health. Manufacturing generates pollution that affects agricultural production and health; while agriculture employs the pollutant as a factor for production which only affects health. Under the framework, we investigate impacts of environmental protection policies and a rise in self-mitigation cost of skilled and unskilled labor on wage inequality. A larger environmental tax expands wage gap if partial elasticity of substitution between labor and dirty input in urban unskilled sector is small enough. More restrictive agricultural pollutants control narrows down the wage gap. The impact of an increase in the self-mitigation cost of skilled labor on wage inequality is ambiguous, depending on the factors substitution in agriculture and the elasticity of manufacturing pollution on agricultural production; while a larger self-mitigation cost of unskilled labor brings down wage gap.

Further research on the causes of wage inequality also could be conducted from external and internal aspects. Possible research from external aspects could consider the impact of trade liberalization in the service sector on wage inequality. And further research on wage inequality from internal aspects, like protection of property right, improvement of the financial market, an increase in factor mobility, etc.

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