Effect of International Economic Transactions on Economic Inequality and Development

by

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Submitted in partial fulfillment of the requirements

for the degree of

Doctor of Philosophy

in

Economics

Graduate School of Economics

Hitotsubashi University

2016

Preface

International economic transactions have come a long way over the last few decades. Yet, the effects of this globalization on eco-social outcomes such as inequality, the environment, and economic growth remain controversial. The goal of this dissertation is to offer frameworks to think about the role of international trade in shaping economic inequality and the development of infant industries. There are two reasons for the selection of this topic. First and foremost, I have an aspiration for conducting research dealing with problems in the real economy. Second, I have a great interest in economic inequality and infant industry protection because they may have a tangible impact on economic development and income distribution.

Two features stand out in my approach to this dissertation. First, the frameworks here are developed with realistic assumptions, such as the assumption of time limit for tariff protection during the transition to a free trade organization in Chapter 2, or the assumption of endogenous choice of technology system in Chapter 3. Second, after the theoretical analysis, these models are calibrated to explore their quantitative properties. Therefore, I believe these frameworks are valuable from both theoretical and practical perspectives.

The dissertation is structured as follows. Chapter 1 provides background information on the development of international trade and investment, the motivation of the dissertation, and an overview of each chapter. Chapter 2 investigates the optimal path for infant industry protection during the transition to World Trade Organization membership. Chapter 3 discusses the effects of trade openness on domestic and international wage inequality with endogenous technology. Chapter 4 studies shifts in wealth distribution in response to the entry of foreign direct investment firms.

I develop three theoretical models to study the mechanisms behind international macroeconomics and trade. My results challenge conventional wisdom and contrast previous studies'. These new results demonstrate that in order to understand the effects of trade policies in a specific country, we need to develop theoretical models with more realistic assumptions and to simulate such models using real data. Understanding these effects comprehensively will help policy makers design optimal trade policies, choose suitable development strategies, and address well income inequality problems.

Acknowledgement

I would like to express my deepest gratitude to my academic advisor, Professor Etsuro Shioji, for his kindness and constant support during the entire process of writing this dissertation, from preliminary ideas, through problem-solving, to dissertation completion. He not only supported me with my academic journey, but also deeply influenced my personal growth. Without his supervision and constant support, I would not have had such a solid foundation for my research career, and I would not have been able to finish this dissertation.

It gives me great pleasure to acknowledge the support and help of Professor Naohito Abe and Professor Taiji Furusawa, who have always had a certain care for my work and were always generous with their time to discuss with me about my dissertation in particular or my academic career in general.

I would like to thank my other committee members, Professor Jota Ishikawa and Professor Yoichi Sugita, the editors, and anonymous reviewers in journals where I submitted the papers for their valuable comments and suggestions, which were helpful in improving the dissertation.

My warm thanks go to Dr. Hiroshi Morita, Dr. Shinya Tanaka, Dr. Mai Fujita, Dr. Ivan Deseatnicov, seminar participants at Hitotsubashi University, and participants at conferences and workshops in which I have had many helpful discussions and insights. Special thanks are due to Dr. Ralph Paprzycki, Dr. Ha Nguyen, Dr. Trang Tran and Ms. Tuyet-Anh Lam Tran for their proofreading and valuable comments.

I would also like to acknowledge financial support from the Japanese Government Scholarship, Hirose International Scholarship Foundation, Global COE Program Research Unit for Statistical and Empirical Analysis in Social Sciences at Hitotsubashi University, and the Takuetsu

Program at Hitotsubashi University by the Ministry of Education, Culture, Sports, Science and Technology of Japan.

I am indebted to my parents for their unconditional love and their lifelong sacrifices. They have shown me the importance of study, provided me with the best educational environment in Vietnam, and have always supported me in every big decision in my life despite their occasionally differing perspectives.

I owe deep gratitude to my husband, for continuously providing me with all sorts of visible and invisible support and for having absolute faith in my work. Without his deep love and sacrifices, I was not able to have many of my achievements today.

Lastly, I would like to thank my baby for being a good child during my pregnancy, which has allowed me enough health to complete my dissertation defense and last revisions to this dissertation.

All remaining errors are my own.

Contents

Chapter 1

Overview

1.1 Background

International economic transactions have never been as prevalent as it currently is. Over the last two decades, world export growth is three times higher than gross domestic product (GDP) growth,[1] implying a rapid development in international trade. The number of member countries participating in global free trade agreements is steadily increasing as well. The World Trade Organization (WTO) has approved terms for its 162nd member to join by the end of 2015. Along with the WTO, negotiations and implementations of new free trade and bilateral trade agreements have become ubiquitous worldwide. In addition, the world economy has witnessed a significant increase in foreign direct investment (FDI), especially in developing countries. From 1990 to 2012, FDI inflows into developing countries increased more than thirtyfold, which is nearly four times higher than the world inflows during the same period.[2]

Increasingly, there are concerns that this rapid intensification of international economic integration might negatively affect income inequality and economic development. This dissertation focuses on the following two aspects: 1. International integration might give rise to serious conflicts of interest by increasing domestic and international income inequality, 2. Integration might affect the development of domestic industries, especially infant industries. Although re-

[1] Author's calculations using the World Development Indicators database.
[2] Author's calculations using the World Development Indicators database.

searchers have been trying to examine the issue from economic perspectives, research on these topics remains inconclusive.[3]

For that reason, the principal goal of this dissertation is to re-evaluate and clarify the impacts of international economic policies on income inequality and economic development. The three major research questions are described as follows. First, I address the issue of when and how tariff policies should be used to protect infant industries during the process of joining the WTO. To address this question, I propose a framework to derive the optimal dynamic path of tariffs to protect infant industries when a country initiates a process to join the WTO. Subsequently, I apply this model to numerically analyze the Vietnamese motorcycle industry, a typical infant industry in a country which is in the process of joining the WTO.

Second, I examine how trade openness affects wage inequality in trading countries, both within and between them. To address this research question, I derive a general-equilibrium monopolistic competition trade model between two asymmetric countries under the assumption of endogenous technology choice.

Last, I investigate the impact of FDI firms' entry on household wealth distribution. Changes in domestic wealth distribution arise in response to the entry of FDI firms under the assumption of borrowing constraint for domestic agents, caused by credit market imperfections.

The contribution of this dissertation is threefold. First, I propose three theoretical models to study the mechanisms behind the impacts of trade policies on income inequality and economic development. Specifically, these theoretical models are developed under assumptions reflecting important aspects of the real economy. These assumptions are time limit for protection of infant industry in Chapter 2, endogenous technology choice in Chapter 3, and the entry of FDI firms as an additional foreign factor in the domestic labor market in Chapter 4.

Second, I have performed calibrations on theoretical models presented in the dissertation to reflect the real world outcomes. In Chapter 2, the calibration exercise using actual data of the Vietnamese motorcycle industry offers explicit policy prescriptions for the protection process.

[3]Basu and Guariglia (2007), Sampson (2014), and Houpt (2002) make an explicit claim about the negative impact, while Lindert and Williamson (2002), Milanovic (2005), and Krugman and Venables (1995) hold the opposite opinions.

As such, the model and methodology can be generalized for adaptation to other countries and other industries.

Third, my results challenge conventional wisdom and help clarify the role of international economic policies. This is because my theoretical models use assumptions matching essential aspects of the real economy and are calibrated using real data. This dissertation helps policy makers design optimal trade policies, choose suitable development strategies, and better deal with problems of income inequality.

1.2 Structure of the dissertation

The rest of this dissertation comprises of three chapters.

Chapter 2 aims to address the issue of when and how tariff policies should be used to protect infant industries during the process of joining the World Trade Organization (WTO). More specifically, under the assumption that an infant industry experiences dynamic externalities, this chapter investigates what a government should do to protect such an industry before tariff barriers are reduced to fulfil commitment to a free trade regime. In the chapter, a framework is proposed to derive the optimal dynamic path of tariffs to protect infant industries when a country initiates the process of joining the WTO. The framework is based on the model of Melitz (2005), in which externalities associated with dynamic learning-by-doing provide a rationale for infant industry protection. Unlike the original model, this chapter assumes that there is a time limit for protection: after a fixed number of years, tariffs are required to be constant over time at a low level. This setup reflects the nature of the actual WTO agreement. This model is solved analytically to derive quantitative implications for the optimal tariff path, unlike in Melitz (2005), where only qualitative analyses are undertaken. An interesting result emerges: conventional wisdom holds that a country should reduce the tariff rate gradually over time so that it converges to its long-run rate at the terminal date of protection. By contrast, this chapter finds that, under plausible scenarios, the optimal time path of the tariff can be upward sloping. A numerical analysis applied to the Vietnamese motorcycle industry, a typical infant industry in a country joining the WTO, confirms such a pattern.

Chapter 3 investigates how trade openness affects wage inequality of trading countries, both within and between them. Specifically, based on the theoretical literature on monopolistic competition between two asymmetric countries, I derive a new framework under the assumption of endogenous technology choice. This assumption implies that firms simultaneously choose to adopt different technology compositions which are appropriate for its labor composition. In other words, instead of utilizing standard constant technology as in most of other research, firms in this model are allowed to choose the technology system that maximizes their profits. With this framework, I find that firms in countries which are skilled-labor-abundant choose technologies that are appropriate for skilled labor, and vice versa for firms in unskilled-labor-abundant countries. The wage gap between different types of labor depends on the comparative level of technological capability, the skill composition in the two countries, and the skill bias. During the transition from autarky to free trade, if the size of the labor force and its composition in both countries satisfy a particular condition, I find that the decline in transport cost will increase the relative wage between two countries in both types of labor. Moreover, these effects on wage inequality in all phases, i.e., autarky, free trade, and the transition from autarky to free trade, are partially absorbed by the endogeneity in technology choice. In other words, if a firm utilizes a standard constant technology only, the effect on wage inequality is amplified. This amplification is also analyzed based on calibration results, utilizing data from 52 countries, helping the chapter capture a more comprehensive understanding on the situation in each specific country.

Chapter 4 examines the role of foreign direct investment (FDI) firms on household wealth distribution. Based on Matsuyama (2011)'s framework on credit market imperfections and wealth distribution, I derive a new model that introduces the entry of FDI firms as an additional foreign factor. This version resolves the inconsistency regarding the impact of FDI on wealth inequality among previous empirical studies. It does so by providing country-specific conditions, under which the entry of FDI firms accounts for (in)equality in domestic wealth. The chapter yields some interesting results. First, the entry of FDI firms can provide a "big push" to move the poor out of a poverty trap, resulting in increased equality in wealth distribution and job selection. Second, this entry can also reduce inequality in a different way: it causes an "underdevelopment trap" whereby all domestic agents have no choice other than to work for FDI firms. On the other hand, the entry of FDI firms may widen the gap between the rich and poor, leading to greater inequality. It does so by redistributing wealth to make the richest agents who survive after the competition with FDI firms better off. In addition, the cost of starting a new business, the bequest motive, the global interest rate, and home country productivity play critical roles in determining the effects of FDI firm entry.

Chapter 2

Optimal Infant Industry Protection during Transition to World Trade Organization Membership

- A Numerical Analysis for the Vietnamese Motorcycle Industry -

2.1 Introduction

Recent decades have seen the rapid intensification of globalization with respect to trade. Membership in global free trade organizations is steadily increasing.[1]

The World Trade Organization (WTO) unambiguously lowers barriers to international trade, stimulates international transactions, and gives consumers access to a greater variety of goods at lower prices. However, there are concerns that the WTO may adversely affect infant industries. Throughout history, numerous countries have used tariff policies to protect infant industries, with varying degrees of success. For example, Head (1994) and Zussman (2008) suggest, respectively, that the tariff protection afforded the United States steel rail industry and the German iron and steel industry from the 1850s to the 1950s helped to raise welfare and promote development. On the other hand, Houpt (2002) argues that tariff protection for the Spanish iron and steel industry was harmful.

The aim of this chapter is to address the issue of when and how tariff policies should be used to protect infant industries during the process of joining the WTO. More specifically, under the

[1] The WTO currently has 153 member states, and 30 observers (Observers must start accession negotiations within five years of becoming observers.).

assumption that the infant industry under study is experiencing dynamic externalities, this chapter investigates what a rational government should do to protect such an industry before tariff barriers are reduced to a low level upon full commitment to a free trade regime. Generally, a free trade regime is a system of trade rules that includes detailed and lengthy tariff reduction schedules negotiated based on generalized formulas. For example, according to the Swiss formula for agricultural free trade agreements of the WTO (see Figure 2.1), after becoming a WTO member, a country has about five to seven years to reduce tariffs to the level stipulated through the course of initial negotiations.

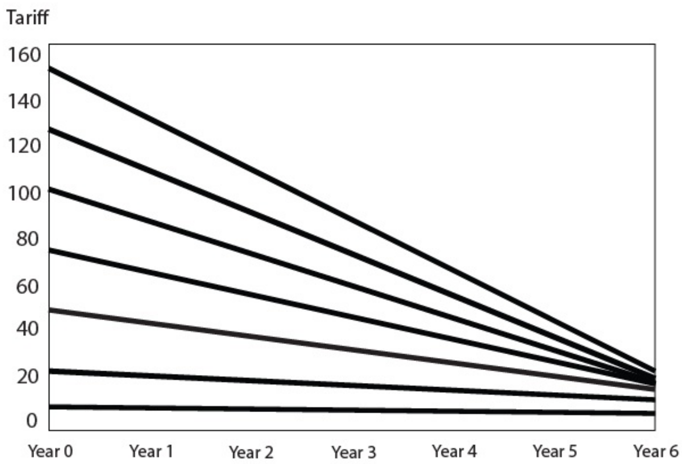

Figure 2.1. The Swiss formula of the WTO applied to current agriculture negotiations (See WTO Agriculture Negotiations (2003))

The theoretical argument for infant industry protection is that it shields newly emerging industries from full exposure to international markets. One of the first to put forward the argument for infant industry protection was John Stuart Mill in the 19th century. According to Mill (1848), industry protection is beneficial under the following conditions: (1) the industry should exhibit dynamic learning tendencies that are external to individual firms;(2) any protection should be temporary; and (3) the industry must eventually become viable without protection. In recent years, there has been a growing literature, both empirical and theoretical, on infant industries based on Mill's argument. For instance, Harrison (1994) and Tybout (1992) empirically show that there is a significant positive correlation between increased protection and higher productivity growth. Head (1994), using a numerical simulation, shows that intervention had positive effects on welfare in the United States steel rail industry. In addition, there are theoretical studies that model various aspects of the infant industry argument. Examples include the studies of Bardhan (1971), who develops a model of the learning effect in a dynamic framework, and Krugman (1987) and Young (1991), who examine the impact of learning spillovers across industries and countries.

A theoretical model of particular interest in the context of the current study is the learning-by-doing model of Melitz (2005), which enables the comparison of three policy instruments —tariffs, subsidies, and quotas —from which a hypothetical social planner could choose. Melitz (2005) focuses on a given industry's learning potential, the shape of the learning curve, and the degree of substitutability between domestic and foreign goods. His model incorporates the key features of an infant industry, but is sufficiently simple to permit extension for the purpose of the current analysis.

This chapter applies the model of Melitz (2005) to the process of a country joining the WTO. As already mentioned, WTO membership imposes many regulations, especially time-based restrictions. However, Melitz's model does not incorporate time restrictions. Rather, the model assumes that the social planner can protect the infant industry until it becomes mature. This is clearly unrealistic. Hence, in this chapter, restricted-time protection is incorporated into Melitz's model. The optimal tariff path during the protection period is derived using both analytical and numerical means. Analytically, two important factors influence this path: (1) the slope of the demand curve; and (2) the growth level of the industry. It is found that during the implementation period, the optimal tariff path may slope upward for some feasible cases. This result challenges the conventional wisdom that governments should gradually reduce tariffs to reach the stipulated level at the required time.

In fact, the calibration of the model used in this chapter to analyze the case of the Vietnamese motorcycle industry supports the analytical results by showing that the optimal tariff path over the protection period is upward sloping.

The contribution of this chapter is threefold. First, it is one of only a small number of researches that reexamine the current schedule of tariff reductions in the wake of a country's accession to the WTO. Second, the model and methodology can be generalized for adaptation to other countries and other industries. Furthermore, the model is applicable to any country planning to join an optional free trade organization in the future. Third, the calibration exercise using actual data offers explicit policy prescription for the protection process. Specifically, the calibration suggests that the optimal tariff path during the protection period may be upward sloping.

The rest of this chapter is organized as follows. Section 2.2 presents the infant industry protection model used in this study. Section 2.3 discusses the calibration. Section 2.4 concludes the chapter.

2.2 The model

This section presents a model of infant industry protection in which the industry is experiencing a dynamic learning effect. The model extends that of Melitz (2005) in two respects. First, by incorporating the actual conditions of joining the WTO, time restrictions are modeled when there is a commitment to reduced import tariff rates. In practice, an infant industry does not have unlimited time to reach maturity before a country joins the WTO. Second, a calibration exercise based on actual data is done to derive some quantitative results. For purposes of the calibrations later, all the functions used in the model are explicitly specified.

The basic assumptions of the model are as follows. Consider a world consisting of two countries, the home country and a foreign country. Firms in both countries are price takers. The home country is assumed to be a semi-open economy that imports goods only to overcome domestic supply shortages; it does not export. Hence, only the foreign country's exports to the home country are taken into account. Only in the home country are there learning effects in the industry. In this model, tariffs are the only tools available to the social planner to protect an industry, as is the case under the rules of the WTO. Time is assumed to be discrete.

2.2.1 The model

The learning function

The home country's total production at time t is denoted by q_t, and the foreign country's production exported to the home country is denoted by $\tilde{q}_t$. Both are assumed to be nonnegative ($q_t, \tilde{q}_t \geq 0$). Because time is discrete, the relationship linking total production in one period of time, q_t, to cumulative production at the end of that period, $Q_t = \sum_{s=0}^{t} q_s$, can be written as follows:

$$q_t = Q_t - Q_{t-1} \tag{2.1}$$

The home country's industry is assumed to be an infant industry, in which marginal cost at time t, denoted by c_t, is a decreasing function of cumulative production Q_t, to reflect the assumption that the industry is experiencing dynamic learning effects that are external to firms. This marginal cost function (i.e. the learning function) is specified as follows:

$$\begin{cases} c(Q_t) = exp(b - aQ_t), a \geq 0 & Q_t \leq \bar{Q} \\ c = \bar{c} & Q_t \geq \bar{Q} \end{cases} \tag{2.2}$$

When cumulative production has risen above the threshold level $\bar{Q}$, the industry has matured and thereafter produces at a constant marginal cost $\bar{c}$ because learning ceases. In the foreign country, the industry is assumed to be mature and no longer experiences learning effects. It produces at a constant marginal cost $\tilde{c}$ for the entire time. The foreign good is assumed to be an imperfect substitute for the domestic one.

Each country values output at its current marginal cost as follows:

$$\begin{aligned} \text{Home:} \quad & p_t = c(Q_t) = exp(b - aQ_t) \\ \text{Foreign:} \quad & \tilde{p}_t = \tilde{c} + \tau_t \end{aligned} \tag{2.3}$$

where p_t is the price of the domestic good, $\tilde{p}_t$ is the price of the imported good, and τ_t denotes the import tariff rate.

It is assumed that the social planner in the home country can only use import tariffs to protect the domestic industry against international trade. Unlike in Melitz's model, which does not incorporate restricted-time protection, in the current model, the time by which all tariffs must be reduced is given. This point of time is denoted by T. Until this time, the social planner can protect the domestic industry by imposing import tariffs, but after this time, tariffs must be reduced to the level fixed by the requirements of the WTO agreement. Thus, the foreign price can be rewritten as follows:

$$\begin{cases} \tilde{p}_t = \tilde{c} + \tau_t & t < T \\ \tilde{p}_t = \tilde{c} + \overline{\tau} & t \geq T \end{cases} \tag{2.4}$$

Domestic demand and utility functions

On the domestic demand side of the model, it is assumed that there is a representative consumer who generates demand for both domestic and imported goods. Her utility function is assumed to have a symmetric quadratic form,[2] which can be written as follows:

$$U(q_t, \tilde{q}_t) = \beta(q_t^2 + \tilde{q}_t^2) + \eta q_t \tilde{q}_t + \alpha_1 q_t + \alpha_2 \tilde{q}_t, \quad \beta, \eta < 0; \alpha_1, \alpha_2 > 0 \tag{2.5}$$

This utility function describes a hump-shaped curve: to the right of the peak, utility decreases as q_t or $\tilde{q}_t$ rises.[3] To ensure that the utility function is not decreasing with consumption, two additional conditions are imposed on q_t and $\tilde{q}_t$:

$$q_t < \frac{-\eta \tilde{q}_t - \alpha_1}{2\beta} \quad \text{and} \quad \tilde{q}_t < \frac{-\eta q_t - \alpha_2}{2\beta}$$

Given that the price p_t and $\tilde{p}_t$ must be positive, the problem of the representative consumer

[2]As in Melitz (2005), in order to simplify the analysis on tariffs, this chapter will use a symmetric quadratic utility function because this type of utility function can generate a simple linear parametrization of the demand system. As a result, the slope of demand curve and the substitutability between the domestic and imported good are constant. This setting does not affect the result of the chapter. Refer to Section 2.2.2 for the analysis on tariffs to find that the conclusion on optimal tariff path does not depend on the form of utility function.

[3]The signs of β, η, α_1 and α_2 are explained following equations (2.7) and (2.8).

is to maximize her benefit, which is given by the utility derived from consuming domestic and imported goods minus their cost, as follows:

$$CB_t = U(q_t, \tilde{q}_t) - p_t q_t - \tilde{p}_t \tilde{q}_t \tag{2.6}$$

The first-order necessary conditions for the benefit-optimization problem, $\frac{\partial CB_t}{\partial q_t} = \frac{\partial CB_t}{\partial \tilde{q}_t} = 0$, yield the following demand functions for domestic and foreign goods, respectively:

$$p_t = U_q(q_t, \tilde{q}_t) = 2\beta q_t + \eta \tilde{q}_t + \alpha_1 \tag{2.7}$$

$$\tilde{p}_t = U_{\tilde{q}}(q_t, \tilde{q}_t) = \eta q_t + 2\beta \tilde{q}_t + \alpha_2 \tag{2.8}$$

The slope of each demand curve is 2β, which must therefore be negative ($2\beta < 0$). Substitutability between foreign and domestic goods is measured by $\frac{\eta}{2\beta}$, which means that η must be negative and lie between 2β and zero ($\eta \in [2\beta, 0]$). In addition, because the first and second terms on the right-hand sides of equations (2.7) and (2.8) are negative, α_1 and α_2 must be positive to keep prices positive.

Domestic welfare and policy

Domestic welfare at time t is given by the sum of domestic consumer benefit, domestic firm profit, and tariff revenue. Since firms in this model are assumed to be perfectly competitive, domestic firm profit is zero. Thus, domestic welfare will be calculated as follows:

$$TW_t = CB_t + \tau_t \tilde{q}_t$$

By using the price valuation functions and the consumer benefit function, total welfare can be rewritten as:

$$TW_t = U(q_t, \tilde{q}_t) - c_t q_t - \tilde{c} \tilde{q}_t$$

The problem of the social planner is to maximize the sum of discounted domestic welfare over time. Thus, the social planner's problem can be written as:

$$\max_{\tau_t} TW = \sum_{t=0}^{\infty} \left(\frac{1}{1+r}\right)^t [U(q_t, \tilde{q}_t) - c_t q_t - \tilde{c}\tilde{q}_t] \tag{2.9}$$

where $\frac{1}{1+r}$ is the exogenous discount rate.

According to equation (2.3), marginal cost at time t of domestic good c_t is a function of cumulative production Q_t. In addition, from equation (2.7), $\tilde{q}_t$ can be rewritten as a function of q_t and Q_t. Total production in period t, q_t, and cumulative production Q_t have relationship formulated in equation (2.1). Therefore, the social planner solves the above optimization problem subject to equation (2.1). The computation is presented in Appendix 2.A, in which it is shown that the chosen variable for the social planner reduces to cumulative production at time T, Q_T. Then, the procedure to obtain optimal Q_T using numerical simulation is described in Appendix 2.D.

2.2.2 Analytical computation

Conventional wisdom is that a country in this situation should reduce tariff rates gradually to its long-run rate at the terminal date of protection or at least should keep the tariff unchanged until that terminal date. This is because unless the tariff rate is gradually reduced or kept unchanged, it may cause a distortion of the benefit of consumer.

In Melitz (2005), the optimal tariff path is also determined in the same way as what the conventional wisdom suggests. Without a particular assumption on the terminal date of protection, optimal tariff protection is also found to decrease as learning progresses and to cease with learning at the time the infant industry becomes mature. The explanation of Melitz (2005) is that as the industry grows due to the learning-by-doing effect, its marginal cost falls, raising its competitiveness. Thus, the more the industry grows, the less protection it needs. Moreover, the decline in the protection also benefits the consumers.

By contrast, this chapter finds that in some plausible scenarios, the optimal time path of the tariff rate can be upward sloping.[4] Mathematically, the following tariff rate can be derived by solving the social planner's problem given in Section 2.2.1:[5]

$$\tau_t = 2\beta\left(\frac{\eta}{2\beta} - \frac{2\beta}{\eta}\right)q_t + \frac{2\beta}{\eta}e^{b-a(q_t+Q_{t-1})} - \frac{2\beta}{\eta}\alpha_1 + \alpha_2 - \bar{c} \tag{2.10}$$

From this equation, we can calculate the change in tariff in two consecutive years as follows:

$$\tau_{t+1} - \tau_t = 2\beta\left(\frac{\eta}{2\beta} - \frac{2\beta}{\eta}\right)(q_{t+1} - q_t) + \frac{2\beta}{\eta}\left(e^{b-a(q_{t+1}+Q_t)} - e^{b-a(q_t+Q_{t-1})}\right) \tag{2.11}$$

In order to discuss the optimal tariff path, let us pay attention to the relationship between $(\tau_{t+1} - \tau_t)$ and $(q_{t+1} - q_t)$. In almost all infant industries, the production q_t is increasing year by year. As an example, we can observe the increasing in motorcycle production of 8 developing countries in from 1997 to 2007 shown in Figure 2.2 This increase in the production of an infant industry can be interpreted mathematically as $q_{t+1} > q_t$, thus $(q_{t+1} - q_t)$ is positive.

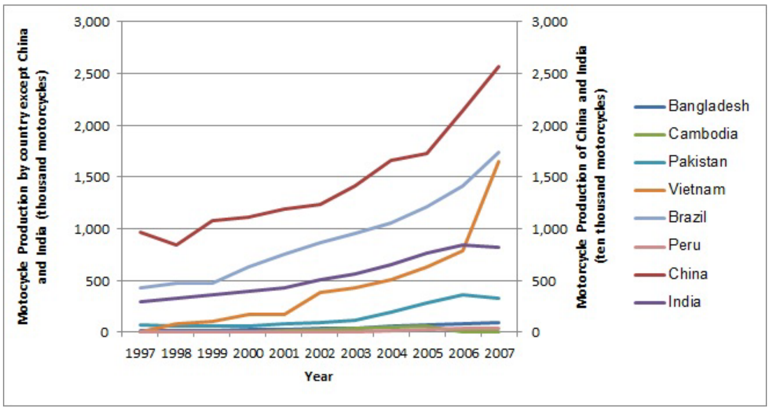

Figure 2.2. Motorcycle production in some developing countries

Source: 2008 World Motorcycle Facts & Figures.

[4] According to the accession rules of the WTO, once a country makes a commitment in terms of market access, tariffs should not be increased above the bound rate. However, in almost all member countries, the applied rates (i.e. the tariffs actually levied in 2011) were generally well below the bound rates drawn from the approved schedule of concessions of WTO members. This is confirmed by World Tariff Profiles (2011) - a joint publication of the WTO, the International Trade Centre and the United Nations Conference on Trade and Development. Therefore, countries are given discretion to introduce upward-sloping tariff paths as long as their tariff rates are below the bound rates. I would like to thank an anonymous reviewer for bringing this point to my attention.

[5] The solution is presented in Appendix 2.A.

The positive coefficient of the first term on the right-hand side of equation (2.11) indicates a monotonically increasing relationship between $(\tau_{t+1} - \tau_t)$ and $(q_{t+1} - q_t)$.[6] The coefficient of the second term clearly indicates a monotonically decreasing relationship between $(\tau_{t+1} - \tau_t)$ and the gap between q_{t+1} and q_t. The trend exhibited by the optimal tariff path depends on which term is dominant. If the first term increases faster than the second, the optimal tariff path will exhibit an upward sloping, and vice versa. The following factors can influence such dominance.

First, ceteris paribus, the steeper the slope of the demand curve (2β), the more likely is the tariff path to exhibit an upward trend. Mathematically, when $\frac{\eta}{2\beta}$ and a are constant, if 2β is sufficiently large, the increase in the first term dominates, and the optimal tariff path exhibits an upward trend. Intuitively, the steeper the slope of the demand curve, the less responsive is demand to price. Therefore, the price distortion to welfare caused by an increase in tariff will be less pronounced.

Second, if the industry grows sufficiently large, the social planner can increase the tariff. Mathematically, when Q_{t-1} is large,[7] the increase in production no longer leads to a large decrease in marginal cost; thus, the negative effect of the second term is less likely to dominate. As a result, there is a possibility that the tariff path will exhibit an upward trend. Intuitively, in the early stages of development, the marginal cost is still too high for a high level of production. However, when the marginal cost becomes lower as the industry grows sufficiently large, production should increase. Understanding this, the social planner has an incentive to increase tariffs gradually to stimulate production in the following stages.

In summary, contrary to conventional wisdom, the tariff could be upward sloping. To examine this possibility in practice, a numerical example of an upward-sloping tariff path —based on the Vietnamese motorcycle industry —is presented in the next section.

[6] This follows from the condition that $\eta \in [2\beta, 0]$.

[7] Because Q_t is cumulative production, if Q_{t-1} is large, Q_t will definitely be large.

2.3 Calibration

In this section, the model is calibrated based on 1998-2007 data on the Vietnamese motorcycle industry. The Vietnamese motorcycle industry is chosen for analysis for several reasons. First, Vietnam is a developing country that has been heavily dependent on international trade since the "Doi Moi reforms" initiated in 1986,[8] and has many new infant industries. Almost all of these are currently given tariff protection by the Vietnamese government; they include the motorcycle industry, the electronics industry, and the shipbuilding industry. However, Vietnam officially became the WTO's 150th member on 11 January 2007, since when it has had to comply with the tariff-cutting schedule set by the WTO that is applied to all developing countries. This schedule indicates the time and scale of cuts for each WTO member country. Specifically, after a stipulated time from formal accession, countries have to reduce their protective tariffs to levels that are calculated based on tariff levels at the time of joining.

A second reason for focusing on the motorcycle industry is that it is an industry that uses advanced technology and hence is expected to exhibit strong learning effects. In addition, the protection afforded the motorcycle industry by the Vietnamese government is quite substantial, with a tariff rate of up to 90% on imported finished goods, and a lower rate of 30% on imported parts. Under the WTO's tariff-reduction process, the tariff rate on finished goods must be reduced to 60% by 2012.

2.3.1 Description of model parameters

There are 12 model parameters: 2β (the slope of the demand curve); $\frac{\eta}{2\beta}$ (the degree of substitutability between domestic and foreign goods); α_1, α_2 (free demand parameters); a, b (coefficients of the learning function); $\frac{1}{1+r}$ (the exogenous discount rate); $\overline{c}$ (marginal cost in the mature domestic industry); $\tilde{c}$ (marginal cost in the foreign industry); Q_0 (initial cumulative production); $\overline{Q}$ (the cumulative production of the domestic industry right after it matures); and $\overline{\tau}$ (the com-

[8] The ratios of imports and exports to GDP for Vietnam in 2007 were 90% and 77%, respectively. (Source: World Development Indicators.)

mitted import tariff rate after T).[9] In the following, each of these parameters is discussed in turn.

Parameters in the demand functions

β, η, α_1 and α_2: Coefficients of the demand functions:

$$\begin{cases} p_t = 2\beta q_t + \eta \tilde{q}_t + \alpha_1 \\ \tilde{p}_t = \eta q_t + 2\beta \tilde{q}_t + \alpha_2 \end{cases}$$

Coefficients of the demand functions, β, η, α_1 and α_2, are estimated using the Seemingly Unrelated Regression Equations (SURE) system with cross equations constraints. For the estimation, 1998-2007 data on domestic prices, domestic production, foreign prices, and foreign production were used. The theoretical explanation for the estimation is provided in Appendix 2.C.

Parameters in the learning function

a, b: Coefficients of learning function $\ln p_t = b - aQ_t$ (derived from equation (2.2)). Because there are only 10 observations, Ordinary Least Square estimates are insignificant. Thus, to calculate the values of a and b, a linear connection is assumed between the two data points for 1998 and 2007, with the logarithm of the price treated as an abscissa and cumulative production treated as an ordinate. The values of a and b are then calculated algebraically as the coefficients of this line.

Cumulative production

Q_0: 1998 is the first year of the sample; thus, production in 1998 is assumed to be the initial cumulative production.

$\bar{Q}$: Calculated from equation (2.3) using a, b and $\bar{c}$.

[9] The data on the Vietnamese motorcycle industry used in the calibration are described in Appendix 2.B.

Marginal cost in the mature industry

$\overline{c}$: This value is calculated from the average price, excluding tariffs, of motorcycles imported from three countries, Taiwan, Thailand, and Indonesia, in 2007. These three countries are chosen because their motorcycle industries were "born" nearly half a century ago, and the production and exports of the motorcycle industry in these three countries have been stable over recent years. Thus, in these countries, the motorcycle market is stable, and their motorcycle industries can be considered mature industries.

$\tilde{c}$: This value is assumed to be equal to $\overline{c}$; i.e., marginal costs are assumed to be the same at home and abroad when the industry is mature.

Other parameters

r: The annual demand deposit interest rate is used.

$\overline{\tau}$: Calculated as $\overline{\tau} = rate \times \tilde{c}$, using the tariff rate required by the WTO when the time for tariff reduction comes. As mentioned above, this *rate* is 60%.

The calibrated parameter values are reported in Table 2.1.

Table 2.1. Calibration parameters

Parameter	**Value**
2β	-404.76 [78.91]
η	-183.76 [52.5]
α_1	2,105,021.2 [182,936.92]
α_2	2,503,490.02 [200,731.42]
a	0.000045
b	14.56
r	0.041
$\overline{c}$	535,795 (USD per thousand motorcycles)
$\tilde{c}$	535,795 (USD per thousand motorcycles)
Q_0	12,790 (thousand motorcycles)
$\underline{Q}$	30,410.93 (thousand motorcycles)
$\overline{\tau}$	321,477.4 (USD per thousand motorcycles)

Note: Values in square brackets are standard errors.

2.3.2 Findings

This section reports the results of the calibration.[10] The first issue of interest is the appropriateness of the time horizon for the loosening of trade barriers in the Vietnamese motorcycle industry. The calibration results show that this industry needs more time to develop before the tariff is greatly reduced. In other words, the implication for the government is that it should continue to protect the motorcycle industry for a few more years. This is illustrated in Figure 2.3, which shows the tariff rates for simulated time periods corresponding to different committed tariff-reduction times T. As the value of T decreases, the level of the tariff path corresponding to each T increases. Intuitively, the sooner tariff barriers are to be lowered (the lower is T), the less time the infant industry has to prepare for lower protection and, thus, the greater the protection it needs before tariff are lowered. This extra protection is reflected in the tariff rates from the initial point in time to time T. Comparing the magnitude of the hypothetical tariff rates with the actual rate leads to the conclusion that the industry needs more protection. More specifically, when there are five years to go until tariffs are reduced, as in reality (from 2007 to 2012), i.e., when T is equal to five years, the calculated initial tariff rate (the tariff rate in 2007) is about 800%, which is much higher than the current rate of 90%. This means that the current rate is too low and that in order both to protect industry and to maximize total welfare over time, the government should impose a higher tariff rate on imports than the current rate. As Figure 2.3 shows, the longer the tariff-reduction time T, the more the initial tariff rate can be reduced. According to this analysis, the optimal T that corresponds to the current tariff rate (90%) is eight years. This means that the Vietnamese motorcycle industry needs eight years of protection rather than the five years granted under the WTO schedule. Thus, the analysis suggests that in the case of this particular industry, accession to the WTO has come slightly too early.

[10] A description of the numerical exercises is provided in Appendix 2.D.

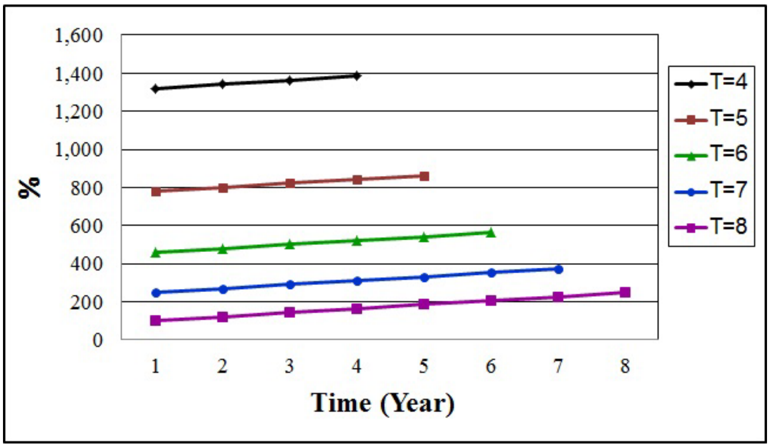

Figure 2.3. The optimal tariff path for various values of T

The second issue of interest is the optimal tariff path for the period preceding the reduction in trade barriers. This is illustrated in Figure 2.3, which shows that the optimal tariff paths for different values of T are all slightly upward sloping. As discussed in Section 2.2.2, this upward trend may be the product of a steeply sloped demand curve, a sufficiently high growth level of the industry, or a combination of both.

Corresponding to the upward-sloping tariff path during the protection period, the transition paths of other variables such as domestic production and imports, are illustrated in Figure 2.4. This figure is based on $T = 6$, and the overall period exhibits three distinct phases.

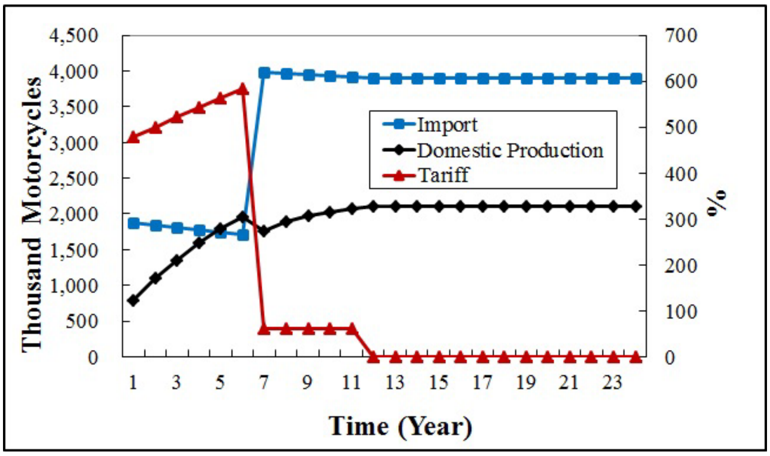

Figure 2.4. Tariff path and paths for domestic production and imports over time

The first phase is the time before tariffs are reduced. During this phase, imports follow a downward trend whereas domestic production follows an upward trend. These divergent trends can be explained by tariff protection and the learning effect. As shown by Figure 2.3, because the government imposes a rising tariff on imports, the more expensive foreign good is less attractive to consumers. Simultaneously, the learning effect improves the competitiveness of the domestic product by lowering its marginal cost. Thus, the upward-sloping trend in domestic production can be attributed to a combination of the protective trade policy and the learning effect.

Following the first phase, the second phase consists of the period from when the import tariff rate is reduced to a target level to when the industry reaches maturity. The import tariff rate is reduced in accordance with the initial agreement formed upon joining the WTO, and the resulting tariff rate is quite low relative to the current rate. Therefore, if import prices fall following the lowering of the tariff rate, the demand for foreign products, and hence imports, will rise. Consequently, during this period, foreign production trends upward. However, a surprising result is that although protective barriers are lowered, domestic production continues to trend upward slightly following the small drop at the beginning of this phase. This can be explained by the predominance of the learning effect over the effect of increased competition from imports.

During the final phase, once the industry has matured, domestic production and imports remain constant at the levels attained at the end of the second period. At this stage, Q_t reaches $\bar{Q}$, and $c = \exp(b - aQ)$ is equal to $\bar{c}$ or $\tilde{c}$. As a result, q_t reaches $\bar{q}$. The same applies to $\tilde{q}_t$ and $\bar{\tilde{q}}$.

Finally, the following conclusions can be drawn. First, the Vietnamese motorcycle industry remains immature. This suggests that increased protection from the government is needed to guarantee successful development in the face of international competition. Second, contrary to conventional wisdom, before tariffs must be reduced, the optimal tariff path is upward sloping. In other words, as long as tariff protection can be used and the infant industry is experiencing learning externalities, the government should continue to raise tariffs without worrying that high tariffs may limit consumer access to cheaper goods. This is because learning effects will counteract such distortions.

2.4 Conclusions

The purpose of this chapter was to examine the infant industry protection policies of a country about to join a free trade organization. The chapter presented a simple learning-by-doing model to illustrate the relationship between the market mechanism and infant industry protection policy under the following assumptions: (1) that the industry is experiencing dynamic learning effects; and (2) that the social planner has committed to lowering tariffs to a stipulated level by a specified point of time in the future. Thus, the social planner can use tariff protection as a policy instrument only until that point in time. The goal is therefore to protect the industry and maximize total welfare within this allotted time period.

Against this background, the model developed was used to derive an optimal tariff path based on the country having made a specific tariff-reduction commitment upon joining the WTO. Through computation, the shape of this optimal tariff path was found to depend on exogenous factors. Specifically, if there is a sufficiently steeply sloped demand curve, or if the industry grows sufficiently high, the optimal tariff path could be upward sloping. This result contrasts with the conventional wisdom that governments should gradually reduce tariff rates so that they reach the stipulated level at the required time. In some cases, the upward-sloping tariff path may violate the current WTO agreements. However, it is believed that this result can be considered as a policy recommendation. That is, this model suggests that if the WTO policies on tariff setting are relaxed to some extent, the welfare of particular member countries can be improved.

In the next step of the analysis, the model was calibrated by using data on the Vietnamese motorcycle industry. The contribution of this numerical approach is fourfold. First, few studies analyze the current schedule of tariff reductions in the wake of a country's accession to the WTO. Second, the model and methodology can be generalized for adaptation to other countries and other industries; the model could also be applied to any country planning to join the WTO.

Third, the calibration exercise based on actual data generates an optimal tariff path that represents a policy prescription for the protection process. Fourth, the calibration results support the analytical finding that the optimal tariff path during the protection period may be upward sloping.

Limitations and possible extensions should be mentioned. First, the model assumes a semi-open economy. In practice, infant industries export and mature domestic industries import goods that compete with domestic products. A more realistic model would comprise more than two open economies.

Second, this study analyzed an infant industry experiencing learning effects. However, a common problem when examining real-world cases is that, because infant industries are young by definition, available data are limited. For example, only 10 years of data from 1998 to 2007 are available on the Vietnamese motorcycle industry. Using a small sample size may affect parameter estimation.

Appendix 2.A. The computation

This appendix describes the computation of the transition paths of all variables. According to the model, the social planner must maximize total domestic welfare over time. However, for any case of the tariff policy, after an industry matures, the values of all variables remain constant. Welfare W will remain at $\bar{W}$ permanently after the industry matures. Thus, the social planner only needs to maximize cumulative welfare until a certain time in the future. This time period is given by the time in which an industry under any protection level, even the weakest one (under which industry growth is slowest), definitely matures. This time is denoted by t_{max}. Specifically, the period over which total domestic welfare is maximized by the social planner can be divided into three phases. The first phase runs from the current time period to the time by which tariffs must be reduced to a very low rate upon full commitment to the WTO. During this period, the social planner uses import tariffs as the only instrument to protect an infant industry and maximize total welfare. The policy chosen during this phase will determine welfare for the entire period. The second phase runs from the end of the first period to the time when learning ceases. During this phase, the infant industry has not yet matured and marginal costs decrease as cumulative production rises. At the end of this second phase, the industry has matured.[11] The third phase runs from when the industry matures until t_{max}. During this phase, there are neither learning effects nor protection and total domestic production at any time t is constant ($q_t = \overline{q}$). The calculation of welfare differs for each phase, reflecting the different policy and industry circumstances.

First phase

During the first phase, the social planner can use import tariffs as a policy instrument to protect the industry and to maximize social welfare. Let $\mathscr{L}$ be the Lagrangian associated with this problem:

$$\mathscr{L} = \sum_{t=0}^{T} \left(\frac{1}{1+r}\right)^t [U(q_t, \tilde{q}_t) - c_t q_t - \tilde{c}\tilde{q}_t + \lambda_t(Q_{t-1} + q_t - Q_t)]$$

From equation (2.7), $\tilde{q}_t$ can be rewritten as a function of q_t and Q_t:

$$\tilde{q}(q_t, Q_t) = \frac{e^{b-aQ_t} - 2\beta q_t - \alpha_1}{\eta} \tag{2.7'}$$

Substitute the utility function defined in equations (2.5), marginal cost of domestic good derived in equations (2.3), and $\tilde{q}$ calculated in equations (2.7'), the Lagrangian can be rewritten as follows:

$$\mathscr{L} = \sum_{t=0}^{T} \left(\frac{1}{1+r}\right)^t [\beta(q_t^2 + (\tilde{q}(q_t, Q_t))^2) + \eta q_t \tilde{q}(q_t, Q_t) + \alpha_1 q_t + \alpha_2 \tilde{q}(q_t, Q_t)$$
$$- e^{b-aQ_t} q_t - \tilde{c}\tilde{q}(q_t, Q_t) + \lambda_t(Q_{t-1} + q_t - Q_t)]$$

[11]Summing welfare until industry maturity, or summing welfare from the first and second phases, causes the following problem. The industry afforded the weakest tariff protection, which gives this industry the slowest growth, takes the longest time to mature. Hence, in this case, the total welfare added up until the industry becomes mature may take a larger value than other cases of tariff protection. This would be wrong. Welfare levels among cases of tariff protection should be compared over the same length of time. The preceding discussion of t_{max} shows that, after achieving maturity, the welfare of an industry should be continuously summed until t_{max}.

The social planner can only use tariffs as a policy instrument during the first phase. Nevertheless, according to marginal cost of domestic good derived from equation (2.3) and demand function from equations (2.7) and (2.8), the tariff, τ_t, can be mathematically calculated via q_t and Q_t. Thus, we find the first order conditions of the Lagrangian with respect to the three variables, q_t, Q_t, and λ_t, as follows:

The partial derivatives of the Lagrangian with respect to q_t:

$$\frac{\partial \mathscr{L}}{\partial q_t} = 2\beta q_t + 2\beta\tilde{q}_t\left(\frac{-2\beta}{\eta}\right) + \eta\tilde{q}_t + \eta q_t\left(\frac{-2\beta}{\eta}\right) + \alpha_1 + \alpha_2\left(\frac{-2\beta}{\eta}\right) - e^{b-aQ_t} - \tilde{c}\left(\frac{-2\beta}{\eta}\right) + \lambda_t = 0$$
$$\Longleftrightarrow \left(\frac{\eta^2-4\beta^2}{\eta}\right)\tilde{q}_t - \left(e^{b-aQ_t} - \alpha_1\right) + \left(\frac{2\beta}{\eta}\tilde{c} - \frac{2\beta}{\eta}\alpha_2\right) + \lambda_t = 0$$
$$\Longleftrightarrow \left(\frac{\eta^2-4\beta^2}{\eta}\right)\tilde{q}_t - (2\beta q_t + \eta\tilde{q}_t) + \frac{2\beta}{\eta}(\eta q_t + 2\beta\tilde{q}_t - \tau_t) + \lambda_t = 0$$

Thus, we have:

$$\tau_t = \frac{\eta}{2\beta}\lambda_t \tag{2.A.1}$$

The partial derivatives of the Lagrangian with respect to Q_t:

$$\frac{\partial \mathscr{L}}{\partial Q_t} = 2\beta\tilde{q}_t\left(\frac{-a}{\eta}\right)e^{b-aQ_t} + \eta q_t\left(\frac{-a}{\eta}\right)e^{b-aQ_t} + \alpha_2\left(\frac{-a}{\eta}\right)e^{b-aQ_t} + ae^{b-aQ_t}vq_t - \tilde{c}\left(\frac{-a}{\eta}\right)e^{b-aQ_t} - \lambda_t + \left(\frac{1}{1+r}\right)\lambda_{t+1} = 0$$
$$\Longleftrightarrow \frac{-2\beta a}{\eta}\tilde{q}_t e^{b-aQ_t} - \frac{a}{\eta}\alpha_2 e^{b-aQ_t} + \frac{a}{\eta}\tilde{c}e^{b-aQ_t} - \lambda_t + \left(\frac{1}{1+r}\right)\lambda_{t+1} = 0$$
$$\Longleftrightarrow \frac{-2\beta a}{\eta}\tilde{q}_t e^{b-aQ_t} - \frac{a}{\eta}e^{b-aQ_t}(\alpha_2 - \tilde{c}) - \lambda_t + \left(\frac{1}{1+r}\right)\lambda_{t+1} = 0$$
$$\Longleftrightarrow \lambda_t = \frac{1}{\left(1+\frac{a}{2\beta}e^{b-aQ_t}\right)}\left(\left(\frac{1}{1+r}\right)\lambda_{t+1} + ae^{b-aQ_t}q_t\right)$$

Thus, we have:

$$\lambda_t = \frac{1}{\left(1+\frac{a}{2\beta}e^{b-aQ_t}\right)}\left(\left(\frac{1}{1+r}\right)\lambda_{t+1} + ae^{b-aQ_t}q_t\right) \tag{2.A.2}$$

The partial derivatives of the Lagrangian with respect to λ_t:

$$\frac{\partial \mathscr{L}}{\partial \lambda_t} = Q_{t-1} + q_t - Q_t = 0$$

From equations (2.3), (2.7), (2.8), and (2.A.1), we have

$$q_t = \frac{1}{\eta}[\tilde{c} + \frac{\eta}{2\beta}\lambda_t - 2\beta\left(\frac{e^{b-aQ_t} - 2\beta q_t - \alpha_1}{\eta}\right) - \alpha_2]$$

Solving for q_t, we get:

$$q_t = 2\beta\left(\frac{\eta}{2\beta} - \frac{2\beta}{\eta}\right)\left(\frac{\eta}{2\beta}\lambda_t - \frac{2\beta}{\eta}e^{b-aQ_t} + \frac{2\beta}{\eta}\alpha_1 - \alpha_2 + \tilde{c}\right) \tag{2.A.3}$$

Solving for λ_t in equation (2.A.3), then substituting into equation (2.A.1), we get equation (2.10):

$$\tau_t = \left(\frac{\eta^2 - 4\beta^2}{\eta}\right)q_t + \frac{2\beta}{\eta}e^{b-aQ_t} - \frac{2\beta}{\eta}\alpha_1 + \alpha_2 - \tilde{c}$$

Second phase

During this phase, the industry remains immature and the social planner can no longer adjust tariffs. Tariff barriers have to be reduced to a very low rate ($\bar{\tau}$) upon full commitment to the WTO. Using the marginal cost function (2.3) and demand function (2.8), we have

$$\tilde{c} + \tau_t = \eta q_t + 2\beta\left(\frac{e^{b-aQ_t} - 2\beta q_t - \alpha_1}{\eta}\right) + \alpha_2$$

Solving for q_t, we get

$$q_t = \left(\frac{1}{\eta^2 - 4\beta^2}\right)[\eta\tilde{c} + \eta\tau_t - 2\beta e^{b-aQ_t} + 2\beta\alpha_1 - \eta\alpha_2]$$

Because $q_t = Q_t - Q_{t-1}$, the cumulative production function in this period can be derived as follows:

$$Q_t = Q_{t-1} + \frac{1}{4\beta^2 - \eta^2}\left[2\beta e^{b-aQ_t} - \eta\left(\tilde{c} + \bar{\tau} - \alpha_2 + \frac{2\beta}{\eta}\alpha_1\right)\right] \tag{2.A.4}$$

Third phase

The third phase is the period when the industry has reached maturity; i.e., the industry has reached a steady state and total domestic production at any time t in this period is constant. After maturity, because the optimal policy is clearly free trade, protection is eliminated in this phase ($\bar{\tau} = 0$).[12] During this phase, solutions for domestic production and imports are obtained from the cumulative production function and demand function:

$$\bar{q} = \frac{(2\beta - \eta)\tilde{c} - 2\beta\alpha_1 + \eta\alpha_2}{4\beta^2 - \eta^2} \tag{2.A.5}$$

$$\bar{\tilde{q}} = \frac{(2\beta - \eta)\tilde{c} + \eta\alpha_1 - 2\beta\alpha_2}{4\beta^2 - \eta^2} \tag{2.A.6}$$

The social planner can only use tariffs as a policy instrument during the first phase. This tariff setting will determine the level of cumulative production at the end of this phase, Q_T. This cumulative production subsequently determines the production levels in the following phases. As a result, total welfare over the three phases can be calculated through Q_T. That is, through this Q_T, the policy chosen during the first phase determines welfare for the entire period.

The optimal Q_T is the value that maximizes total welfare, in other words, the key factor in this dynamic model is Q_T. Thus, the key objective is to find the optimal Q_T. However, the calculation of the optimal Q_T which maximizes total welfare cannot be done analytically, thus a numerical approach is required. This is described in Appendix 2.D.

Appendix 2.B. Data

This appendix provides details of the data used for the calibration exercise. Specifically, the data used cover the period 1998-2007. The Vietnamese motorcycle industry was "born" in 1995. Because the next two years were devoted to building the necessary infrastructure, there was little actual production during this period. For example, in 1997, Honda Vietnam produced only 73 motorcycles. Therefore, in order to obtain significant parameter estimates, data from

[12] In fact, a complete phasing out of protection is not part of the WTO commitments. Once a country has implemented the agreed tariff reductions, tariffs stay at the agreed level until a new round of negotiations leads to further liberalization. However, even when tariffs in the third phase are set to nonzero values (i.e. 30%, 60%, etc.), the chapter's main conclusions do not change. In other words, the conclusions of the chapter are robust to such variations. As a benchmark specification, I assumed a tariff rate of zero in the third phase. In this case, the optimal result can be obtained from the model theoretically. Thus, the result of the chapter represents a suggestion for the WTO to consider when conducting the next round of negotiations. This should help the WTO to implement commitments that avoid introducing additional distortions when tariffs are set following industry maturity. I would like to thank an anonymous referee for this suggestion.

1998 are used. The most recent data available relate to 2007.

Data sources for domestic production, imports, domestic prices, foreign prices, current import tariff rates, and the annual demand deposit interest rate are described in Table 2.B.

Table 2.B. Data sources

Name of Variable	**Source**
Domestic production (q_t)	General Statistics Office of Vietnam (GSO)
Imports ($\tilde{q}_t$)	*Until 2001* : Calculated by the author based on motorcycle registration data from the Ministry of Public Security of Vietnam and domestic production data from the GSO *From 2001*: World Trade Atlas.
Domestic price (p_t)	Calculated by the author. Weighted average price of three companies: Honda Vietnam, FDI without Honda Vietnam and domestic companies (state and non-state). *Price data*: The price of the main product line for each sector is used. Data sources: until 2001: "Vietnam Automotive News"; from 2001: Japan International Cooperation Agency (JICA) and Hanoi National Economics University (See Ministry of Industry of Vietnam (2007)). *Share data*: Calculated using production data for Honda from "2008 World Motorcycle Facts & Figures" and domestic and FDI production data from the GSO.
Import price ($\tilde{p}_t$)	World Trade Atlas
Current tariff (τ_0)	General Department of Vietnam Customs
Treasury Bill rate (r)	International Financial Statistics (IFS)

Appendix 2.C. Estimation of the demand function's coefficients

Coefficients of the demand functions, β, η, α_1, and α_2, are estimated using the SURE system with cross equations constraints. The demand functions:

$$\begin{cases} p = 2\beta q + \eta\tilde{q} + \alpha_1 + \epsilon_1 \\ \tilde{p} = \eta q + 2\beta\tilde{q} + \alpha_2 + \epsilon_2 \end{cases}$$

Step 1: Set up

The simultaneous equations above can be rewritten as:

$$\mathbf{P} = \mathbf{X}\gamma + \epsilon$$

where

$$\mathbf{P} = \begin{pmatrix} p \\ \tilde{p} \end{pmatrix}; \mathbf{X} = \begin{pmatrix} \mathbf{q} & \tilde{\mathbf{q}} & \mathbf{1} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{q} & \tilde{\mathbf{q}} & \mathbf{1} \end{pmatrix}; \gamma = \begin{pmatrix} 2\beta \\ \eta \\ \alpha_1 \\ \eta \\ 2\beta \\ \alpha_2 \end{pmatrix} = \begin{pmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \\ \gamma_4 \\ \gamma_5 \\ \gamma_6 \end{pmatrix}; \boldsymbol{\epsilon} = \begin{pmatrix} \boldsymbol{\epsilon}_1 \\ \boldsymbol{\epsilon}_2 \end{pmatrix}$$

Step 2: Ordinary Least Squares result

The Ordinary Least Squares estimator:

$$\hat{\gamma} = (\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{P}$$

The variance-covariance matrix of the disturbances is

$$\hat{\mathbf{\Sigma}} = \begin{pmatrix} \hat{\sigma}_{11} & \hat{\sigma}_{12} \\ \hat{\sigma}_{21} & \hat{\sigma}_{22} \end{pmatrix} \text{ where } \hat{\sigma}_{ij} = \frac{1}{N}\hat{\boldsymbol{\epsilon}}_i'\hat{\boldsymbol{\epsilon}}_j; \boldsymbol{\epsilon} = \begin{pmatrix} \hat{\boldsymbol{\epsilon}}_1 \\ \hat{\boldsymbol{\epsilon}}_2 \end{pmatrix} = [\mathbf{I} - \mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}']\mathbf{P}$$

The disturbance formulation is, therefore

$$E[\hat{\epsilon}|\mathbf{X}] = \hat{\mathbf{\Omega}} = \hat{\mathbf{\Sigma}} \otimes \mathbf{I}$$

Step 3: Feasible Generalized Least Square result[13]

[13] See Econometric Theory and Methods P.503-508.

The Feasible Generalized Least Square estimator:

$$\hat{\hat{\gamma}} = (\mathbf{X}'\hat{\mathbf{\Omega}}^{-1}\mathbf{X})^{-1}\mathbf{X}'\hat{\mathbf{\Omega}}^{-1}\mathbf{P}$$

And its variance-covariance matrix is

$$Var(\hat{\hat{\gamma}}) = (\mathbf{X}'\hat{\mathbf{\Omega}}^{-1}\mathbf{X})^{-1}$$

The constraints in this case are

$$\begin{cases} \gamma_1 = \gamma_5 \\ \gamma_2 = \gamma_4 \end{cases}$$

Or they can be rewritten as: $\mathbf{R}\boldsymbol{\gamma}_* = \mathbf{0}$ where $\mathbf{R} = \begin{pmatrix} 1 & 0 & 0 & 0 & -1 & 0 \\ 0 & 1 & 0 & -1 & 0 & 0 \end{pmatrix}$

Step 4: SURE system with cross equation constraints result[14]

SURE system with cross equation constraints estimator:

$$\gamma_* = \hat{\hat{\gamma}} - \mathbf{Cm} = (\mathbf{I} - \mathbf{CR})\hat{\hat{\gamma}}$$

where $\mathbf{C} = (\mathbf{X}'\hat{\mathbf{\Omega}}^{-1}\mathbf{X})^{-1}\mathbf{R}'[\mathbf{R}(\mathbf{X}'\hat{\mathbf{\Omega}}^{-1}\mathbf{X})^{-1}\mathbf{R}']^{-1}$; $\mathbf{m} = \mathbf{R}\hat{\hat{\gamma}}$

And its variance-covariance matrix is

$$Var[\gamma_*|\mathbf{X}] = (\mathbf{I} - \mathbf{CR})Var(\hat{\hat{\gamma}})(\mathbf{I} - \mathbf{CR})'$$

Appendix 2.D. Description of the numerical exercises

This appendix describes the numerical simulation used to obtain the optimal Q_T. The first task is to clarify the potential intervals for Q_T. They must lie between the initial cumulative production level, Q_0, and the cumulative production level attained when learning ceases, $\bar{Q}$;

[14] See Econometric Analysis 6th Edition P.88.

i.e., $Q_T \in [Q_0, \overline{Q}]$. Assume that $[Q_0, \overline{Q}]$ is a discrete interval containing multiple values.

Second, with each of these values, a shooting algorithm is used to compute all values of cumulative production from initial cumulative production, Q_0, to production at time T, Q_T. With this information, total welfare for the first phase, W_1, can be calculated.

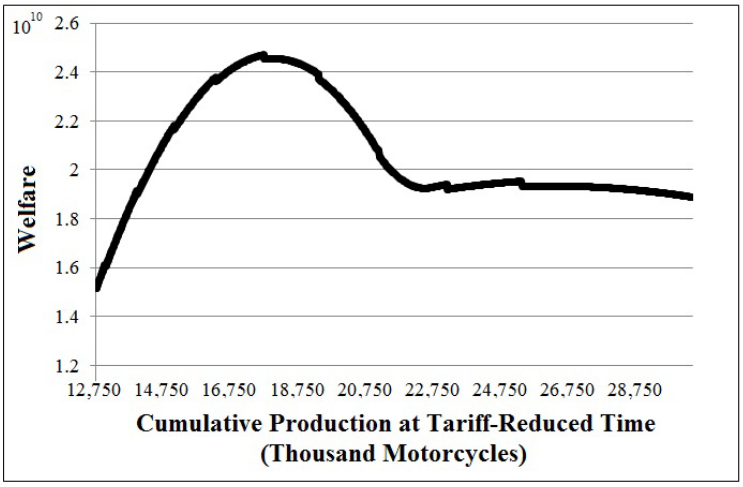

Figure 2D. Total welfare for various values of Q_T

Third, the cumulative production function derived from equation (2.A.4) is used to compute all cumulative production in the second phase from Q_T, and then to calculate the total welfare for this phase, W_2.

Fourth, during the third phase, when cumulative production has risen above the threshold level $\overline{Q}$, production in each period t remains constant, as shown in equations (2.A.5) and (2.A.6). Hence, welfare for each of these periods is also constant. Consequently, total welfare for the third phase, W_3, is calculated as the sum of the constant values for all periods within this phase. The longer this third phase lasts, the higher is W_3. The length of this phase depends on the learning speed, which mainly determines whether the industry matures quickly or slowly.

Fifth, cumulative production at time T, Q_T, is calculated to maximize total welfare over the three periods ($TW = W_1 + W_2 + W_3$). Figure 2D illustrates optimal value of Q_T within the interval $[Q_0, \overline{Q}]$ that maximize total welfare.

Figure 2D shows that the relationship between TW and Q_T is represented by a hump-shaped curve. Cumulative production at time T, Q_T, which is where total welfare reaches its maximum, lies somewhere in the middle of its potential interval $[Q_0, \bar{Q}]$.

Chapter 3

Effect of International Trade on Wage Inequality with Endogenous Technology Choice

3.1 Introduction

Together with the rapid trade globalization in recent decades, there are increasing concerns about how trade openness affects wage inequality in trading partners, both within and between them. Early analyze first appeared in the Heckscher-Ohlin framework. They show that the rise in the skill premium - the relative wage of skilled to unskilled workers - is mainly due to cheaper unskilled-labor-intensive imports. Recently, trade economists have proposed more sophisticated trade models to examine the key determinant of the skill premium. For example, Feenstra and Hanson (1996) have shown that outsourcing unskilled-labor intensive production can raise the skill premium in both trade partners. Acemoglu (1999) shows how trade liberalization can induce skill-biased technological progress in models with endogenous innovation. Epifani and Gancia (2008) focus on the trade-induced scale effect. In this chapter, I aim to examine the effect of trade openness on wage inequality under an assumption of endogenous technology choice.

The motivation for such assumption is the fact that in reality, different types of technology systems are appropriate for different inputs. Hence, together with choosing different combinations of labor, firms simultaneously choose to adopt different technology compositions which are appropriate for its labor composition. For example, a firm can choose to be unskilled-labor-intensive by having its factory mainly run by unskilled labor and supervised by a few number of skilled labor, or choose to be skilled-labor-intensive by introducing an automatic system operated by skilled labor. As a result, a firm can choose its particular technology system, which could be different from the selection of other firms in the same country.

Under the assumption of endogenous technology choice, a firm's decision of input volume and technology system will interact endogenously, leading to different results, compared to the case with the standard assumption of fixed technology system. Thus, applying this assumption to a trade model could lead to different effects of trade on wage inequality. For that reason, the core of the framework in this chapter is a new version of a two-country general equilibrium trade model with monopolistic competition analyzed under the assumption of endogenous technology choice.

The use of this non-standard assumption has been developed since the late 1960s by Atkinson and Stiglitz (1969). Their paper introduces discrimination between labor-intensive and capital-intensive techniques and claims that a firm cannot choose its techniques solely due to factor prices, but must take into account the technical knowledge specific to each technique under the spillover effect. Since the pioneering work of Atkinson and Stiglitz (1969), endogeneity in technology choice has been discussed in several ways. Basu and Weil (1996) introduce the concept of appropriate technology into a learning-by-doing model where different technologies are specific to particular combinations of inputs. Acemoglu (2002) finds that technical change will be biased to optimize the conditions and factor suppliers in the country where the technology is developed.

Despite the importance of the endogenous technology choice assumption, not many trade models incorporate this important notion. In one of the most influential studies in the field, Yeaple (2005) builds a general equilibrium trade model where homogeneous firms in identical countries can choose its own technology and employees from a set of labor of heterogeneous skills. He finds that a decline in trade costs induces firms to adopt new technologies, leading to wage premium expansion between highly and moderately skilled labor. In departure from the common assumption that technology is chosen depending on endowment characteristics, Acemoglu et al.(2007) develop a framework where a firm chooses its own technology corresponding to the range of intermediate inputs used in production. Their framework shows that a combination of contractual imperfections and technology adoption may influence cross-country income differences and patterns of trade.

In this chapter, a firm is allowed to choose a large number of different technologies that differ in the use of unskilled and skilled labor. Firms choose their optimal compositions of technology, thus these sets are all non-dominated and located at the country's "technology frontier". Under these settings, the introduction of countries that are heterogeneous in technological capability and labor composition can lead to a very different effects of trade on wage inequality. A theoretical model of particular interest in the context of the production functions with endogenous technology choice is the model of Caselli and Coleman (2006). They adopt the idea that each type of labor could be more or less effective with different types of technology. They assume imperfect substitutions between unskilled and skilled labors, and find that in a given economy, an appropriate technology is chosen depending on the skill composition of labor. Their model incorporates the key features of factor-specific productivity, but is sufficiently simple to permit extension for the purpose of my analysis. This chapter applies the specification of the production structure à la Caselli and Coleman (2006), in which skill bias in technology could arise endogenously, to a two-country general equilibrium trade model with monopolistic competition.

The chapter yields some interesting results. In autarky, firms in countries which are skilled-labor-abundant choose technologies that are appropriate for skilled labor, and vice versa for firms in unskilled-labor-abundant countries. In trade, the wage gap between types of labor depends on the relative level of technological capability, the skill composition in both countries, and the skill bias. During the transition from autarky to free trade, if the labor force and labor composition in both countries satisfy a particular condition, I find that the decline in transport cost will increase the relative wage between the two countries in both types of labor. Moreover, these effects on wage inequality in all phases, i.e., autarky, free trade, and the transition from autarky to free trade, are also partially explained by the endogeneity in technology choice. In other words, if a firm only utilizes a standard constant technology, the effect on wage inequality is amplified. Furthermore, based on calibration results utilizing data from 52 countries, I find that in some plausible scenarios, the amplification derived from the standard constant technology assumption may generate different understandings of the role of openness on wage inequality.

The remainder of the chapter is organized as follows. Section 3.2 lays out the model and characterizes the autarkic equilibrium. Section 3.3 solves for the free trade equilibrium in an asymmetric two-country setting. Section 3.4 provides analytical and numerical analysis on transport cost. Section 3.5 details the conclusions and extensions.

3.2 Autarky economy

In this chapter, I rely on a general-equilibrium monopolistic competition model that emphasizes production differentiation. In order to highlight the mechanisms through which a firm's choice of technology and employment affect wage, I start with a closed economy and then examine the implications of opening to international trade.

3.2.1 The setup

The economic environment assumes that in a country, there are N firms with monopolistic competition. Each firm produces a differentiated good and uses different technologies. The production requires two factors of production, which is unskilled and skilled labor. Each type of labor works with different technology.

Firm i hires a composition of unskilled and skilled labor to produce only good i. Production function of good i:

$$x_i = [(A_i^u l_i^u)^\gamma + (A_i^s l_i^s)^\gamma]^{\frac{1}{\gamma}} \tag{3.1}$$

where γ is substitutability between unskilled and skilled labor ($0 < \gamma < 1$). l_i^u and l_i^s are the number of unskilled and skilled labor hired by firm i, respectively. A_i^u and A_i^s are appropriate technologies to unskilled and skilled labor hired by firm i, respectively.

Firm i chooses A_i^u and A_i^s from a menu of a large number of different technologies that differ in comparability to unskilled and skilled labor. It means that a firm can choose which type of firm it wants to become, e.g. an unskilled-labor-intensive firm, or a skilled-labor-intensive firm. However, a country has its own level of technological capability so that a firm faces limitation in choosing technology. The menu of feasible technical choice is shown as follows:

$$(1-\alpha)(A_i^u)^\beta + \alpha(A_i^s)^\beta \leq B \tag{3.2}$$

where B is the level of technological capability ($B > 0$), α is skill bias parameter, and β is a parameter that determines the trade-off between A_i^u and A_i^s. Mathematically, it shows the curvature of the technology constraint curve. α, β and B are strictly positive parameters. Specifically, for unchanged B, a large α makes it difficult to access skilled labor's technology. When α is 0.5, it is the symmetric case. This setting of production function is borrowed from Caselli and Coleman (2006). That paper introduces a general production function where the assumption of perfect substitutability of different types of labor is relaxed, and technology used for each type of labor is endogenized. The paper shows that this type of production function can explain real data well.

Population in this country is L. Skilled labor takes a share of σ of the population, the rest $(1-\sigma)$ is unskilled labor, $(0 < \sigma < 1)$. Let $\rho = \frac{1-\sigma}{\sigma}$ be the ratio of unskilled labor over skilled labor. Then we have full employment condition like this:

Unskilled labor:

$$\sum_i^N l_i^u = L^u = (1-\sigma)L \tag{3.3}$$

Skilled labor:

$$\sum_i^N l_i^s = L^s = \sigma L \tag{3.4}$$

Note that N is the number of firms. Wages for unskilled and skilled labor are w^u and w^s, respectively. These three variables are determined in equilibrium.

Goods enter symmetrically into demand. All consumers in the economy are assumed to have the same utility function:

$$U = \sum_{i=1}^{N} c_i^{\theta} \tag{3.5}$$

where $0 < \theta < 1$. This corresponds to the constant elasticity of substitution utility function, which is homothetic and has elasticity equal to $\frac{1}{1-\theta} > 1$.

k-type labor's utility maximization is

$$\begin{cases} \max \sum_i^N (c_i^k)^{\theta} \\ \text{s.t } \sum_i^N p_i c_i^k = w^k \end{cases}$$

where k is unskilled or skilled labor ($k = u, s$). Then, price is determined by the demand curve as follows:

$$p_i = \frac{\theta}{\lambda^k}(c_i^k)^{\theta-1} \tag{3.6}$$

where λ^k is Lagrange multiplier in utility maximization problem of k-type labor. Price elasticity of demand curve is $\frac{1}{\theta-1}$.

Given that the wages w^u and w^s must be positive, the problem of firm i is to maximize its profit under the technology constraint shown in equation (3.2). The profit function is computed by subtracting labor cost from revenue, as follows:

$$\begin{cases} \max p_i(x_i - f_e) - w^s l_i^s - w^u l_i^u \\ \text{s.t } (1-\alpha)(A_i^u)^{\beta} + \alpha(A_i^s)^{\beta} = B \end{cases} \tag{3.7}$$

where f_e is fixed cost needed to pay to set up a firm.[1]

Firms can freely enter the market. However, firms do not choose to do that unless their

[1]Here, firm pays fixed cost f_e by its production, not by its input. With this setting, the analysis on wage inequality is considerably simplified but the main features in the conclusion of the chapter are still maintained. Refer to propositions presented in Sections 3.2, 3.3, and 3.4 to find that intuitive explanation for each proposition does not depend on the form of fixed cost. Clearly, if firm pays fixed cost by its input, there will have more interesting aspects to discuss, and some quantitative effects may change. However, in order to focus on the consequences of the main assumption of the chapter, the assumption of endogenous technology choice, this setting is left for future work.

expected profits become equal to the fixed cost. Free entry condition can be written as:

$$\pi_i = p_i x_i - w^s l_i^s - w^u l_i^u = p_i f_e \tag{3.8}$$

Under the good market clearing condition, output must equal the product of consumption of a representative individual in each type of labor and the corresponded size of labor force:

$$x_i - f_e = L^s c_i^s + L^u c_i^u \tag{3.9}$$

Here, I assume that firms are symmetric. Then, labor market clearing condition will become $Nl^u = (1-\sigma)L$ and $Nl^s = \sigma L$.

3.2.2 Closed economy equilibrium

Under the condition of that parameter β is larger than $\frac{\gamma}{1-\gamma}$, there exists a unique interior solution. At equilibrium, the technology and employment choice are[2]

$$A^s = \left(\frac{B}{\alpha[1+(\frac{\alpha}{1-\alpha}\rho^\beta)^{\frac{\gamma}{\beta-\gamma}}]}\right)^{\frac{1}{\beta}} ; A^u = \left(\frac{B(\frac{\alpha}{1-\alpha}\rho^\beta)^{\frac{\gamma}{\beta-\gamma}}}{(1-\alpha)[1+(\frac{\alpha}{1-\alpha}\rho^\beta)^{\frac{\gamma}{\beta-\gamma}}]}\right)^{\frac{1}{\beta}}$$

$$l^u = \frac{f_e \alpha^{\frac{1}{\beta}} \rho}{(1-\theta)B^{\frac{1}{\beta}}\left[1+\left(\frac{\alpha}{1-\alpha}\rho^\beta\right)^{\frac{\gamma}{\beta-\gamma}}\right]^{\frac{\beta-\gamma}{\beta\gamma}}} ; l^s = \frac{f_e \alpha^{\frac{1}{\beta}}}{(1-\theta)B^{\frac{1}{\beta}}\left[1+\left(\frac{\alpha}{1-\alpha}\rho^\beta\right)^{\frac{\gamma}{\beta-\gamma}}\right]^{\frac{\beta-\gamma}{\beta\gamma}}}$$

The relative wage at the equilibrium of unskilled and skilled labor is computed as follows:

$$w^s = \left(\frac{1-\alpha}{\alpha}\right)^{\frac{\gamma}{\beta-\gamma}} \rho^{\frac{\beta-\gamma-\beta\gamma}{\beta-\gamma}} \equiv \varphi$$

The number of entry firms can be determined by using the condition of full employment. From (3) we have:

$$N = \frac{\sigma L}{l^s} = \frac{(1-\theta)B^{\frac{1}{\beta}}\left[1+\left(\frac{\alpha}{1-\alpha}\rho^\beta\right)^{\frac{\gamma}{\beta-\gamma}}\right]^{\frac{\beta-\gamma}{\beta\gamma}} L}{f_e(1+\rho)\alpha^{\frac{1}{\beta}}}$$

[2]See Appendix 3.A.

The influence of parameters on variables at the equilibrium is shown in Table 3.1:

Table 3.1

	ρ	α	B	θ	f_e	L
A^u	$+$	$+$	$+$	0	0	0
A^s	$-$	$-$	$+$	0	0	0
l^u	$+$	?	$-$	$+$	$+$	0
l^s	$-$	?	$-$	$+$	$+$	0
$\frac{w^s}{w^u}$	$+$	$-$	0	0	0	0
N	?	?	$+$	$-$	$-$	$+$

There also exist some interesting features to interpret.

Proposition 3.1. *The weight of technology system appropriate for unskilled labor over that for skilled labor* $\left(\frac{A^u}{A^s}\right)$ *increases with* α *and* ρ.

Mathematically, the weight of technology system used for unskilled labor over that used for skilled labor $\left(\frac{A^u}{A^s}\right)$ is equal to $\left(\frac{\alpha}{1-\alpha}\rho^{\gamma}\right)^{\frac{1}{\beta-\gamma}}$. The exponent $\frac{1}{\beta-\gamma}$ is positive if β is larger than γ under the condition for existence of interior solution. The intuitive explanation for the result is as follows. First, if technology system of unskilled labor is relatively easier to access ($\alpha \uparrow$) compared to that of skilled labor, firm obviously chooses to utilize more technology appropriate for unskilled labor, A^u. Second, if this country is unskilled-labor-abundant ($\rho \uparrow$), firms tend to choose more technology appropriate for unskilled labor. For example, a developing country with unskilled-labor-abundant usually has more firms with technology used for unskilled labor.

Proposition 3.2. *The increase in the rate of unskilled over skilled labor* ($\rho \uparrow$) *reduces the relative wage between these two types of labor* $\left(\frac{w^u}{w^s} \downarrow\right)$. *The change in this wage premium is partially absorbed by the endogeneity in technology choice.*

This feature is intuitive. However, compared to the case of standard constant technology (A_i^u and A_i^s are given), the decrease in the relative wage in the case of endogenized technology choice is smaller. The selectability of technology has partially absorbed this effect. Specifically, under assumption that the South country is abundant in unskilled labor, wage of unskilled labor is relatively low. However, because technology system is endogenized, firms choose the system that can utilize resource which is abundant as much as possible; that is unskilled labor. As a result, demand for unskilled labor increases, it will absorb partly the effect of large number of unskilled labor. Therefore, with the endogenous technology choice model, we find that the inequality between two types of labor is not as serious as the case of fixed technology model. The same setting and result happen to the case of the relative wage between unskilled and skilled labor $\left(\frac{w^s}{w^u}\right)$.

3.3 Free trade

3.3.1 The setup

In this section, I suppose that two countries open trade with one another at zero transportation cost. The two countries are the North country (N) and the South country (S), which are different in level of technological capability (B^J) and ratio between unskilled and skilled labor (ρ^J), $J = N, S$.

The setting is similar to autarky version. Each good is produced by only one firm in one country. A firm in each country hires unskilled and skilled labor, taking as given wage of $w^{J,u}$ and $w^{J,s}$, to produce good i with production function

$$x_i^J = [(A_i^{J,u} l_i^{J,u})^\gamma + (A_i^{J,s} l_i^{J,s})^\gamma]^{\frac{1}{\gamma}} \tag{3.10}$$

The technology constraint has the form of

$$(1-\alpha)(A_i^{J,u})^\beta + \alpha(A_i^{J,s})^\beta \leq B^J \tag{3.11}$$

The firm maximizes its profit under the technology constraint. We have profit maximization problem

$$\begin{cases} \max \ p_i^J(x_i^J - f_e) - w^{J,s}l_i^{J,s} - w^{J,u}l_i^{J,u} \\ \text{s.t } (1-\alpha)(A_i^{J,u})^\beta + \alpha(A_i^{J,s})^\beta = B^J \end{cases} \tag{3.12}$$

Full employment condition is as follows:

- Unskilled labor:

$$\sum_i^{N^J} l_i^{J,u} = N^J l^{J,u} = L^{J,u} = (1-\sigma^J)L^J \tag{3.13}$$

- Skilled labor:

$$\sum_i^{N^J} l_i^{J,s} = N^J l^{J,s} = L^{J,s} = \sigma^J L^J \tag{3.14}$$

The ratio of unskilled labor over skilled labor in country J, ρ^J is defined as $\frac{1-\sigma^J}{\sigma^J}$.

Under the free entry condition, firms' expected profits become equal to the fixed cost:

$$\pi_i^J = p_i^J x_i^J - w^{J,s}l_i^{J,s} - w^{J,u}l_i^{J,u} = p_i^J f_e \tag{3.15}$$

Good market clearing condition in free trade accounts for good consumed both domestically and internationally.

$$x_i^J - f_e = L^{J,u}c_i^{J,u} + L^{J,s}c_i^{J,s} + L^{-J,u}c_i^{J*,u} + L^{-J,s}c_i^{J*,s} \tag{3.16}$$

where

· $-J$ means "not country J"

· $c_i^{J,k}$ is consumption of good produced in country J of the k-type labor living in country J

· $c_i^{-J*,k}$ is consumption of imported good from country $-J$ of the k-type labor living in country J, $k = u, s$

Utility maximization problem of k-type labor in country J is as follows:

$$\begin{cases} \max \; \sum_i^{N^J} (c_i^{J,k})^\theta + \sum_j^{N^{-J}} (c_j^{-J*,k})^\theta \\ \text{s.t} \; \sum_i^{N^J} p_i^J c_i^{J,k} + \sum_j^{N^{-J}} p_j^{-J} c_j^{-J*,k} = w^{J,k} \end{cases} \tag{3.17}$$

where $c_i^{J*,k}$ is consumption of imported good from country $-J$ of k-type labor living in country $J, k = u, s$.

Trade balance condition shows that export and import value of a country have to be equal:

$$\sum_i^{N^J} p_i^J (c_i^{J*,k} L^{-J,k} + c_i^{J*,-k} L^{-J,-k}) = \sum_j^{N^{-J}} p_j^{-J} (c_j^{-J*,k} L^{J,k} + c_j^{-J*,-k} L^{J,-k}) \tag{3.18}$$

3.3.2 Free trade equilibrium

The result for $A_i^{J,u}, A_i^{J,s}, l_i^{J,u}, l_i^{J,s}, \frac{w^{J,u}}{w^{J,s}}$ and N^J does not change from that in autarky version. At free trade, price indices between two countries become equal. Thus, the relative real wage between two countries with respect of unskilled and skilled labor respectively is[3]

$$\frac{w^{J,s}}{w^{-J,s}} = \left(\frac{B^J}{B^{-J}}\right)^{\frac{1}{\beta}} \left[\frac{1 + \left(\frac{\alpha}{1-\alpha}(\rho^J)^\beta\right)^{\frac{\gamma}{\beta-\gamma}}}{1 + \left(\frac{\alpha}{1-\alpha}(\rho^{-J})^\beta\right)^{\frac{\gamma}{\beta-\gamma}}} \right]^{\frac{\beta-\gamma-\beta\gamma}{\beta\gamma}} \tag{3.19}$$

$$\frac{w^{J,u}}{w^{-J,u}} = \left(\frac{B^J}{B^{-J}}\right)^{\frac{1}{\beta}} \left[\frac{1 + \left(\frac{\alpha}{1-\alpha}(\rho^J)^\beta\right)^{\frac{-\gamma}{\beta-\gamma}}}{1 + \left(\frac{\alpha}{1-\alpha}(\rho^{-J})^\beta\right)^{\frac{-\gamma}{\beta-\gamma}}} \right]^{\frac{\beta-\gamma-\beta\gamma}{\beta\gamma}} \tag{3.20}$$

Proposition 3.3. *The larger the gap of technological capability between the North and the South is* $\left(\frac{B^N}{B^S} \uparrow\right)$*, the higher the relative wages between the two countries for both types of labor become* $\left(\frac{w^{N,u}}{w^{S,u}} \uparrow, \frac{w^{N,s}}{w^{S,s}} \uparrow\right)$.

This result is very intuitive. We can think of a fact that with level of technological capability higher than China, both unskilled and skilled labor in the United States earn higher wage than

[3] See Appendix 3.B.

labor in China.

Proposition 3.4. *If the North is less unskilled-labor-abundant than the South* ($\rho^N < \rho^S$)*, the North's relative wage of unskilled labor is higher* $\left(\frac{w^{N,u}}{w^{S,u}} \uparrow\right)$ *while the relative wage of skilled labor is lower* $\left(\frac{w^{N,s}}{w^{S,s}} \downarrow\right)$*. The changes in these relative wages are also partially absorbed by the endogeneity in technology choice.*

The scarcity of unskilled labor in the North will increase the demand for this type of labor, thus raise the wage of unskilled labor in comparison of that of skilled labor. This result can be derived easily in classical trade model as Heckscher-Ohlin model. However, this chapter shows that although the scarcity of a type of labor may affect the wage inequality, the magnitude of the change under such influence is not as large as in classical models. The effect of labor composition on wage is absorbed partially because a firm can choose its own technology together with the number of labor to hire.

Proposition 3.5. *If technology appropriate for unskilled labor is relatively easier to access compared to that for skilled labor* ($\alpha \uparrow$)*, the country which is more unskilled-labor-abundant* ($\rho^S > \rho^N$) *will have higher relative wage of both types of labor* $\left(\frac{w^{S,u}}{w^{N,u}} \uparrow, \frac{w^{S,s}}{w^{N,s}} \uparrow\right)$.

Intuitively, when technology appropriate for unskilled labor is relatively easier to access ($\alpha \uparrow$) compared to that for skilled labor, firms will utilize technology which is appropriate for unskilled labor, A^u. This is especially effective for production in the country abundant in unskilled labor. Thus, wages for both types of labor in this country are improved.

Proposition 3.6. *If the difficulty in accessing to technologies appropriate for both types of labor is the same* ($\alpha = 0.5$)*, country with higher unskilled-labor-abundant level* ($\rho^S > \rho^N > 1$) *will exhibit larger wage inequality* $\left(\frac{w^{S,s}}{w^{S,u}} > \frac{w^{N,s}}{w^{N,u}} > 1\right)$*. The difference between these relative wages is also partially absorbed by the endogeneity in technology choice.*

This result is very intuitive. Country with higher unskilled-labor-abundant has relatively higher unskilled labor supply and lower skilled labor supply, thus the wage gap between these two types of labor will be higher. Once again, the chapter emphasizes that the magnitude of the effect on wage inequality in two countries trading with each other is not as large as in classical literature. Firm in this country will utilize more technology appropriate for unskilled labor, thus wage of unskilled labor is not that low. As a result, the wage gap between unskilled and skilled labor is partially absorbed by this endogeneity in technology choice..

3.4 Transport cost

3.4.1 The setup

In this section, the model is extended to allow for transport cost. The main purpose of this extension is to find how this cost affects wage inequality for both types of labor within and between two trade partners via the decision of choosing technology system.

The world here consists of two countries (paying cost) to trade with each other. This cost is assumed to be the "ice-berg" type, which means only a fraction τ ($0 \leq \tau \leq 1$) of any good shipped arrives. The rest, a fraction of $1 - \tau$, is lost during transportation. When $\tau = 0$, the economy is autarky; and when $\tau = 1$, the economy is free trade. The introduction of transport costs causes some changes in the setting of the model compared to free trade.

While the price of a domestic good is the same as the payoff that the firm receives, the price of imported good is the c.i.f price, which is calculated by the division of the producer's price by transport cost. This means that consumers in country J pay $\hat{p}_j^{-J} (= \frac{p_j^{-J}}{\tau})$ to buy good j produced in country $-J$ and consumers in country $-J$ pay $\hat{p}_i^J (= \frac{p_i^J}{\tau})$ for good i of country J. Thus, the individual budget constraint becomes:

$$\sum_{i}^{N^J} p_i^J c_i^{J,k} + \sum_{j}^{N^{-J}} \hat{p}_j^{-J} c_j^{-J*,k} = w^{J,k} \tag{3.21}$$

where p: f.o.b price, $\hat{p} (= \frac{p}{\tau})$: c.i.f price.

Because only a fraction τ of goods used for export arrives, the good market clearing condition is

$$x_i^J - f_e = L^{J,u} c_i^{J,u} + L^{J,s} c_i^{J,s} + \frac{1}{\tau} L^{-J,u} c_i^{J*,u} + \frac{1}{\tau} L^{-J,s} c_i^{J*,s} \tag{3.22}$$

Trade balance condition has the form of

$$\sum_{i}^{N^J} \hat{p}^J (L^{-J,s} c_i^{J*,s} + L^{-J,u} c_i^{J*,u}) = \sum_{j}^{N^{-J}} \hat{p}^{-J} (L^{J,s} c_j^{-J*,s} + L^{J,u} c_j^{-J*,u}) \tag{3.23}$$

3.4.2 The equilibrium

The solution of the equilibrium is described in Appendix 3.C. This section focuses on the effect of transport cost on the relative real wage, both within and across trading partners.

First, in the equilibrium, the relative wage between skilled and unskilled labor in country J is calculated as follows:

$$\frac{w^{J,u}}{w^{J,s}} = \left(\frac{\alpha}{1-\alpha}\right)^{\frac{\gamma}{\beta-\gamma}} (\rho^J)^{\frac{\gamma+\beta\gamma-\beta}{\beta-\gamma}}$$

The wage ratio between skilled and unskilled labor in country J only depends on labor specific to that country. The wage ratio does not depend on any specific trading partner or transport cost. The reason for this is that the change in price and consumption of each good absorbs all the effects of trade in this case.

Next, let us focus on the relative real wage between two countries for both types of labor. Unlike the case of free trade where the relative wage depends only on the specifics of both trading countries, the wage rate in this case also depends on transport cost. In order to examine this relationship, I study the impact of transport cost on nominal wage rate and price index ratio between two countries, separately.

First, the impact of transport cost on nominal wage rate is shown in the following proposition.

Proposition 3.7. *In the world of two countries, when the size of labor force and the ratio of unskilled over skilled labor in both countries satisfy that $D^{J,-J} < 1$, the decline in transport cost ($\tau \uparrow$) will increase the wage ratio between two countries in both types of labors ($\frac{w^{J,s}}{w^{-J,s}} \uparrow$ and $\frac{w^{J,u}}{w^{-J,u}} \uparrow$).*

Here, $D^{J,-J} \equiv \dfrac{\left[1+\left(\frac{\alpha}{1-\alpha}(\rho^J)^\beta\right)^{\frac{\gamma}{\beta-\gamma}}\right]^{\frac{\beta-\gamma}{\beta\gamma}}}{\left[1+\left(\frac{\alpha}{1-\alpha}(\rho^{-J})^\beta\right)^{\frac{\gamma}{\beta-\gamma}}\right]^{\frac{\beta-\gamma}{\beta\gamma}}} \frac{1+\rho^{-J}}{1+\rho^J} \frac{L^J}{L^{-J}}$

$D^{J,-J}$ consists of two aspects: the size of labor force and the ratio of unskilled over skilled labor of both countries. The following part analyzes how each aspect affects the influence of transport cost on relative wage via $D^{J,-J}$. First, assume that the ratio of unskilled over skilled labor of both countries are the same ($\rho^J = \rho^{-J}$); if country J has a smaller labor force than country $-J$ ($L^J < L^{-J}$), $D^{J,-J}$ will be smaller than 1. As Proposition 3.7 suggests, the decline in transport cost will increase the relative wage between country J and $-J$ in both types of labor. Intuitively, the lower the transport cost is, the freer trade becomes. As a result, trade flows between two countries will rise because of the increase in the demand for import goods. The demand for import goods in both countries increases in the same amount because of trade balances. Regarding the same demand level for import good in both countries, country J has a smaller labor force, wages of both types of labor in country J will be relatively higher than that in country $-J$. Second, holding the size of the labor force between two countries the same ($L^J = L^{-J}$), and skill bias between two types of labor the same ($\alpha = 0.5$), and both countries are unskilled-labor-abundant ($\rho^J, \rho^{-J} > 1$), if country J is more unskilled-labor-abundant than country $-J$ ($\rho^J > \rho^{-J}$), $D^{J,-J}$ will be smaller than 1. According to Proposition 3.7, the decline in transport cost will increase the relative wage between country J and $-J$ in both types of labor. Intuitively, if both countries are unskilled-labor-abundant, both countries will choose the technology system that is able to utilize unskilled labor as much as possible. As decreasing transport cost leads to the increase in demand for import good in both countries, country J, which is more unskilled labor intensive, will be more effective in production, raising wages for both types of labor.

Second, I discuss the impact of transport cost on price index ratio. As τ approaches one, the economy is closer to free trade, leading the price indices between two countries become equal. Thus, when transport cost reduces to zero, the price index ratio between two countries converges to one. Nevertheless, the transition of the price index ratio from autarky to free trade cannot be examined analytically. Therefore, a numerical approach is required. This is described in Appendix 3.E.

3.4.3 Calibration

In this section, the model is calibrated based on data from 52 countries, both developed and developing, to examine how the difference between the exogenous technology and the endogenous technology choice matters for impact of transport cost on relative wage between two countries.

Data

This chapter uses a dataset of cross-section of 52 countries for a single year, constructed by Caselli and Coleman (2006). In their dataset, the wage premium between unskilled and skilled labor, which are divided by "secondary completed", is constructed from data of the Mincerian rate of return[4] and difference in schooling years between these two types of labor in 1985. Here, "Secondary completed" is defined as having achieved high school diploma. The Mincerian rate of return is the marginal effect of an extra year of education on wage. Difference in schooling years is estimated from the duration of primary, secondary, and tertiary schooling. The data of gross domestic production (GDP) based on purchasing power parity (PPP) in current international US dollar, and population aged 15-64 from the World Development Indicators in 1990. The data on skilled and unskilled labor share are calculated from educational attainment for population aged 15 and over in 1990, provided in the dataset by Barro and Lee (2001).[5]

Description of model parameters

There are eight model parameters: γ (substitutability between unskilled and skilled labor); σ (share of skill labor); ρ (ratio of unskilled labor over skilled labor); θ (preference parameter);

[4] The Mincerian rate of return is estimated from the following equation: $ln(w_t) = \lambda_0 + \lambda_1 s_i + \lambda_2 exp_i + \lambda_3 exp_i^2 + \epsilon_i$ where w is wage, s is years of schooling, and exp is experience. Data using for the estimation is from 52 countries with about 5,200 persons per country and a median sample size of 2,469 from 1970 to 1990.

[5] Skilled labor share = Share of "completed secondary" + Share of "total tertiary".

f_e (fixed cost); β (the curvature of the technology constraint); α (the skill bias); and B (level of technological capability). In the following, each of these parameters is discussed in turn.

Substitutability between unskilled and skilled labor

Following Katz and Murphy (1992), elasticity of substitution between unskilled and skilled labor (denoted by $\frac{1}{1-\gamma}$) is set at 1.4, thus γ is equal to 0.286.

Labor share

From data of unskilled and skilled labor, we can calculate the share of skilled labor in total labor force (σ) for each country. The ratio of unskilled labor over skilled labor (ρ^J) for each country J is derived by dividing the share of number of unskilled labor in total labor force by that of skilled labor. ($\rho^J = \frac{1-\sigma^J}{\sigma^J}$).

Preference parameter

According to Broda and Weinstein (2006), elasticity of substitution (denoted by $\frac{\theta-1}{\theta}$) is assumed to be 2.7, thus $\theta = 0.63$.

Fixed cost

Assume that fixed cost f_e equals to 1. Robustness will be checked with respect to alternative values of fixed cost, f_e.

Parameters in the technology constraint equation

From the first-order condition regarding the demand for both types of labor, $l^{J,u}$ and $l^{J,s}$,[6] we have

$$\frac{A^{J,s}}{A^{J,u}} = \left(\frac{w^{J,s}}{w^{J,u}}\right)^{\frac{1}{\gamma}} \left(\frac{l^{J,s}}{l^{J,u}}\right)^{\frac{1-\gamma}{\gamma}} \tag{3.24}$$

Using equation (3.24), the optimal technology ratio, $\frac{A^{J,s}}{A^{J,u}}$, can be calculated from skill premium $\frac{w^{J,s}}{w^{J,u}}$ and labor ratio $\frac{l^{J,s}}{l^{J,u}}$ obtained from the data set.

[6]See equations (3.C.13) and (3.C.14) in Appendix 3.C.

From the first-order condition regarding technology appropriate for both types of labor, $A^{J,u}$ and $A^{J,s}$, of the firm profit maximization problem,[7] we can derive the following

$$\frac{A^{J,s}}{A^{J,u}} = \left(\frac{1-\alpha}{\alpha}\right)^{\frac{1}{\beta-\gamma}} \left(\frac{l^{J,s}}{l^{J,u}}\right)^{\frac{\gamma}{\beta-\gamma}}$$

Take logarithm of both sides, we have

$$\ln\left(\frac{A^{J,s}}{A^{J,u}}\right) = \frac{\gamma}{\beta-\gamma}\ln\left(\frac{l^{J,s}}{l^{J,u}}\right) + \frac{1}{\beta-\gamma}\ln\left(\frac{1-\alpha}{\alpha}\right) \tag{3.25}$$

Next, I estimate equation (3.25) by OLS with $\ln\left(\frac{A^{J,s}}{A^{J,u}}\right)$ as the dependent variable and $\ln\left(\frac{l^{J,s}}{l^{J,u}}\right)$ as the sole regressor. The estimation result gives the value of the slope $\frac{\gamma}{\beta-\gamma}$, thus, the parameter β can be calculated. Treat $\frac{1}{\beta-\gamma}\ln\left(\frac{1-\alpha}{\alpha}\right)$ as the intercept, then skill bias α is derived.

From the aggregate production function in equation (3.10) in country J, we have $X^J = [(A^{J,u}L^{J,u})^\gamma + (A^{J,s}L^{J,s})^\gamma]^{\frac{1}{\gamma}}$ where X^J is total production. Combine with the optimal technology ratio, $\frac{A^{J,s}}{A^{J,u}}$, which is calculated from equation (3.24), we can derive the value of each optimal technology, $A^{J,s}$ and $A^{J,u}$ for each country J. Given these optimal technology values, I use the technology constraint in equation (3.11) to obtain the level of technological capability B^J.

The estimation results

The result of estimated parameters is shown as follows: $\alpha = 0.408$, $\beta = 0.437$, $\gamma = 0.286$, $\theta = 0.63$. Other parameters, optimal technology $A^{J,s}$ and $A^{J,u}$, and estimations of 2 countries Indonesia and Malaysia as an example are shown in Table 3.2 below.

Table 3.2

	σ	ρ	A^u	A^s	B	L
Indonesia	0.127	6.880	0.073	0.124	0.352	181,436,821
Malaysia	0.247	3.050	0.160	0.189	0.463	18,211,097

[7] See equations (3.C.11) and (3.C.12) in Appendix 3.C.

Findings

This section reports the results of the calibration. I show how transport cost matters for the difference of exogenous technology and the endogenous technology choice.

Figure 3.1 shows the impact of transport cost on relative real wage of both unskilled and skilled labor between Indonesia and Malaysia. In this figure, the horizontal axis corresponds to τ. Note that, since this variable measures the fraction of goods that reach the importer country safely, transport cost decreases as we move to the right along this axis. The vertical axis shows the real wage rate between two countries. Figure 3.1.A shows the case of unskilled labor while Figure 3.1.B shows the case of skilled labor. The solid lines represent endogenous technology choice while the dotted lines represent constant technology.[8]

Although relative real wage curves between Indonesia and Malaysia in both cases are downward sloping, their difference has different implications for the effect of openness on wage inequality. In the case of skilled labor in Figure 3.1.B, there is a horizontal line where the wages of skilled labor in two countries are completely equal; in other words, wage rate equals one for any transport cost. We call this line “line one”. We can find that a part of this line lies wholly in between the solid line and the dotted line, corresponding to transport cost between point A and point B.[9]

[8]The setting and solution of the standard model with exogenous technology are shown in Appendix 3.C. Here, the constant technologies for both types of labor in Indonesia and Malaysia are $\bar{A}^{IND,u} = 0.088, \bar{A}^{IND,s} = 0.09, \bar{A}^{MYS,u} = 0.17$, and $\bar{A}^{MYS,s} = 0.173$, where IND and MYS are the acronyms for Indonesia and Malaysia, respectively.

[9]Point A and B correspond to where transport cost equals 0.37 and 0.8, respectively.

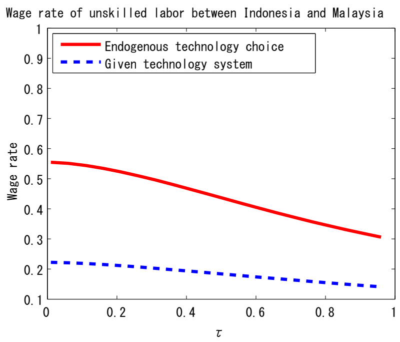

Fig 3.1.A

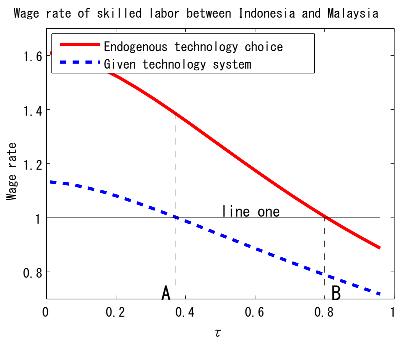

Fig 3.1.B

Figure 3.1

Note: Since τ measures the fraction of goods that reach the importer country safely, transport costs decrease as we move to the right along the horizontal axis.

Let us analyze the response of relative real wage to transport cost when the cost decreases from point A to point B. In the case of standard constant technology (the dotted line), the relative real wage curve between two countries diverges far away from "line one"; in other words, two countries become less equal in the wage of skilled labor as τ goes up from point A to point B. In contrast, the solid line decreases toward the "line one". It means that in the cases of endogenous technology choice, the relative wage of skilled labor between Indonesia and Malaysia becomes more equal as transport cost falls. Therefore, exogenous and endogenous technology choices matter for the impact of trade openness on wage inequality between two countries.

Similar results can also be found in other pairs of countries such as Sweden and Switzerland, Chile and Peru, and Greece and Hongkong. They are illustrated in Figure 3.2. We find that dotted lines and solid lines move in the same direction, and lie around or intersect with "line one" partly or wholly. This yields qualitatively different impacts of trade openness on wage inequality between the cases of exogenous and endogenous technology choice.

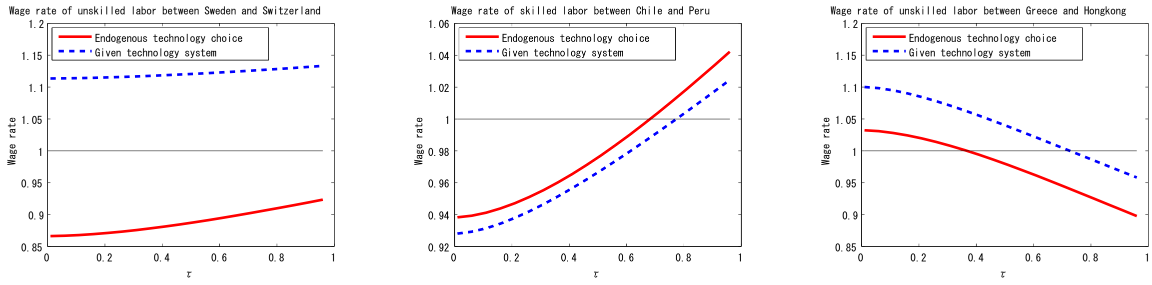

Fig 3.2.A   Fig 3.2.B   Fig 3.2.C

Figure 3.2

Note: Since τ measures the fraction of goods that reach the importer country safely, transport costs decrease as we move to the right along the horizontal axis.

The dotted lines and the solid lines lie around or intersect with "line one". This is because two countries have similar labor composition and technology capacity. However, even if the dotted lines and the solid lines do not lie around or intersect with "line one", qualitatively different impacts of trade openness on wage inequality between the cases of exogenous and endogenous technology choice remain. An example of this situation is discussed below.

The examples above share the same following feature: the solid line and the dotted line move in the same direction, either upward sloping or downward sloping. However, there is also a case where the solid lines and the dotted lines move in different directions. That happens in the case of France and Italy, shown in Figure 3.3. Specifically, for both unskilled and skilled workers, the dotted line is downward sloping while the solid line is upward sloping. In the case of unskilled workers shown in Figure 3.3.A, both lines lie above "line one". Therefore, as transport cost falls, the relative real wage of unskilled labor between France and Italy in the endogenous technology choice model becomes less equal, while that with constant technology becomes more equal. On the other hand, in the case of skilled workers shown in Figure 3.3.B, both lines lie below "line one", thus the opposite outcome happens to the relative real wage. As transport cost falls, the relative real wage of skilled labor between the two countries with endogenous technology choice becomes more equal, while that with constant technology becomes less equal. In short, endogenous technology choice and constant technology have different implications for the impact of trade openness on real wage inequality.

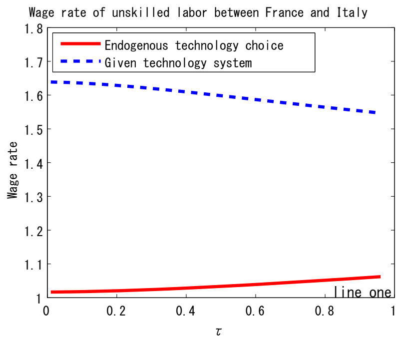

Fig 3.3.A

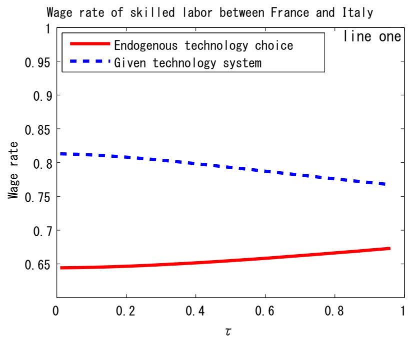

Fig 3.3.B

Figure 3.3

Note: Since τ measures the fraction of goods that reach the importer country safely, transport costs decrease as we move to the right along the horizontal axis.

3.5 Conclusions and extensions

This chapter strives to explain how trade openness affects wage inequality, both domestically and internationally, under the new assumption of endogenous technology choice. Based on the theoretical literature on a two-country general equilibrium trade model with monopolistic competition, the chapter proposes a new version under the assumption of endogenous technology choice. The assumption implies that firms can choose which technology system to maximize their profits. The effect of trade openness here is examined by considering the impact on wage rate when they move from autarky to free trade, both within and across trading partners.

In autarky, I find that firms in skilled-labor-abundant countries choose technologies that are appropriate for skilled labor, and vice versa for firms in unskilled-labor-abundant countries. Furthermore, the effect of labor composition on the skill premium between unskilled and skilled labor is partially absorbed by the endogeneity in technology choice. In other words, in the case of standard constant technology, skill composition has strong influence on wage inequality, while in the case of endogenous technology choice, such effect is not so strong. In trade, wage inequality between types of labor is influenced by the comparative level of technological capability, the labor composition in both countries, and the skill bias. Moreover, countries with higher ratio of unskilled labor will exhibit larger wage inequality. Compared to the case of standard constant technology, these effects on wage inequality is also weaker. During the transition from autarky to free trade, the impact that the decline of transport cost has on wage inequality is also analyzed. If the size of labor force as well as its skill composition in both countries satisfies a particular condition, the decline in transport cost will increase the relative wage between two countries in both types of labor.

Furthermore, I run a calibration using data from 52 countries to examine the difference between the standard model with exogenous technology and the new model with endogenous technology choice. As suggested by the results of the calibration, the impact of openness on real wage inequality under the cases of standard constant technology and endogenous technology choice is both qualitatively and quantitatively different in some pairs of countries.

The model presented in this chapter can be extended in some other directions. First, the two parameters, the skill bias (α), and the parameter that determines the curvature of the technology constraint (β) play a very important role in the model. Thus, introducing differences in these parameters across countries may provide interesting results. Second, transport cost of all goods is the same in this model, hence we can allow different goods to face different transport cost. For example, transport cost in the service sector may be lower than that in the manufacturing sector. Additionally, each sector is more or less intensive in different types of labors, thus the extension will be more fruitful in analyzing the effect of endogeneity in technology choice toward wage inequality. Third, except the aspect of labor, two countries in this model are not different in level of technology capability. Firm i in any country can choose any set of A_i^u and A_i^s from a menu of feasible technical choice which is shown in equation (3.11). In fact, a firm in a country with low level of technology capability may find it difficult to access to a high A_i^s, appropriate technology to skilled labor, even when it eagers to give up all A_i^u, appropriate technology to unskilled labor. Thus, introducing a limitation to the choice of appropriate technology for skilled labor, A_i^s, may bring the model closer to the reality.

Appendix 3.A. Solution for autarky equilibrium

k-type labor's utility maximization:

$$\begin{cases} \max \sum_i^N (c_i^k)^\theta \\ \text{s.t } \sum_i^N p_i c_i^k = w^k \end{cases}$$

Solve the utility maximization, we have

$$p_i = \frac{\theta}{\lambda^k}(c_i^k)^{\theta-1} \quad (3.A.1)$$

Apply for both types of labor

$$c_i^u = \left(\frac{\lambda^u}{\lambda^s}\right)^{\frac{1}{\theta-1}} c_i^s \quad (3.A.2)$$

Substitute equation (3.A.1) into good market clearing condition in equation (3.9), we have:

$$\begin{aligned} x_i - f_e &= L^s c_i^s + L^u c^u \\ &= L^s c_i^s + L^u \left(\frac{\lambda^u}{\lambda^s}\right)^{\frac{1}{\theta-1}} c_i^s \\ &= \left[\sigma + (1-\sigma)\left(\frac{\lambda^u}{\lambda^s}\right)^{\frac{1}{\theta-1}}\right] c_i^s L \end{aligned}$$

c_i^s can be rewritten as follows: $c_i^s = \frac{x_i - f_e}{\left[\sigma+(1-\sigma)\left(\frac{\lambda^u}{\lambda^s}\right)^{\frac{1}{\theta-1}}\right]L}$

Substitute this into equation (3.6), we get

$$p_i = \frac{\theta}{\Lambda}\left(\frac{x_i - f_e}{L}\right)^{\theta-1} \tag{3.A.3}$$

where $\Lambda = [\sigma(\lambda^s)^{\frac{1}{\theta-1}} + (1-\sigma)(\lambda^u)^{\frac{1}{\theta-1}}]^{\theta-1}$

Firm i's profit maximization:

$$\begin{cases} \max\ p_i(x_i - f_e) - w^s l_i^s - w^u l_i^u \\ \text{s.t } (1-\alpha)(A_i^u)^\beta + \alpha(A_i^s)^\beta = B \end{cases}$$

The Lagrangian is

$$\mathscr{L} = p_i(x_i - f_e) - w^s l_i^s - w^u l_i^u - \mu[(1-\alpha)(A_i^u)^\beta + \alpha(A_i^s)^\beta - B]$$

Firms are symmetry. Substitute the price in equation (3.A.3) into the Lagrangian, we have

$$\mathscr{L} = \frac{\theta}{\Lambda}\left(\frac{1}{L}\right)^{\theta-1}(x - f_e)^\theta - w^s l^s - w^u l^u - \mu[(1-\alpha)(A^u)^\beta + \alpha(A^s)^\beta - B]$$

The first-order conditions:

$$\frac{\partial \mathscr{L}}{\partial A^u} = 0 \Leftrightarrow \frac{\theta^2}{\Lambda}\left(\frac{x - f_e}{L}\right)^{\theta-1} x^{1-\gamma}(A^u l^u)^{\gamma-1} l^u = (1-\alpha)\mu\beta(A^u)^{\beta-1} \tag{3.A.4}$$

$$\frac{\partial \mathscr{L}}{\partial A^s} = 0 \Leftrightarrow \frac{\theta^2}{\Lambda}\left(\frac{x - f_e}{L}\right)^{\theta-1} x^{1-\gamma}(A^s l^s)^{\gamma-1} l^s = \alpha\mu\beta(A^s)^{\beta-1} \tag{3.A.5}$$

$$\frac{\partial \mathscr{L}}{\partial l^u} = 0 \Leftrightarrow \frac{\theta^2}{\Lambda}\left(\frac{x - f_e}{L}\right)^{\theta-1} x^{1-\gamma}(A^u l^u)^{\gamma-1} A^u = w^u \tag{3.A.6}$$

$$\frac{\partial \mathscr{L}}{\partial l^s} = 0 \Leftrightarrow \frac{\theta^2}{\Lambda}\left(\frac{x - f_e}{L}\right)^{\theta-1} x^{1-\gamma}(A^s l^s)^{\gamma-1} A^s = w^s \tag{3.A.7}$$

Substitute price in equation (3.A.3) into the free entry condition in equation (3.8) and aggregate to the whole economy, we have

$$\frac{\theta}{\Lambda L^{\theta}} N(x - f_e)^{\theta} = \sigma w^s + (1-\sigma) w^u \tag{3.A.8}$$

Let w^s to be numeraire, $w^s = 1$

Using the technology constraint in equation (3.2), full employment condition in equations (3.3) and (3.4), first order condition of profit maximization in equations (3.A.4)-(3.A.7), and free entry condition in equation (3.A.8) to solve for $A^u, A^s, l^u, l^s, \mu, \Lambda, N$ and w^u.

Appendix 3.B. Solution for free trade equilibrium

Utility maximization of k-type labor in country J:

$$\begin{cases} \max \ \sum_i^{N^J} (c_i^{J,k})^{\theta} + \sum_j^{N^{-J}} (c_j^{-J*,k})^{\theta} \\ \text{s.t} \ \sum_i^{N^J} p_i^J c_i^{J,k} + \sum_j^{N^{-J}} p_j^{-J} c_j^{-J*,k} = w^{J,k} \end{cases}$$

The same setting is applied to country $-J$. Solve the utility maximization problem for both countries, we have

$$p_i^J = \frac{\theta}{\lambda^{J,k}} (c_i^{J,k})^{\theta-1} = \frac{\theta}{\lambda^{-J,k}} (c_i^{J*,k})^{\theta-1} \tag{3.B.1}$$

Using equation (3.B.1) applied for two countries, we get

$$\left(\frac{c_i^{J,k}}{c_i^{J,-k}}\right)^{\theta-1} = \frac{\lambda^{J,k}}{\lambda^{J,-k}} \text{ and } \left(\frac{c_i^{J*,k}}{c_i^{J*,-k}}\right)^{\theta-1} = \frac{\lambda^{-J,k}}{\lambda^{-J,-k}} \tag{3.B.2}$$

$$\left(\frac{c_i^{J,k}}{c_i^{J*,k}}\right)^{\theta-1} = \frac{\lambda^{J,k}}{\lambda^{-J,k}} \tag{3.B.3}$$

Substitute equations (3.B.2), (3.B.3) into good market clearing equation (3.16), we get:

$$
\begin{aligned}
x_i^J - f_e &= L^{J,u}c_i^{J,u} + L^{J,s}c_i^{J,s} + L^{-J,u}c_i^{J*,u} + L^{-J,s}c_i^{J*,s} \\
&= L^J\left[\sigma^J + (1-\sigma^J)\left(\frac{\lambda^{J,u}}{\lambda^{J,s}}\right)^{\frac{1}{\theta-1}}\right]c_i^{J,s} + L^{-J}\left[\sigma^{-J} + (1-\sigma^{-J})\left(\frac{\lambda^{-J,u}}{\lambda^{-J,s}}\right)^{\frac{1}{\theta-1}}\right]\left(\frac{\lambda^{-J,s}}{\lambda^{J,s}}\right)^{\frac{1}{\theta-1}}c_i^{J,s} \\
&= \left[\underbrace{[\sigma^J(\lambda^{J,s})^{\frac{1}{\theta-1}} + (1-\sigma^J)(\lambda^{J,u})^{\frac{1}{\theta-1}}]}_{\Lambda^J}L^J + \underbrace{[\sigma^{-J}(\lambda^{-J,s})^{\frac{1}{\theta-1}} + (1-\sigma^{-J})(\lambda^{-J,u})^{\frac{1}{\theta-1}}]}_{\Lambda^{-J}}L^{-J}\right]\frac{c_i^{J,s}}{(\lambda^{J,s})^{\frac{1}{\theta-1}}} \\
&= [\Lambda^J L^J + \Lambda^{-J}L^{-J}]\frac{c_i^{J,s}}{(\lambda^{J,s})^{\frac{1}{\theta-1}}}
\end{aligned}
$$

Thus, we have

$$c_i^{J,s} = \frac{(x_i^J - f_e)(\lambda^{J,s})^{\frac{1}{\theta-1}}}{\Lambda^J L^J + \Lambda^{-J}L^{-J}}$$

Using equations (3.B.2), (3.B.3), we have

$$c_i^{J,k} = \frac{(x_i^J - f_e)(\lambda^{J,k})^{\frac{1}{\theta-1}}}{\Lambda^J L^J + \Lambda^{-J}L^{-J}} \text{ and } c_i^{J*,k} = \frac{(x_i^J - f_e)(\lambda^{-J,k})^{\frac{1}{\theta-1}}}{\Lambda^J L^J + \Lambda^{-J}L^{-J}} \tag{3.B.4}$$

Substitute into equation (3.B.1),

$$p_i^J = \frac{\theta}{\lambda^{J,k}}(c_i^{J,k})^{\theta-1} = \frac{\theta}{\Lambda}(x_i^J - f_e)^{\theta-1} \tag{3.B.5}$$

where $\Lambda = [\Lambda^J L^J + \Lambda^{-J}L^{-J}]^{\theta-1}$

Remind the individual budget constraints:

$$\sum_i^{N^J} p_i^J c_i^{J,k} + \sum_j^{N^{-J}} p_j^{-J} c_j^{-J*,k} = w^{J,k}$$

Substitute the price in equation (3.B.5) into the budget constraints

$$\frac{\theta}{\Lambda^{\frac{\theta}{\theta-1}}}(\lambda^{J,k})^{\frac{1}{\theta-1}}[N^J(x_i - f_e)^\theta + N^{-J}(x_j - f_e)^\theta] = w^{J,k} \tag{3.B.6}$$

Firm i in country J maximize its profit

$$\begin{cases} \max\ p_i^J(x_i^J - f_e) - w^{J,s} l_i^{J,s} - w^{J,u} l_i^{J,u} \\ \text{s.t } (1-\alpha)(A_i^{J,u})^\beta + \alpha(A_i^{J,s})^\beta = B^J \end{cases}$$

The Lagrangian is

$$\mathscr{L}^J = p_i^J(x_i^J - f_e) - w^{J,s} l_i^{J,s} - w^{J,u} l_i^{J,u} - \mu^J[(1-\alpha)(A_i^{J,u})^\beta + \alpha(A_i^{J,s})^\beta - B^J]$$

Firms in country J are symmetry. Substitute the price in equation (3.B.5) into the Lagrangian, we have

$$\mathscr{L}^J = \frac{\theta}{\Lambda}(x^J - f_e)^\theta - w^{J,s} l_i^{J,s} - w^{J,u} l_i^{J,u} - \mu^J[(1-\alpha)(A_i^{J,u})^\beta + \alpha(A_i^{J,s})^\beta - B^J]$$

The first-order conditions:

$$\frac{\partial \mathscr{L}^J}{\partial A^{J,u}} = 0 \Leftrightarrow \frac{\theta^2}{\Lambda}(x^J - f_e)^{\theta-1}(x^J)^{1-\gamma}(A^{J,u} l^{J,u})^{\gamma-1} l^{J,u} = (1-\alpha)\mu^J \beta (A^{J,u})^{\beta-1} \tag{3.B.7}$$

$$\frac{\partial \mathscr{L}^J}{\partial A^{J,s}} = 0 \Leftrightarrow \frac{\theta^2}{\Lambda}(x^J - f_e)^{\theta-1}(x^J)^{1-\gamma}(A^{J,s} l^{J,s})^{\gamma-1} l^{J,s} = \alpha\mu^J \beta (A^{J,s})^{\beta-1} \tag{3.B.8}$$

$$\frac{\partial \mathscr{L}^J}{\partial l^{J,u}} = 0 \Leftrightarrow \frac{\theta^2}{\Lambda}(x^J - f_e)^{\theta-1}(x^J)^{1-\gamma}(A^{J,u} l^{J,u})^{\gamma-1} A^{J,u} = w^{J,u} \tag{3.B.9}$$

$$\frac{\partial \mathscr{L}^J}{\partial l^{J,s}} = 0 \Leftrightarrow \frac{\theta^2}{\Lambda}(x^J - f_e)^{\theta-1}(x^J)^{1-\gamma}(A^{J,s} l^{J,s})^{\gamma-1} A^{J,s} = w^{J,s} \tag{3.B.10}$$

Let $w^{S,s}$ to be numeraire, $w^{S,s} = 1$

Using the technology constraint in equation (3.11), full employment condition in equations (3.13) and (3.14), first order condition of profit maximization problem in equations (3.B.7)-(3.B.10) for both countries; budget constraint in equation (3.B.6) for both countries and both types of labor; and trade balance condition in equation (3.18) (all 19 equations) to solve for 19 variables as follows: $A^{N,s}$, $A^{N,u}$, $A^{S,s}$, $A^{S,u}$, $l^{N,s}$, $l^{N,u}$, $l^{S,s}$, $l^{S,u}$, μ^S, μ^N, N^S, N^N, $w^{N,s}$, $w^{N,u}$, $w^{S,u}$, $\lambda^{N,s}$, $\lambda^{N,u}$, $\lambda^{S,s}$, $\lambda^{S,u}$.

Note: From trade balance in equation (3.18), budget constraint in equation (3.B.6) and good market clearing in equation (3.16), we can derive the following free entry condition.

$$\frac{\theta}{\Lambda}N^J(x^J - f_e)^\theta = [\sigma w^{J,s} + (1-\sigma)w^{J,u}]L^J \tag{3.B.11}$$

Appendix 3.C. Solution for transport cost

Consumption side

Utility maximization of k-type labor in country J:

$$\begin{cases} \max\ \sum_i^{N^J}(c_i^{J,k})^\theta + \sum_j^{N^{-J}}(c_j^{-J*,k})^\theta \\ \text{s.t}\ \sum_i^{N^J} p_i^J c_i^{J,k} + \sum_j^{N^{-J}} \hat{p}_j^{-J} c_j^{-J*,k} = w^{J,k} \end{cases}$$

Solve the utility maximization, price of good i produced in country J will be as follows:

$$p_i^J = \frac{\theta}{\lambda^{J,k}}(c_i^{J,k})^{\theta-1} = \tau\frac{\theta}{\lambda^{-J,k}}(c_i^{J*,k})^{\theta-1} \tag{3.C.1}$$

Using equation (3.C.1) applying for both countries, we have

$$\frac{c_i^{J,k}}{c_i^{J,-k}} = \frac{c_j^{-J*,k}}{c_j^{-J*,-k}} = \left(\frac{\lambda^{J,k}}{\lambda^{J,-k}}\right)^{\frac{1}{\theta-1}} \text{ and } \frac{c_i^{J*,k}}{c_i^{J*,-k}} = \frac{c_j^{-J,k}}{c_j^{-J,-k}} = \left(\frac{\lambda^{-J,k}}{\lambda^{-J,-k}}\right)^{\frac{1}{\theta-1}} \tag{3.C.2}$$

$$\frac{c_i^{J*,k}}{c_i^{J,k}} = \left(\frac{\lambda^{-J,k}}{\tau\lambda^{J,k}}\right)^{\frac{1}{\theta-1}} \text{ and } \frac{c_j^{-J*,k}}{c_j^{-J,k}} = \left(\frac{\lambda^{J,k}}{\tau\lambda^{-J,k}}\right)^{\frac{1}{\theta-1}} \tag{3.C.3}$$

Substitute this into good market clearing condition in equation (3.22)

$$x_i^J - f_e = L^{J,u}c_i^{J,u} + L^{J,s}c_i^{J,s} + \frac{1}{\tau}L^{-J,u}c_i^{J*,u} + \frac{1}{\tau}L^{-J,s}c_i^{J*,s}$$

$$= \left[\underbrace{[\sigma^J (\lambda^{J,s})^{\frac{1}{\theta-1}} + (1-\sigma^J)(\lambda^{J,u})^{\frac{1}{\theta-1}}]}_{\Lambda^J} L^J + \frac{1}{\tau^{\frac{\theta}{\theta-1}}} \underbrace{[\sigma^{-J} (\lambda^{-J,s})^{\frac{1}{\theta-1}} + (1-\sigma^{-J})(\lambda^{-J,u})^{\frac{1}{\theta-1}}]}_{\Lambda^{-J}} L^{-J} \right] \frac{c_i^{J,s}}{(\lambda^{J,s})^{\frac{1}{\theta-1}}}$$

$$= [\Lambda^J L^J + \tau^{\frac{\theta}{1-\theta}} \Lambda^{-J} L^{-J}] \frac{c_i^{J,s}}{(\lambda^{J,s})^{\frac{1}{\theta-1}}}$$

The same for production in country $-J$

$$x_j^{-J} - f_e = [\tau^{\frac{\theta}{1-\theta}} \Lambda^J L^J + \Lambda^{-J} L^{-J}] \frac{c_j^{-J,s}}{(\lambda^{-J,s})^{\frac{1}{\theta-1}}}$$

Thus, we have

$$c_i^{J,k} = \frac{(x_i^J - f_e)(\lambda^{J,k})^{\frac{1}{\theta-1}}}{(\tilde{\Lambda}^J)^{\frac{1}{\theta-1}}} \tag{3.C.4}$$

and

$$c_j^{-J,k} = \frac{(x_j^{-J} - f_e)(\lambda^{-J,k})^{\frac{1}{\theta-1}}}{(\tilde{\Lambda}^{-J})^{\frac{1}{\theta-1}}} \tag{3.C.5}$$

where

$$\tilde{\Lambda}^{-J} \equiv (\tau^{\frac{\theta}{1-\theta}} \Lambda^J L^J + \Lambda^{-J} L^{-J})^{(\theta-1)} \tag{3.C.6}$$

$$\tilde{\Lambda}^{J} \equiv (\Lambda^J L^J + \tau^{\frac{\theta}{1-\theta}} \Lambda^{-J} L^{-J})^{(\theta-1)} \tag{3.C.7}$$

Substitute into equation (3.C.4) into equation (3.C.1),

$$p_i^J = \frac{\theta}{\tilde{\Lambda}^J} (x_i^J - f_e)^{\theta-1} \tag{3.C.8}$$

The same for price in country $-J$

$$p_j^{-J} = \frac{\theta}{\tilde{\Lambda}^{-J}} (x_j^{-J} - f_e)^{\theta-1} \tag{3.C.9}$$

Substitute the price in equations (3.C.8) and (3.C.9) and consumption in equations (3.C.1), (3.C.3)-(3.C.5) into the budget constraint in equation (3.21)

$$\theta (\lambda^{J,k})^{\frac{1}{\theta-1}} \left(\frac{N^J (x^J - f_e)^\theta}{(\tilde{\Lambda}^J)^{\frac{\theta}{\theta-1}}} + \frac{N^{-J} (x^{-J} - f_e)^\theta}{\tau^{\frac{\theta}{\theta-1}} (\tilde{\Lambda}^J)^{\frac{\theta}{\theta-1}}} \right) = w^{J,k} \tag{3.C.10}$$

Let $w^{S,s}$ to be numeraire, $w^{S,s} = 1$ [10]

Price index

Utility maximization of k-type labor in country J

$$\begin{cases} \max \ \sum_i^{N^J} (c_i^{J,k})^\theta + \sum_j^{N^{-J}} (c_j^{-J*,k})^\theta \\ \text{s.t} \ \sum_i^{N^J} p_i^J c_i^{J,k} + \sum_j^{N^{-J}} \hat{p}_j^{-J} c_j^{-J*,k} = w^{J,k} \end{cases}$$

This utility maximization problem has similar form with that in Dixit-Stiglitz model. The price index can be calculated as

$$P^J = \left(\sum_i^{N^J} (p_i^J)^{\frac{\theta}{\theta-1}} + \sum_j^{N^{-J}} (\hat{p}_j^{-J})^{\frac{\theta}{\theta-1}} \right)^{\theta-1} \tag{3.C.11}$$

Production side

Endogenous technology choice model

Firm i in country J maximize its profit

$$\begin{cases} \max\limits_{l_i^{J,u}, l_i^{J,s}, A_i^{J,u}, A_i^{J,s}} p_i^J (x_i^J - f_e) - w^{J,s} l_i^{J,s} - w^{J,u} l_i^{J,u} \\ \text{s.t} \ (1-\alpha)(A_i^{J,u})^\beta + \alpha (A_i^{J,s})^\beta = B^J \end{cases}$$

The Lagrangian is

$$\mathscr{L}_i^J = p_i^J (x_i^J - f_e) - w^{J,s} l_i^{J,s} - w^{J,u} l_i^{J,u} - \mu^J [(1-\alpha)(A_i^{J,u})^\beta + \alpha (A_i^{J,s})^\beta - B^J]$$

Firms in country J are symmetry. Substitute the price in equation (3.C.8) into the La-

[10] In calibration, in order to convert other variables in the model into numeraire equivalent, it is necessary to calculate this wage for each country. The average wage of a country can be calculated in two ways. First, assume that all 52 countries have the same labor share in income as of 65%, then the average wage of a labor will be $\frac{0.65 \times GDP}{\text{Total population}} \left(= \frac{0.65 X^J}{L^J} \right)$. Second, this average wage can also be calculated as $\sigma^J w^{J,s} + (1-\sigma^J) w^{J,u}$. Equalizing these two calculations, we have $\sigma^J w^{J,s} + (1-\sigma^J) w^{J,u} = \frac{0.65 \times X^J}{L^J}$. Given the share of each type of labor and the skill premium $\frac{w^{J,s}}{w^{J,u}}$, the wage of skilled labor in each country can be derived.

grangian, we have

$$\mathscr{L}^J = \frac{\theta}{\tilde{\Lambda}^J}(x^J - f_e)^\theta - w^{J,s} l_i^{J,s} - w^{J,u} l_i^{J,u} - \mu^J[(1-\alpha)(A_i^{J,u})^\beta + \alpha(A_i^{J,s})^\beta - B^J]$$

The first-order conditions:

$$\frac{\partial \mathscr{L}^J}{\partial A^{J,u}} = 0 \Leftrightarrow \frac{\theta^2}{\tilde{\Lambda}^J}(x^J - f_e)^{\theta-1}(x^J)^{1-\gamma}(A^{J,u} l^{J,u})^{\gamma-1} l^{J,u} = (1-\alpha)\mu^J \beta (A^{J,u})^{\beta-1} \tag{3.C.12}$$

$$\frac{\partial \mathscr{L}^J}{\partial A^{J,s}} = 0 \Leftrightarrow \frac{\theta^2}{\tilde{\Lambda}^J}(x^J - f_e)^{\theta-1}(x^J)^{1-\gamma}(A^{J,s} l^{J,s})^{\gamma-1} l^{J,s} = \alpha\mu^J \beta (A^{J,s})^{\beta-1} \tag{3.C.13}$$

$$\frac{\partial \mathscr{L}^J}{\partial l^{J,u}} = 0 \Leftrightarrow \frac{\theta^2}{\tilde{\Lambda}^J}(x^J - f_e)^{\theta-1}(x^J)^{1-\gamma}(A^{J,u} l^{J,u})^{\gamma-1} A^{J,u} = w^{J,u} \tag{3.C.14}$$

$$\frac{\partial \mathscr{L}^J}{\partial l^{J,s}} = 0 \Leftrightarrow \frac{\theta^2}{\tilde{\Lambda}^J}(x^J - f_e)^{\theta-1}(x^J)^{1-\gamma}(A^{J,s} l^{J,s})^{\gamma-1} A^{J,s} = w^{J,s} \tag{3.C.15}$$

Using the technology constraint in equation (3.11), full employment condition in equations (3.13) and (3.14), first order condition of profit maximization in equations (3.C.12)-(3.C.15) for both countries; budget constraint in equation (3.C.10) for both countries and both types of labor; and trade balance condition in equation (3.23) (all 19 equations) to solve for 19 variables as follows: $A^{N,s}$, $A^{N,u}$, $A^{S,s}$, $A^{S,u}$, $l^{N,s}$, $l^{N,u}$,$l^{S,s}$, $l^{S,u}$, μ^S, μ^N, N^S, N^N, $w^{N,s}$, $w^{N,u}$, $w^{S,u}$, $\lambda^{N,s}$, $\lambda^{N,u}$, $\lambda^{S,s}$, $\lambda^{S,u}$.

Standard constant technology model

In this model, the world technology combination, $\frac{\bar{A^s}}{A^u}$, is constant. This technology combination is the weighted average of the logarithm of $\frac{A^{J,s}}{A^{J,u}}$ of each country, which is derived from equation (3.24). Each weight involved in this weighted average equals the share of labor force of each country in the total labor force of all 52 countries provided in the data. From data of unskilled and skilled labor share, wage premium between these two types of labor, and labor force which are described in Section 3.4.3, the world technology combination, $\frac{\bar{A^s}}{A^u}$, is 1.02 by calculation. Given this world technology combination, using aggregate production function of each country $X^J = [(\bar{A^{J,u}}L^{J,u})^\gamma + (\bar{A^{J,s}}L^{J,s})^\gamma]^{\frac{1}{\gamma}}$, technology appropriate for unskilled and skilled labor in country J in the standard model with exogenous technology, $\bar{A^{J,u}}$ and $\bar{A^{J,s}}$, can be computed. Now, firms in each country adopt the same technology system and simply choose different combinations of labor. Firm i in country J maximize its profit

$$\max_{l_i^{J,u},l_i^{J,s}} p_i^J(x_i^J - f_e) - w^{J,s}l_i^{J,s} - w^{J,u}l_i^{J,u}$$

Substitute price in equation (3.C.8) into profit maximization problem above, we have

$$\max_{l_i^{J,u},l_i^{J,s}} \frac{\theta}{\tilde{\Lambda}^J}(x^J - f_e)^\theta - w^{J,s}l_i^{J,s} - w^{J,u}l_i^{J,u}$$

The first-order conditions:

$$\frac{\theta^2}{\tilde{\Lambda}^J}(x^J - f_e)^{\theta-1}(x^J)^{1-\gamma}(l^{J,u})^{\gamma-1}(\bar{A^{J,u}})^\gamma = w^{J,u} \tag{3.C.16}$$

$$\frac{\theta^2}{\tilde{\Lambda}^J}(x^J - f_e)^{\theta-1}(x^J)^{1-\gamma}(l^{J,s})^{\gamma-1}(\bar{A^{J,s}})^\gamma = w^{J,s} \tag{3.C.17}$$

Using full employment condition in equations (3.13) and (3.14), first order condition of profit maximization in equations (3.C.16), (3.C.17) for both countries; budget constraint in equation (3.C.10) for both countries and both types of labor; and trade balance condition in equation (3.23) (all 13 equations) to solve for 13 variables as follows: $l^{N,s}$, $l^{N,u}$,$l^{S,s}$, $l^{S,u}$, N^S, N^N, $w^{N,s}$, $w^{N,u}$, $w^{S,u}$, $\lambda^{N,s}$, $\lambda^{N,u}$, $\lambda^{S,s}$, $\lambda^{S,u}$.

Appendix 3.D. Proof of proposition 3.7

Substitute price and consumption in equations (3.C.1), (3.C.3)-(3.C.5) into trade balance in equation (3.23), we have:

$$\frac{\Lambda^J}{\Lambda^{-J}} = \frac{N^J L^{-J}}{N^{-J} L^J}\left(\frac{\tilde{\Lambda}^J}{\tilde{\Lambda}^{-J}}\right)^{\frac{\theta}{1-\theta}}$$

Substitute N^J and N^{-J} which is solved in Appendix 3.C into the previous equation, we have

$$\frac{\Lambda^J L^J}{\Lambda^{-J} L^{-J}} = D\left(\frac{\tilde{\Lambda}^J}{\tilde{\Lambda}^{-J}}\right)^{\frac{\theta}{1-\theta}} \tag{3.D.1}$$

where D[11] is denoted as

$$D \equiv \frac{\left[1 + \left(\frac{\alpha}{1-\alpha}(\rho^J)^\beta\right)^{\frac{\gamma}{\beta-\gamma}}\right]^{\frac{\beta-\gamma}{\beta\gamma}}}{\left[1 + \left(\frac{\alpha}{1-\alpha}(\rho^{-J})^\beta\right)^{\frac{\gamma}{\beta-\gamma}}\right]^{\frac{\beta-\gamma}{\beta\gamma}}} \frac{1+\rho^{-J}}{1+\rho^J} \frac{L^J}{L^{-J}}$$

Using definition of $\tilde{\Lambda}^J$ and $\tilde{\Lambda}^{-J}$ in equations (3.C.6) and (3.C.7) we can derive the following equation:

$$\frac{\Lambda^J L^J}{\Lambda^{-J} L^{-J}} = \frac{\left(\frac{\tilde{\Lambda}^J}{\tilde{\Lambda}^{-J}}\right)^{\frac{1}{\theta-1}} - \tau^{\frac{\theta}{1-\theta}}}{1 - \tau^{\frac{\theta}{1-\theta}}\left(\frac{\tilde{\Lambda}^J}{\tilde{\Lambda}^{-J}}\right)^{\frac{1}{\theta-1}}} \tag{3.D.2}$$

Let $y \equiv \left(\frac{\tilde{\Lambda}^J}{\tilde{\Lambda}^{-J}}\right)^{\frac{1}{1-\theta}}$ and $\kappa = \tau^{\frac{\theta}{1-\theta}}$

Then, from equations (3.D.1) and (3.D.2), we have

$$Dy^\theta = \frac{1-\kappa y}{y-\kappa}$$

or

$$Dy^{\theta+1} - D\kappa y^\theta + \kappa y - 1 = 0 \tag{3.D.3}$$

[11] In the main body of the chapter, this D is clearly denoted as $D^{J,-J}$ to avoid any misunderstanding.

Left hand side of equation (3.D.3) is a function of y and κ: $g(y,\kappa) = Dy^{\theta+1} - D\kappa y^{\theta} + \kappa y - 1$. Thus equation (3.D.3) will be $g(y,\kappa) = 0$. Differentiate function $g(y,\kappa)$ by y,

$$
\begin{aligned}
g'_y(y,\kappa) &= D(\theta+1)y^{\theta} - \theta\kappa D y^{\theta-1} + \kappa \\
&= D\theta y^{\theta} - \theta\kappa D y^{\theta-1} + \frac{Dy^{\theta+1} + \kappa y}{y} \\
&= D\theta y^{\theta} - \theta\kappa D y^{\theta-1} + \frac{D\kappa y^{\theta} + 1}{y} \text{ (by equation (3.D.3))} \\
&= D\theta y^{\theta} + \frac{1}{y} + D\kappa y^{\theta-1}(1-\theta) > 0
\end{aligned}
\tag{3.D.4}
$$

Thus, function $g(y,\kappa)$ is monotonic increasing in y. At $y = \kappa$, function $g(y,\kappa) = \kappa^2 - 1 < 0$. At $y = \frac{1}{\kappa}$, function $g(y,\kappa) = D\kappa^{-(\theta+1)}(1-\kappa^2) > 0$. Thus, solution y of equation (3.D.3) will lie between κ and $\frac{1}{\kappa}$, $\left(\kappa < y < \frac{1}{\kappa}\right)$.

Differentiate function $g(y,\kappa)$ by κ and use equation (3.D.3), we have

$$
g'_\kappa(y,\kappa) = \frac{y^2 - 1}{y - k} \tag{3.D.5}
$$

Because $y > k$, sign of $g'_\kappa(y,\kappa)$ depends on sign of $(y^2 - 1)$.

$$
g'_\kappa(y,\kappa) = \begin{cases} > 0 & \text{when } y > 1 \\ \leq 0 & \text{when } y \leq 1 \end{cases}
$$

Using implicit function theorem, we can derive $\frac{dy}{dk} = -\frac{g'_\kappa(y,\kappa)}{g'_y(y,\kappa)}$, thus

$$
\frac{dy}{d\kappa} = \begin{cases} \leq 0 & \text{when } y > 1 \\ > 0 & \text{when } 0 < y \leq 1 \end{cases} \tag{3.D.6}
$$

Back to equation (3.D.3)

$$\begin{cases} y = 1 \Longrightarrow g(y,\kappa) = D - D\kappa + \kappa - 1 = \underbrace{(1-\kappa)}_{>0}(D-1) \\ y = \kappa \Longrightarrow g(y,\kappa) = \kappa^2 - 1 < 0 \\ y = \frac{1}{\kappa} \Longrightarrow g(y,\kappa) = D\left(\frac{1}{\kappa}\right)^{\theta+1}[1-\kappa^2] > 0 \end{cases} \tag{3.D.7}$$

Treat κ as a parameter,

If $D^{J,-J} > 1 \Longrightarrow \begin{matrix} y = 1 \Longrightarrow g(y,\kappa) > 0 \\ y = \kappa \Longrightarrow g(y,\kappa) < 0 \end{matrix} \Longrightarrow$ Solution of equation (3.D.3) $y \in (\kappa, 1) \xrightarrow{\text{eq.(3.D.6)}}$ $\frac{dy}{d\kappa} > 0$

If $D^{J,-J} < 1 \Longrightarrow \begin{matrix} y = 1 \Longrightarrow g(y,\kappa) < 0 \\ y = \frac{1}{\kappa} \Longrightarrow g(y,\kappa) > 0 \end{matrix} \Longrightarrow$ Solution of equation (3.D.3) $y \in (1, \frac{1}{\kappa}) \xrightarrow{\text{eq.(3.D.6)}}$ $\frac{dy}{d\kappa} < 0$

Wage rate between two countries for skilled labor can be calculated by $\frac{\tilde{\Lambda}^J}{\tilde{\Lambda}^{-J}}$ by equations (3.C.13), (3.C.14) as follows:

$$\frac{w^{J,s}}{w^{-J,s}} = \frac{\tilde{\Lambda}^{-J}}{\tilde{\Lambda}^{J}} \underbrace{\left[\frac{1 + \left(\frac{\alpha}{1-\alpha}(\rho^J)^\beta\right)^{\frac{\gamma}{\beta-\gamma}}}{1 + \left(\frac{\alpha}{1-\alpha}(\rho^{-J})^\beta\right)^{\frac{\gamma}{\beta-\gamma}}}\right]^{\frac{\beta-\gamma-\beta\gamma}{\beta-\gamma}}}_{>0} \Longrightarrow \text{sign}\left[\frac{\partial \frac{w^{J,s}}{w^{-J,s}}}{\partial \tau}\right] = -\text{sign}\left[\frac{\partial \frac{\tilde{\Lambda}^J}{\tilde{\Lambda}^{-J}}}{\partial \tau}\right] = -\text{sign}\left[\frac{dy}{d\kappa}\right]$$

The same for wage rate between two countries for unskilled labor, we can also find that

$$\text{sign}\left[\frac{\partial \frac{w^{J,u}}{w^{-J,u}}}{\partial \tau}\right] = -\text{sign}\left[\frac{\partial \frac{\tilde{\Lambda}^J}{\tilde{\Lambda}^{-J}}}{\partial \tau}\right] = -\text{sign}\left[\frac{dy}{d\kappa}\right]$$

Thus, knowing sign of $\frac{dy}{d\kappa}$, we can find how transport cost τ affects wage rate of labor type

k, $\frac{w^{J,k}}{w^{-J,k}}$. The result will be as follows:

$$\frac{\partial \frac{w^{J,s}}{w^{-J,s}}}{\partial \tau} = \begin{cases} < 0 & \text{when } D > 1 \\ > 0 & \text{when } D < 1 \end{cases} \tag{3.D.8}$$

□

Discussion of D

D is contributed from two aspects: the size of labor force (L) and the ratio of unskilled over skilled labor (ρ) of both countries J and $-J$.

First, keep the ratio of unskilled over skilled labor of both countries are the same ($\rho^J = \rho^{-J}$), if country J has smaller labor force than country $-J$ ($L^J < L^{-J}$), D will be smaller than 1.

Second, keep the size of labor force between two countries are the same ($L^J = L^{-J}$), if country J is more unskilled-labor-abundant than country $-J$ ($\rho^J > \rho^{-J}$), the answer for the question of that D is smaller or larger than 1 depends on characteristic of function $h(\rho) = \left[1 + \left(\frac{\alpha}{1-\alpha}(\rho^J)^\beta\right)^{\frac{\gamma}{\beta-\gamma}}\right]^{\frac{\beta-\gamma}{\beta\gamma}} (1+\rho^J)^{-1}$. Under the condition of that skill bias between two types of labor is the same ($\alpha = 0.5$) and both countries are unskilled-labor-abundant ($\rho^J, \rho^{-J} > 1$), function $h(\rho)$ is found to be monotonic decreasing ($h'(\rho) < 0$). Thus, if $\rho^J > \rho^{-J}$, then $h(\rho^J) < h(\rho^{-J})$. Consequently, $D < 1$.

Appendix 3.E. Some extra calibration results for the impact of transport cost

To fully understand the impact of transport cost on the relative real wage, the sections below discuss the impact of transport cost on the relative nominal wage and price index ratio separately.

Impact of transport cost on relative nominal wage

This section reports calibration results for the impact of transport cost on relative nominal wage. Figure 3E.1 shows the impact of transport cost on the relative nominal wage for both unskilled and skilled labor between Indonesia and Malaysia.

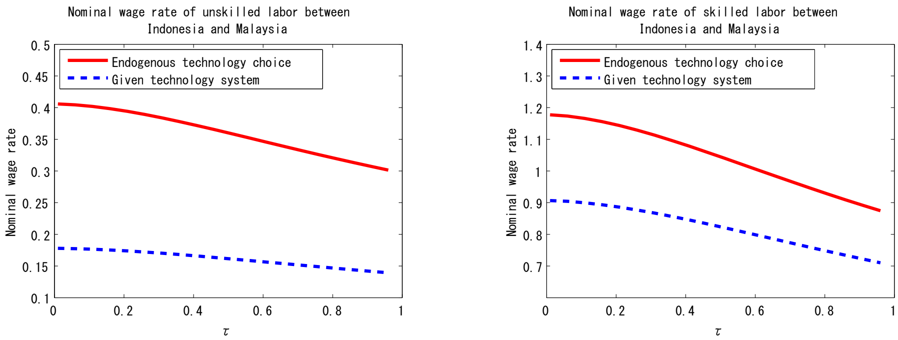

Fig 3E.1.A　　　　Fig 3E.1.B

Figure 3E.1

Note: Since τ measures the fraction of goods that reach the importer country safely, transport costs decrease as we move to the right along the horizontal axis.

In this figure, the horizontal axis corresponds to τ. Note that, since τ measures the fraction of goods that reaches the importer country safely, transport cost decreases as we move to the right along this axis. The vertical axis shows the relative nominal wage between the two countries. Panel A shows the case of unskilled labor, while panel B shows the case of skilled labor. The solid lines represent endogenous technology choice while the dotted lines represent constant technology. The result is consistent with Proposition 3.7 which states that relative nominal wage increases monotonically as transportation costs are reduced. In this case, the factor $D^{IND,MYS}$ denoted in Proposition 3.7 between Indonesia and Malaysia is 5.384, which is larger than 1, thus the relative nominal wage curves are downward sloping for both types of labor as transport cost decreases.

Impact of transport cost on price index ratio

This section reports the calibration results for the impact of transport cost on the price index ratio. Figure 3E.2 shows the impact of transport cost on the price index ratio between two pairs of countries: Indonesia-Malaysia and France-Italy.

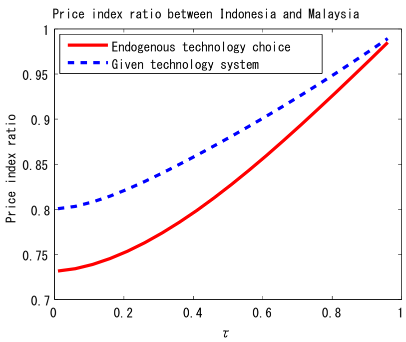

Fig 3E.2.A

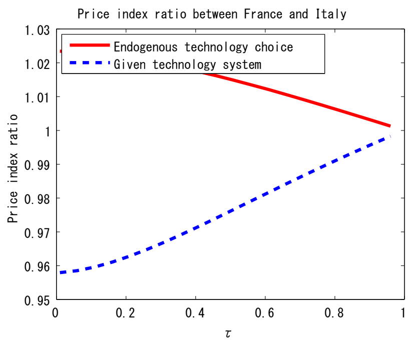

Fig 3E.2.B

Figure 3E.2

Note: Since τ measures the fraction of goods that reach the importer country safely, transport costs decrease as we move to the right along the horizontal axis.

In this figure, the horizontal axis corresponds to τ. The vertical axis shows the price index ratio between two countries. The solid lines represent endogenous technology choice while the dotted lines represent constant technology. Panel A shows the case between Indonesia and Malaysia. In both models of exogenous and endogenous technology choice, the price index ratios between these two countries are monotonic increasing and converge to one during the transition from autarky to free trade. On the other hand, in Panel B, which shows impact of transport cost on the price index ratio between France and Italy, the price index ratios are monotonic increasing and decreasing in the models of exogenous and endogenous technology choice, respectively. However, as the economy is close to free trade, these ratios also converge to one as discussed in Section 3.4.2. This convergence narrows the gap of the impact of transport cost on relative real wage between the two models as the economy is closer to free trade.

Chapter 4

An Analysis of Changes in Wealth Distribution in Response to the Entry of Foreign Direct Investment Firms

4.1 Introduction

Over the last few decades, developing countries have witnessed a significant increase in foreign direct investment (FDI) inflows. From 1990 to 2012, FDI inflows into developing countries increased more than thirtyfold, nearly four times the world average (See Figure 4.1).[1]

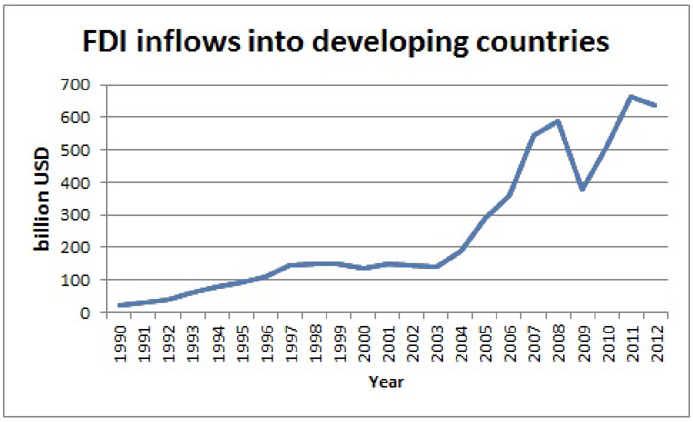

Figure 4.1

Source: The World Development Indicators database.

Accompanying the surge in FDI inflows is an increasing concern about the adverse impacts

[1] Author's calculations using the World Development Indicators database.

of FDI on social wealth equality. Several studies, both theoretical and empirical, examined this relationship. For the most part, the theoretical studies have focused on the effects of wealth distribution on foreign investment. For example, Amissah, Bougheas and Falvey (2011) and Gall, Schiffbauer and Kubny (2014) examine the impact of the distribution of wealth under credit market imperfections. Nevertheless, how foreign investment (especially FDI) affects wealth distribution is less well understood.

Empirical studies investigating the same issue typically specify income distribution as a proxy for wealth distribution. Their results about the impact of FDI on income distribution have been mixed. For example, both Basu and Guariglia (2007) and Choi (2006) use data from more than a hundred developing countries and conclude that FDI promotes income inequality. On the contrary, Lindert and Williamson (2002) and Milanovic (2005) find no evidence of a significant relationship between FDI and income inequality. This controversy might be a result of the lack of theoretical research in the area. The goal of this chapter is to develop a framework in which we examine changes in domestic wealth distribution in response to the entry of FDI firms.

Based on the theoretical framework developed in Matsuyama (2011), we build a new model that includes the entry of FDI firms as an additional foreign factor. Matsuyama (2011) provides a rich framework for highlighting some key results in the theoretical literature regarding credit market imperfections, household wealth distribution, and development. In particular, the paper employs a series of previous models[2] that progressively build on each other to analyze the dynamics of inequality and development under credit market imperfections. It also identifies a number of major research trends and perspectives, and discusses the advantages of a hierarchically integrated approach. More specifically, changes in wealth distribution in this framework is generated by the introduction of a borrowing constraint. This constraint prevents agents from borrowing, thereby establishing a barrier between rich and poor agents. Whether an agent can breach this barrier determines the distribution of wealth. This assumption of a borrowing constraint is natural, especially in developing countries, where the credit market remains generally

[2] See Galor and Zeira (1993), Banerjee and Newman (1993), Aghion and Bolton (1997), and Matsuyama (2006).

immature. Furthermore, although this framework covers almost all of the properties of the relationship between imperfect credit markets and wealth distribution, it is sufficiently general and simple to allow for the extension of these properties to introduce new factors, including the participation of FDI firms. Therefore, the significance of this chapter is that it introduces the entry of FDI firms as an additional foreign factor into the theoretical literature on credit market imperfections and wealth distribution, which hitherto concern only closed economies, and analyzes how FDI firms affect the results of previous studies. More importantly, the FDI firm modeled in this analysis is sufficiently creditworthy such that, unlike the domestic firms, it does not face any credit constraints. From the perspective of the domestic economy, a representative FDI firm is from the "rest of the world". We assume that the rest of the world is then sufficiently large and rich to ensure that while profit remains positive, an FDI firm can always afford the setup costs and join the domestic economy. This is the main difference between FDI and domestic firms in the credit market.

The chapter yields some interesting results. By providing country-specific conditions under which the entry of FDI firms alters (in)equality in domestic wealth, it resolves the existing disagreement concerning the impact of FDI on wealth inequality in existing empirical studies. First, the entry of FDI firms can provide a "big push" to move the poor out of a poverty trap, resulting in increasing job and wealth equality among domestic agents. Second, this can also promote equality by leading to an "underdevelopment trap" whereby all domestic agents have no choice other than to work for FDI firms. In contrast, by redistributing domestic wealth to make the richest agents who survive after the competition with FDI firms better off, the entry of FDI firms may lead to inequality. Last, we identify four specific factors that determine the effects of FDI firm entry, namely, the cost of starting a new business, the bequest motive, the global interest rate, and productivity in the home country. Specifically, when there is a higher cost of starting a new business, a greater bequest to the next generation, a higher global interest rate, or a higher home country's productivity, the entrance of FDI firms will be more likely to "push" the economy toward a state where all domestic agents experience greater equality in wealth and job selection.

The remainder of the chapter is organized as follows. Section 4.2 presents the basic model. Section 4.3 provides the analytical computation and Section 4.4 discusses the simulation. Section 4.5 details the conclusions.

4.2 The model

The model introduced in this chapter is based on Matsuyama (2011). The economic environment assumes that in a country, there are an infinite number of generations. Each generation has a unit mass of identical agents who live for only one period. Thus, the population is assumed to be continuous and its size, L, is set to 1. There is a single numeraire good which may be allocated to consumption or investment.

In this chapter, the country is assumed to be a small open economy where the interest rate, r, is determined exogenously depending on the current world rate.

Domestic agents

At the beginning of period t, an $Agent_t$ inherits h_t units of the numeraire good from his parents. Then, based on his own state of inheritance and ability, he decides to either run a business as an entrepreneur or work for another company as a worker. This job selection allows for endogenous entry and exit of entrepreneurs, which is an important channel of resource allocation. At the end of the period, the agent derives utility by consuming c_t and by leaving a bequest h_{t+1} to the next generation. Thus, the utility function is

$$U_t = c_t^{1-\beta} h_{t+1}^{\beta} \tag{4.1}$$

where β is the bequest share.

If $Agent_t$ decides to become a worker, he can work in a domestic firm or an FDI firm and earn a wage w_t. At the beginning of period t, a worker does not need to spend money on neither consumption nor investment so he lends all of his unemployed inheritance h_t at interest rate r

$(r \geq 1)$. Thus, at the end of period t, his wealth is $w_t + rh_t$.

An entrepreneur, $Agent_t$, establishes a firm. Each domestic firm is assumed to have an identical production function as follows:

$$Y_t = \phi(l_t) \tag{4.2}$$

where $\phi' > 0, \phi'' < 0, \phi(0) = 0$ and l_t is the number of worker working in this domestic firm $(l_t < 1)$. Labor is the sole input into the production process. To start the firm, the entrepreneur has to pay a setup cost $F (F \geq 0)$. At the beginning of period t, if he has more wealth than the setup cost, he can lend the remainder at interest rate r. Thus, the income of the firm, or the wealth of the entrepreneur at the end of period t, can be derived as $\phi(l_t t) - w_t l_t t + r(h_t - F)$. If you separate the part that varies with the number of workers, $\phi(l_t) - w_t l_t$, and denote it as $\pi(l_t)$, the wealth of the entrepreneur can be rewritten as $\pi(l_t) + r(h_t - F)$. In order to maximize the profit, the entrepreneur determines the optimal number of workers to recruit. His profit maximization condition takes the form of $w_t = \phi'(l_t)$. That is, the optimum number of workers is a decreasing function of the equilibrium wage, which is determined in the labor market, $l_t = \phi'^{-1}(w_t), l'(w_t) < 0$.

Every entrepreneur is subject to two constraints: profitability constraint and borrowing constraint. First, in term of a profitability constraint, an entrepreneur has no incentive to invest unless his income is greater than that of a worker. Thus, his profitability constraint is

$$\pi(l(w_t)) + r(h_t - F) \geq w_t + rh_t \Longleftrightarrow \pi(w_t) - w_t \geq rF.$$

Solving the equation, we get

$$w_t \leq w^*. \tag{4.3}$$

Second, in term of a borrowing constraint, an entrepreneur can only run a business if he has enough setup cost, F. Based on this assumption, the borrowing constraint can be written as follows:

$$h_t \geq F. \tag{4.4}$$

This assumption is consistent with the case of developing countries where a credit market has not been developed yet.

FDI firms

A new addition to the basic model in Matsuyama (2011) is the introduction of FDI firms. In contrast to domestic firms, the most important assumption relevant to FDI firms in this model is that they do not face any borrowing constraints. FDI firms come from the "rest of the world," and "the rest of the world" is large and rich enough to ensure that as long as the profitability constraint is satisfied, there will be FDI firms that can afford to pay a setup cost F to join this economy. FDI firms join the economy by hiring workers for production, and at the end of the period, they repatriate the income earned back to their host countries.

Each FDI firm has an identical production function that uses labor as its sole input, and the productivity is also assumed to be identical to that of domestics firms as shown below:

$$\hat{Y}_t = \hat{\phi}(l_t) \tag{4.5}$$

where $\hat{\phi}' > 0, \hat{\phi}'' < 0, \hat{\phi}(0) = 0$ and l_t is the number of workers in the FDI firm. Then, we assume

$$\hat{\phi}'(l_t) = \phi'(l_t), \forall l_t \tag{4.6}$$

Its profit maximization condition takes the form of $w_t = \hat{\phi}'(l_t)$. That is, the optimum number of workers is a decreasing function of the equilibrium wage, which is determined in the labor market as $l_t = \hat{\phi}'^{-1}(w_t)$ where $l'(w_t) < 0$.

Similar to domestic firms, FDI firms also face a profitability constraint. Unless an FDI firm's profit is less than what it gains from lending the setup cost instead of investing it, the FDI firm will invest. Thus, its profitability constraint is

$$\hat{\pi}(w_t) \geq rF$$

where $\hat{\pi}(w_t) = \hat{\phi}[l(w_t)] - l(w_t) \cdot w_t$.

Solving the equation, we get

$$w_t \leq w^{**}. \tag{4.7}$$

It is easy to see that if the profitability constraint of a domestic firm is satisfied, that of FDI firms also holds, as seen in this equation: $w^{**} \geq w^{*}$.

Labor market

In the labor market, both domestic and FDI firms share a common wage $W_t = \phi'(l_t) = \hat{\phi}'(l_t)$ where l_t is optimum number of workers in domestic and FDI firms. The wage, W_t, is an equilibrium wage at period t as it is determined when the labor market is clearing.

The labor supply, defined as participation in the labor force, is the number of people who cannot satisfy the borrowing constraint to run a firm. Therefore, labor supply takes the following form:

$$L_t^S \equiv G_t(F).$$

Here, $G_t(F)$ denotes the fraction at period t of the agents whose inheritance is less than F.[3]

In contrast, labor demand is the number of workers that domestic and FDI firms need to maximize their profit. Labor demand is defined as follows:

$$L_t^D \equiv [1 - G_t(F)]l(W_t) + \theta l(W_t)$$

where θ is the ratio of the number of FDI firms to domestic firms. The first term on the right-hand side of the equation above is a production of the fraction of domestic entrepreneurs whose

[3] Refer to borrowing constraint in equation (4.4).

inheritance is larger than F, $[1 - G_t(F)]$, and the number of workers hired by a domestic firm, $n(V_t)$. Thus, this first term shows the total number of workers in domestic firms. Similarly, the second term on the righ-hand side of the equation above shows the total number of workers who are hired by FDI firms.

The market is clearing when the labor demand equals labor supply $L_t^S = L_t^D$. Then the equilibrium wage at every period W_t is solved.

The bequest rule

Based on the utility function in equation (4.1), to maximize his utility, $Agent_t$ should leave a bequest that is equal to a fraction, β, of his wealth at the end of period t. Thus, the bequest rule is determined as follows:

$$h_{t+1} = \begin{cases} \beta[W_t + rh_t] & h_t \leq F \\ \beta[\pi(W_t) + r(h_t - F)] & otherwise. \end{cases} \tag{4.8}$$

4.3 The analytical computation

Analysis of the entry of FDI firms in an economy will be discussed in this section.

4.3.1 Labor market

This section describes the labor market equilibrium and the wage movements upon the entry of FDI firms.

Proposition 4.1. *Immediately after the entry of FDI firms, the equilibrium wage becomes higher.*

The intuitive picture behind this proposition is quite basic; and the proposition is consistent with the line of empirical research investigating the effect of FDI on domestic wage rate.

Proof. • The case of no FDI firm:

1. Labor demand: (L_t^D):

$$L_t^D = \begin{cases} [1 - G_t(F)]l(w_t) & w_t \leq w^* \\ 0 & w_t > w^* \end{cases}$$

2. Labor supply: (L_t^S):

$$L_t^S = \begin{cases} G_t(F) & w_t \leq w^* \\ 1 & w_t > w^* \end{cases}$$

where $G_t(F)$ is the share of workers at period t.

The labor supply and demand curves described by the equations above are shown in Figure 4.2.A.[4] In this figure, the horizontal axis is the labor share and the vertical axis is the wage. As long as the profitability constraint holds, the equilibrium wage is determined at the intersection of the labor supply and demand curves.

- The case of existing FDI firms:

1. Labor demand:

$$L_t^D = \begin{cases} [1 - G_t(F)]l^{\mathrm{DOS}}(w_t) + l^{\mathrm{FDI}}(w_t) & w_t \leq w^* \\ l^{\mathrm{FDI}}(w_t) & w^* < w_t < w^{**} \\ 0 & w_t \geq w^{**}. \end{cases}$$

2. Labor supply: The equation is the same as for the case of no FDI firm.

Due to the entry of FDI firms, the total demand for labor in this economy increases, thus the demand curve, $L_t^{D'}$, shifts upward. As long as the domestic profitability constraint holds, ($w \leq w^*(\leq w^{**})$), the new equilibrium wage is determined at the intersection of the labor supply curve

[4] In terms of labor demand, if wage is too low, domestic firms need as much labor as possible, thus demand for labor is the whole population, $L_t^D = 1$. If wage increases to a certain level, the labor demand curve is downward sloping.

and new demand curve. Based on Figure 4.2.B, it is clear that the equilibrium wage in the case of existing FDI firms is always higher than in the case of no FDI firms, $W_t' > W_t$.

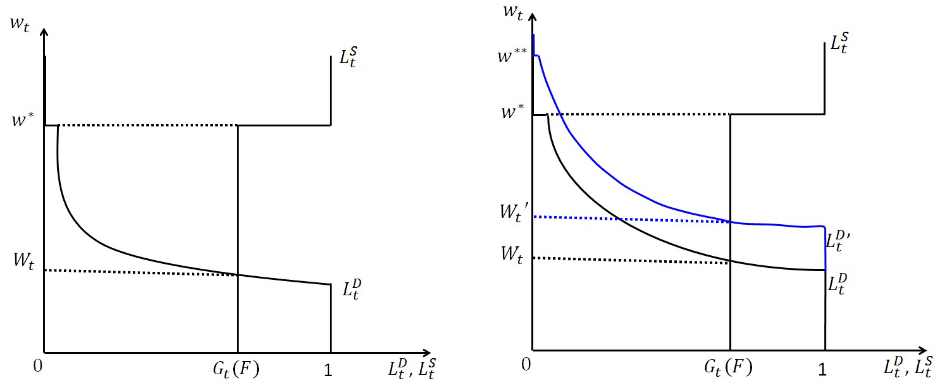

Fig 4.2.A

Fig 4.2.B

Figure 4.2

□

4.3.2 Wealth dynamics

The bequest rule is derived in equation (4.8) as shown again below:

$$h_{t+1} = \begin{cases} \beta[W_t + rh_t] & h_t \leq F \\ \beta[\pi(W_t) + r(h_t - F)] & otherwise. \end{cases}$$

This transition of wealth will take the shape shown in Figure 4.3.

The horizontal axis corresponds to the inheritance that $Agent_t$ receives from his parent h_t, and the vertical axis corresponds to the bequest he leaves to his child, h_{t+1}. To the left of F on the horizontal axis lies the line $\beta(W_t + rh_t)$, called the "lower line," showing the transition of a worker's wealth. The line $\beta(\pi(W_t)+r(h_t-F))$ to the right of F, called the "upper line," indicates the transition of an entrepreneur's wealth. The equilibrium wage obtained in the labor market will determine the position of these two lines in each period. However, due to the profitability

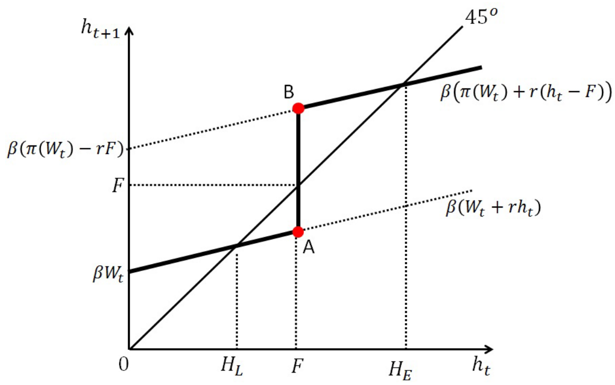

Figure 4.3

constraint of domestic firms, the "upper line" is always vertically higher than the "lower line."

At the steady state, the size of the bequest from an agent to his child is exactly equal to the inheritance he receives from his parent, $h_t = h_{t+1}$. Under the assumption that $\beta r < 1$, the steady state can be solved. The wealth of workers at the steady state is obtained at the intersection of the "lower line" and the 45-degree line, while that of entrepreneurs occurs at the intersection of the "upper line" and the 45-degree line. It is important to note that under the assumption that every agent in the economy is homogeneous in ability, the graph of wealth transition can be applied to the whole economy. Therefore, the steady-state wealth of each agent is also the wealth per capita at the steady state of this economy.[5]

When FDI firms join the economy, an increase in the equilibrium wage causes a shift in the transition path of wealth for all agents. The increase in the equilibrium wage will increase the income and thus increase the bequest toward the next generation of the worker. On the other hand, the increase in the equilibrium wage will decrease the profit of the entrepreneur and thus decrease the income and subsequently decrease the bequest left to his child. Therefore, the transition path of a worker's wealth shows an upward shift and that of an entrepreneur's wealth shows a downward shift. These shifts are shown in Figure 4.4.

With such shifts, the comparative positions of point A and point B change, altering the steady-state wealth of all of the agents. For example, upon the upward shift of the "lower line,"

[5]See Appendix 4.A for the confirmation of the existence and stability of the steady state.

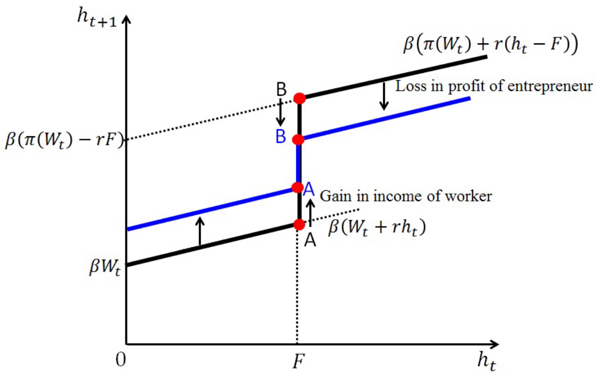

Figure 4.4

point A moves vertically upward. If point A moves above the 45-degree line, the intersection between this line and the "lower line" will disappear. The same situation happens to the intersection of the 45-degree line and the "upper line" when point B moves below the 45-degree line upon the downward shift of the "upper line." Therefore, the participation of FDI firms may cause four cases for the economy: 1. Poverty trap, 2. Big push, 3. Underdevelopment trap, and 4. Inequality.

4.3.3 The equilibria

Case 1: Poverty trap

Figure 4.5 illustrates this case. Graphically, when point A lies below and point B lies above the 45-degree line, a steady state exists that includes both entrepreneurs and workers. At the new steady state, the job share does not change. Agents whose initial wealth is smaller than setup cost F can never become entrepreneurs; hence, this steady state is called the "poverty trap." [6]However, because of the increase in equilibrium wage, the steady-state wealth of workers increases (H_L $\uparrow$), while that of entrepreneurs falls (H_E $\downarrow$). Workers become better off, and entrepreneurs become worse off, and thus the entry of FDI firms makes this economy more equal.

[6]This name is borrowed from Matsuyama (2011).

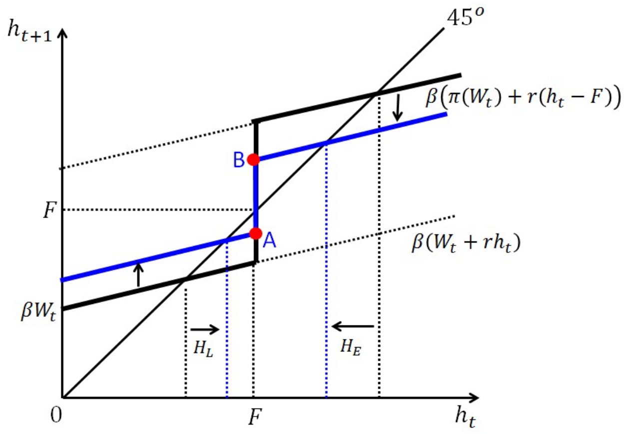

Figure 4.5

Case 2: Big push

Figure 4.6 illustrates this case.

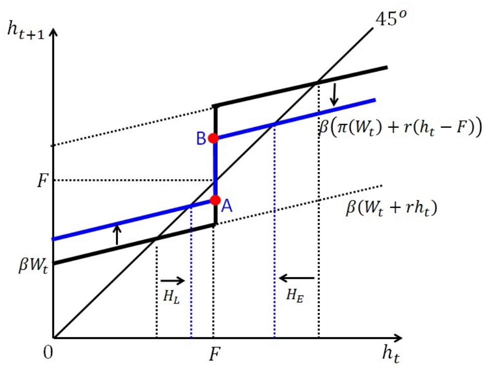

Fig 4.6.A

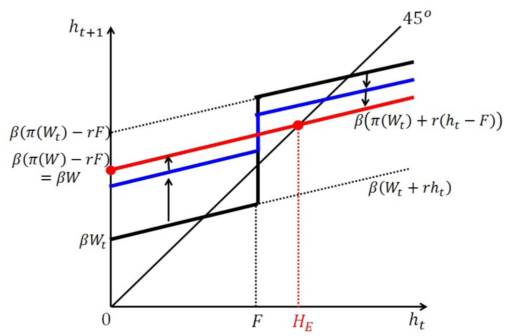

Fig 4.6.B

Figure 4.6

This case occurs when both points A and B lie above the 45-degree line. In this case, workers can escape from the poverty trap and become entrepreneurs. The entry of FDI firms acts as a “big push.” The process of this equilibrium is as follows. First, the increase in equilibrium wage upon the entry of FDI firms can cause the economic condition of all workers to improve, with some of them becoming wealthy enough to run their own businesses. That is, they become entrepreneurs. This leads to a shrinkage of the labor force and an increase in the labor demand. As a result, equilibrium wage increases continuously, and thus more workers can become entrepreneurs. This process repeats itself continuously until the wealth levels of workers and entrepreneurs are equivalent. The "lower line" and "higher line" now merge into a single line somewhere between the original line positions. This steady state is shown in Figure 4.6.B. In this state, every agent has the same level of wealth, which is higher than setup cost F. Therefore, this steady state is also referred to as "big push," and here the economy becomes completely equal. However, there is an indistinctness in wealth between workers and entrepreneurs; the job share is undetermined. Because the wealth of all of the agents is equal at the end of the period, the labor market mechanism becomes functionless. Then, the composition of workers and entrepreneurs is adjusted automatically to keep this steady state unchanged.

Next, case 3 and case 4 happen when both points A and B lie below the 45-degree line as shown in Figure 4.7.

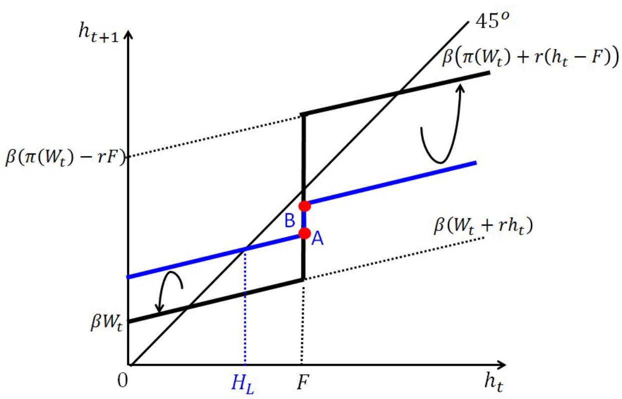

Figure 4.7

The process of reaching this equilibrium is described as follows. First, the increase in equilibrium wage in response to the entry of FDI firms causes all entrepreneurs to become poorer. Some entrepreneurs cannot maintain their own businesses and become workers, leading to a decrease in the labor demand and an increase in the labor force. This leads adversely to a decrease in equilibrium wage. Graphically, the "lower line" and "higher line" initially move toward each other in response to the wage-increasing effect of the entry of FDI firms. However, soon afterwards, they move back again. This backward movement of the transition paths of the wealth of the workers and entrepreneurs makes this case more complicated than the previous two. How far the two lines move away from each other will determine the properties of the new steady state. This depends mainly on the wealth distribution of this economy before FDI firms enter the economy, which is discussed next.

Case 3: Underdevelopment trap

In the case whereby all entrepreneurs in the economy are not rich enough to avoid significant loss of profit following the wage increase caused by the entry of FDI firms, the entrepreneurs will be incapable of leaving a large bequest. The next generation will be unable to continuously run the businesses and will become workers. As a result, the labor force will eventually include the whole population, and labor demand will now be the purview of FDI firms only. Intuitively, the large increase in labor supply together with the decrease in labor demand will lead to a decrease in equilibrium wage. No domestic agent is able to become an entrepreneur; all of the population works for FDI firms. The inheritance at the steady state in this case is lower than the setup cost F; thus, this is called an "underdevelopment trap."[7] There is equality in the economy, and the labor share is 1. Figure 4.8 illustrates this situation. Every agent in this economy now shares the same steady-state wealth at H_L.

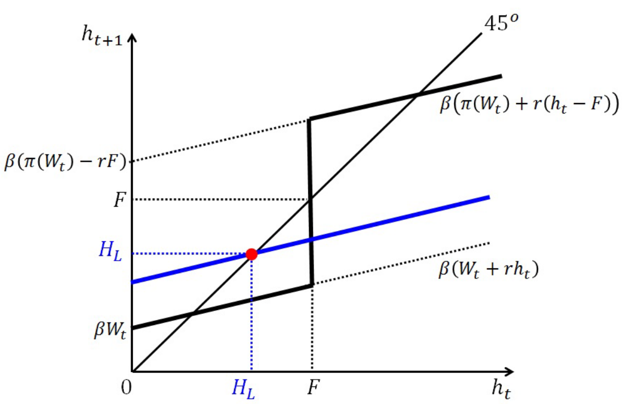

Figure 4.8

[7]This name is borrowed from Matsuyama (2011). He describes this case as "If everyone is poor, nobody hires, and hence everyone remains poor."

There is a good, simple example of this case. Before the introduction of FDI firms, assume that this economy was already at a steady state where the wealth of all the entrepreneurs equals H_E.[8] In this case, if the increase in equilibrium wage resulting from the entry of FDI firms forces an entrepreneur become a worker, other entrepreneurs will become workers as well because they are all identical. This case clearly leads to the "underdevelopment trap" steady state.

Case 4: Inequality

In this case, although some poor entrepreneurs cannot continue running their own businesses when wage increase, others are rich enough so that the loss in profit does not prevent them from continuously leaving the next generation an amount of bequest larger than setup cost F. Thus, the domestic businesses can be maintained. Here, the market exit of poor entrepreneurs leads to an increase in labor supply and a decrease in labor demand, resulting in a wage decrease. However, the decrease in wage reduces the loss in profits of the remaining entrepreneurs. If these relatively rich entrepreneurs can wait until this loss becomes zero, they can continuously maintain their businesses. At the steady state, the number of workers has increased while the number of entrepreneurs has decreased. This case can explain the increased inequality that may occur in response to the entry of FDI firms. Thus, this case is named as "inequality". Figure 4.9 shows such an example.

In Figure 4.9, the "lower line" and "higher line" move to new positions below and above their respective lines at the old steady state prior to the entry of FDI firms. In this case, the wealth of workers decreases while that of entrepreneurs increases. The gap between the wealth of workers and entrepreneurs widens; thus, inequality occurs.

[8] See Figure 4.3.

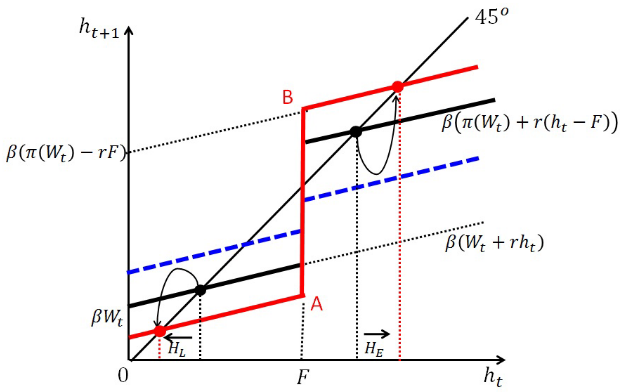

Figure 4.9

The properties of the four equilibria described above are summarized in the Table 4.1. In these cases, the effect of the entry of FDI firms on wealth equality is clarified. In summary, this entry can create both equality and inequality as empirical research indicates.

Table 4.1

Case	Name	Equality	Worker share	Equilibrium wage
Case 1	Poverty trap	Equal	Unchanged	Increase
Case 2	Big push	Completely equal	Undetermined	Increase
Case 3	Underdevelopment trap	Completely equal	1	Increase
Case 4	Inequality	Equal or unequal	Increase	Increase or decrease

There is a point worth noting here. Case 2 and case 4 can only happen if FDI firms first enter the economy when it is **not** at the steady state. In contrast, case 1 and case 3 can happen regardless the economy is at the steady state or not at the entry of FDI firms.

Before the entry of FDI firms, assume that this economy was already at a steady state. At this point, as discussed in Section 4.3.2, all agents whose inheritance from their parent is less than the setup cost F will share the same steady-state wealth at H_L. On the other hand, all agents whose inheritance from their parent exceeds the setup cost F will share the same steady-state wealth at H_E. As a result, there is no diversity in the wealth of workers as well as that of entrepreneurs. In other words, all of workers as well as entrepreneurs are identical with respect to initial wealth at the entry of FDI firms. Under this assumption, only case 1 and case 3 can happen. This is because these two cases share the following property: in each case, all the workers show the same reaction to the entry of FDI firms, and so do all the entrepreneurs.[9]

Nevertheless, case 2 and case 4 are different from the rest in that these two cases happen depending on the wealth diversity workers and entrepreneurs, respectively. Discretely, in case 2, the increase in equilibrium wage upon the entry of FDI firms can improve economic conditions for all workers. Due to the diversity in wealth of workers, some become wealthy enough to run their own businesses. This leads to a shrinkage of the labor force and an increase in labor demand, thus equilibrium wage increases continuously. On the other hand, in case 4, due to the wealth diversity of entrepreneurs, some poor entrepreneurs cannot continue running their own businesses when wage increases. Meanwhile, others are rich enough such that the loss in profit does not prevent them from continuously leaving the next generation a bequest amount larger than the setup cost F. The exit of poor entrepreneurs leads to an increase in labor supply and a decrease in labor demand, resulting in a wage decrease.

4.3.4 Conditions of the equilibria

In this section, the conditions in which these four equilibria may occur will be examined. First, we will discuss the condition in which workers and entrepreneurs exist. The condition for the existence of the worker or entrepreneur or both depends on the comparative position of the 45-degree line on the plane of the wealth transition path.

If the "lower line" and 45-degree line intersect, workers exist and the intersection determines their equilibrium wealth. This happens if and only if point A lies under the 45-degree line, or

$$\beta(W_t + rF) \leq F \iff W_t \leq W_1$$

[9]In case 1, because of the increase in equilibrium wage due to the entry of FDI firms, workers become better off but all of them still cannot leave enough inheritance to their heirs in order for them to become entrepreneurs. On the other hand, entrepreneurs become worse off but all of them still leave enough inheritance to theirs heirs in order for them to continue running their own businesses. Thus, the job composition in this case shows no change before and after the entry of FDI firms. In case 3, the increase in equilibrium wage upon the entry of FDI firms makes all entrepreneurs less profitable, thus all of them cannot leave enough inheritance to the next generation. This makes the next generation have no choice other than becoming workers.

where $W_1 \equiv F(1-\beta r)/\beta$. Thus, W_1 is the minimum wage that ensures the existence of the worker.

On the other hand, if the "higher line" and 45-degree line intersect, entrepreneurs exist and the intersection determines their equilibrium wealth. This happens if and only if point B lies above the 45-degree line, or

$$\beta[\pi(W_t) + r(F - F)] \leq F \Longleftrightarrow \pi(W_t) \leq F/\beta \Leftrightarrow W_t \leq W_2$$

where W_2 is the solution of equation $\pi(W_t) = F/\beta$. Thus, W_2 is the minimum wage that ensures the existence of the entrepreneur.

Next, we will discuss the condition under which the three cases of equilibrium described above may occur.

1. Poverty trap: The condition for this case is that:

$$W_t \leq \min(W_1, W_2)$$

   Intuitively, we know that when the equilibrium wage is low, workers are so poor that they can never own a business, whereas entrepreneurs gain such a high profit that they can maintain their business. Therefore, the economy will contain both workers and entrepreneurs.

2. Big push: The case happens when both point A and point B lie above the 45-degree line. In this case, workers can escape from the poverty trap and reach to a better state under the following condition:

$$W_1 < W_t < W_2$$

3. Underdevelopment trap and inequality: In these cases, both point A and point B lie below the 45-degree line. The condition of the equilibrium wage for this case is as follows:

$$W_2 < W_t < W_1$$

From case 2 to case 4, the condition of equilibrium wage is higher than the case of two equilibria. However, the specific conditions of the economy for each case need to be clarified.

The main difference between these two cases is the scale of W_1 compared with that of W_2. In case 3 and case 4, $W_2 < W_1$ and in case 2, the reverse is true. Figure 4.10 shows the comparative position of W_1 and W_2. The equilibrium wage is shown on the horizontal axis, and the profit is

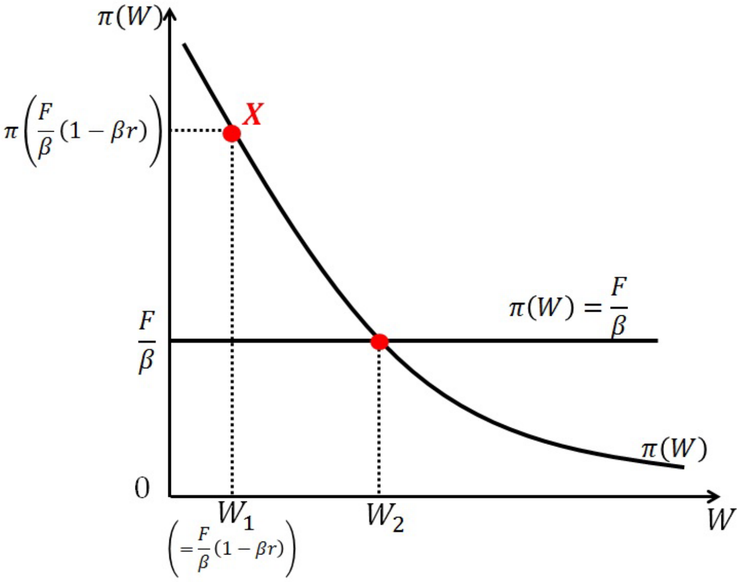

Figure 4.10

shown on the vertical axis. Profit is the decreasing function of wage;[10] thus, the profit function is represented by a downward-sloping curve. W_1 is determined at the value of $F(1-\beta r)/\beta$ on the horizontal axis, and W_2 is determined at the intersection of the profit function curve and the horizontal line F/β. In Figure 4.10, point X appears. The ordinate of this point is calculated as the function $\pi(W)$ at $W_1 = F(1-\beta r)/\beta$. According to Figure 4.10, $W_1 < W_2$ if and only if point X lies above line F/β. Thus, the condition for $W_1 < W_2$ is as follows:

$$\pi\Big(\underbrace{\frac{F}{\beta}(1-\beta r)}_{W_1}\Big) > \frac{F}{\beta} \tag{4.9}$$

[10] $\pi(l_t) = \phi(l_t) - w_t l_t = \phi(l_t) - \phi'(l_t)\cdot l_t \Rightarrow \pi'(l_t) = -\underbrace{\phi''(l_t)}_{<0}\cdot l_t \geq 0 \overset{l'(w_t)}{\Longrightarrow} \pi'(w_t) \leq 0.$

This equation is applied to derive the following proposition:

Proposition 4.2. *The high (low) state exists if at least one of the conditions below holds:*

1. *The setup cost is sufficiently low (high).*

2. *The bequest share is sufficiently high (low).*

3. *The interest rate is sufficiently high (low).*

4. *The Home productivity is sufficiently high (low).*

Mathematically, when F is low or β and r are high, W_1 is more likely to be smaller than W_2. Thus, "big push" case may occur. Intuitively, first, if the cost required for starting a firm is low, the earning at the end of the period is high. Therefore, the bequest that an agent leaves to his child may become larger than that which he received from his parent. Then, his child may receive enough setup cost to start a business, $\beta\pi(W_t) > F$. Here, the increase in the bequest results in social prosperity as well as a better state of the economy. This role of the setup cost in the economic growth leads to a policy implication. The setup cost used in this chapter is the expense associated with the entire process of establishing a new firm. Part of this cost is related to government policies, both tangible (i.e., legal and professional fees, license, etc.) and intangible (i.e., registration time, administration, corruption, etc.). Therefore, if the government establishes policies that ease the environment for firm establishment, the economy can reach to a better state. Second, if the bequest share of the agent is high or he is altruistic, the bequest increases. Third, when the interest rate is high, although none of the agents can borrow, returns to lenders increase because of high capital gains. In this case, the wealth of workers increases, and thus the bequest increases as well. Last, if the Home productivity is high, the wealth of all domestic agents increases. It is obvious that the higher the wealth is, the higher the bequest becomes. Therefore, the economy may move to case 2 - big push case.

4.4 Numerical examples

The goal of this section is to replicate some results in the analytical section by introducing a numerical simulation analysis using assumed parameter values.

4.4.1 Settings

First, the model is approximated by a discrete number of domestic agents in order to be tractable for the simulation.

Second, all functions used in the model need to be explicitly specified. The production functions of domestic and FDI firms are assumed as follows:

$$Y_t = \phi(l_t) = A \cdot l_t^{\gamma}$$

and

$$\hat{Y}_t = \hat{\phi}(l_t) = \hat{A} \cdot l_t^{\gamma}$$

respectively.

Third, inheritance is different for each agent. The initial wealth distribution is assumed to take the Pareto distribution form as follows:

$$h_i^0 = (h_{max}^0 - h_{min}^0)\,(i/L)^k\,, i = 1 \cdots L \tag{4.10}$$

where L is the population and k is the parameter of the Pareto distribution.

Last, in the benchmark case, all of the parameters in the model are set as shown in Table 4.2.

Table 4.2

Parameter	**Value**	**Note**
ν	0.5	Labor share in production function of domestic firm
$\hat{\nu}$	0.5	Labor share in production function of FDI firm
β	0.5	Bequest share
r	1.1	World interest rate
F	0.8	Initial setup cost
A	1	Productivity of domestic firms
$\hat{A}$	1	Productivity of FDI firms
h_{max}	$3 \cdot F$	Wealth of the richest agent
h_{min}	$0.01 \cdot F$	Wealth of the poorest agent
θ	0.01	Share of FDI firms over population
k	20	Parameter of Pareto distribution
L	10,000	Population

With this setting, about 6% of the population in the initial distribution can become an entrepreneur.

4.4.2 Findings

This section discusses the results of the numerical analysis. FDI firms are assumed to enter when the economy is not at the steady state.[11] The initial distribution is as in equation (4.10) in Section 4.4.1. With parameters reported in Section 4.4.1, I simulate all cases indicated in Table 4.1. The results are shown from Figure 4.11 to Figure 4.14. Each figure has four panels named A to D. In panels A, B, and C, the horizontal axes indicate time. The solid lines show the transition paths of wage, worker share, and Gini coefficient in response to the entry of FDI firms at time 1. The dotted lines illustrate the steady state level of wages, worker share, and Gini coefficient when FDI firms do not exist in the economy. Panel D shows the steady-state wealth with and without FDI firm. All agents in the economy are ordered from poorest to richest along the horizontal axes. The solid line shows the case of the entry of FDI firms, while the dotted line illustrates the steady state of the case where there is no FDI firm.

[11] The simulation results for the case of that FDI firms enter when the economy is at the steady state are shown in Appendix 4.B.

Case 1: Poverty trap (Benchmark)

The simulation results are described in Figure 4.11. This benchmark case corresponds to case 1, the "poverty trap" described in Section 4.3.3.

Figure 4.11.A shows the wage schedule. As the solid line lies above the dotted line, wage is found to be higher in the case of FDI firms compared to the case of no FDI firm. Furthermore, wage is unchanged from the second period, indicating a poverty trap where there is no flow from the pool of workers into the pool of entrepreneurs or vice versa. When there is no change in the composition of labor supply and demand, wage takes a constant value, which is equal to the steady-state value.

Figure 4.11.B shows no change in the worker share compared to that at the steady state before FDI firms entered. The worker share is 94.6%.

Due to the increase in wage, workers become richer while entrepreneurs become poorer compared to the case of no FDI firm. The change in agents' wealth and the unchanged composition of the population can be seen in Figure 4.11.D. At the steady state, the wealth of the workers is 8.8% higher while that of the entrepreneurs is 16.3% lower, respectively, in the case of FDI firms.

Finally, Figure 4.11.C shows a lower Gini coefficient at the steady state in the case of FDI firms compared to the case of no FDI firm, representing greater equality in this economy. Better-off workers and worse-off entrepreneurs mean an improvement in equality.

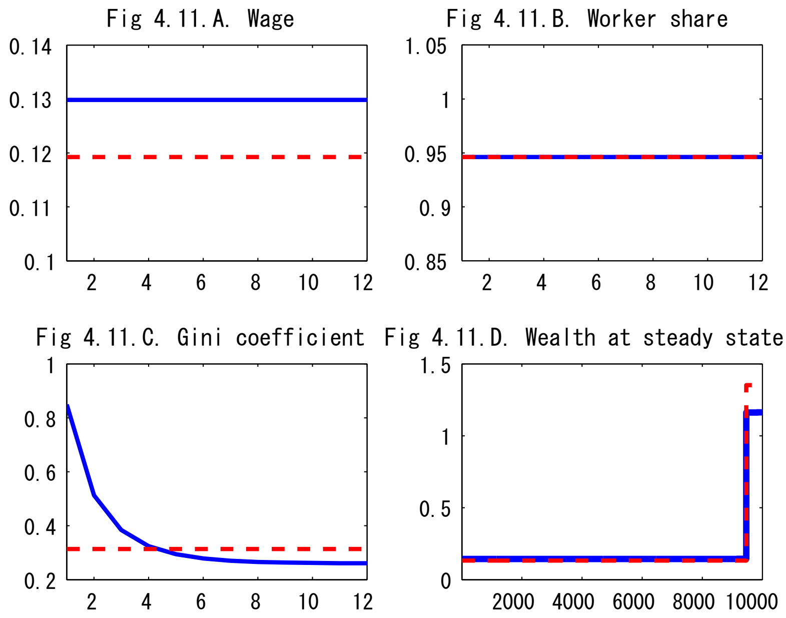

Figure 4.11

Case 2: Big push

This case corresponds to case 2, named "big push", described in Section 4.3.3. Figure 4.12 shows the simulation results when the bequest share increases from 0.5 (the benchmark case) to 0.8.

As the equilibrium wage increases soon after the entry of FDI firms and the bequest share is high enough, workers raise their bequest until their heirs have enough inheritance to pay the setup cost. Due to the profitability condition, when inheritance is larger than setup cost, agents would rather become entrepreneurs than workers. Thus, agents not bound by the borrowing constraint pay the setup cost to run their own businesses. The number of entrepreneurs increases while the number of workers decreases, leading to an overall increase in wage. The continuous increase of equilibrium wage is shown in Figure 4.12.A, while the decrease in worker share is illustrated in Figure 4.12.B. The increase in wage, decrease in firm profit, and transition of agents from workers to entrepreneurs continue until the income of the workers and entrepreneurs become identical. From then on, there is no difference between the income of a worker and of an entrepreneur; the economy shows a more equal distribution of wealth. This equality is indicated as the reduction in Gini coefficient in Figure 4.12.C. Figure 4.12.D shows the wealth at steady state of all agents in the economy in both cases: with and without FDI firms. The wealth of the workers increases by 10.3% while that of the entrepreneurs decreases by 29.8%.

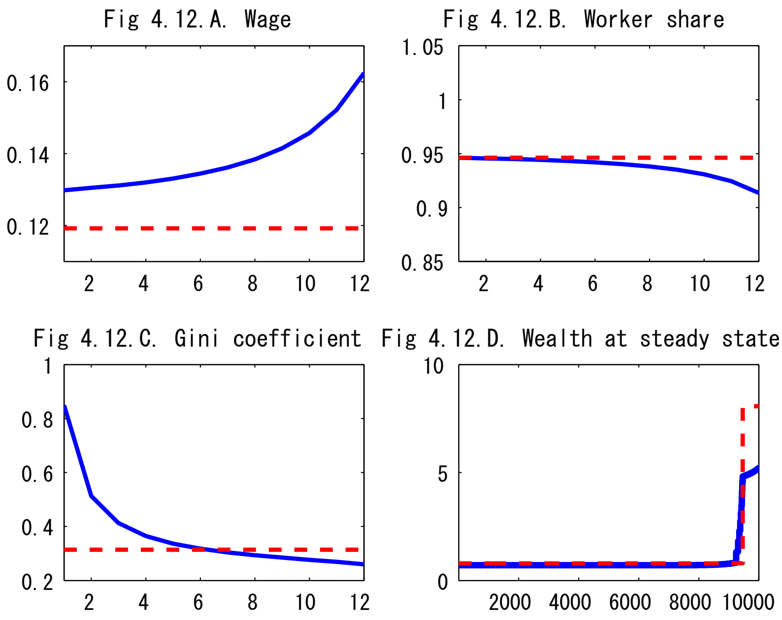

Figure 4.12

Case 3: Underdevelopment trap

This case corresponds to case 3 in Section 4.3.3, referred to as the “underdevelopment trap”, in which the bequest share decreases from 0.5 (the benchmark case) to 0.3. The results are illustrated in Figure 4.13.

Immediately after the entry of FDI firms, equilibrium wage is relatively high at the first period. However, due to the high equilibrium wage, entrepreneurs’ profit decreases. In this case, the decrease in profit along with the lower inheritance makes children of entrepreneurs poorer so that they are eventually unable to continue their businesses. Here, all of the entrepreneurs are poor and they have no choice other than becoming workers for FDI firms. As a result, worker share becomes 1 as shown in Figure 4.13.B.

As every agent in this economy becomes a worker, the abundance in labor supply leads to a decline in wage. Figure 4.13.A shows a reduction in wage from the second period. Wage at the steady state drops to less than a half of what it was at the time when FDI firms enter the economy, but it is still higher than the case of no FDI firm. That is, workers in this case are better off (Figure 4.13.D).

As the economy becomes completely equal, Figure 4.13.C shows the convergence of Gini coefficient to zero. Figure 4.13.D also confirms the equality where the wealth at steady state of all agents in the economy is the same. However, this is an equality in which every agent is poor, no one can become an entrepreneur. Thus, this case is named as “underdevelopment trap.”

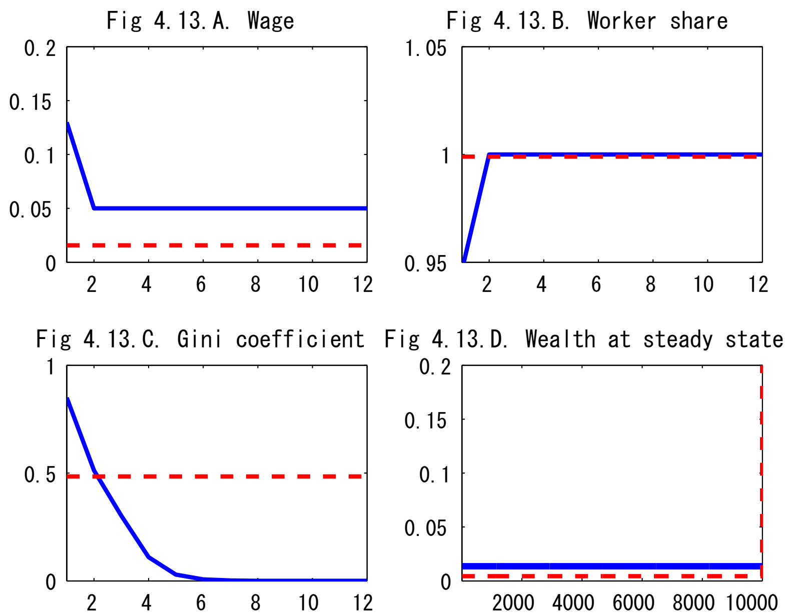

Figure 4.13

Case 4: Inequality

This case corresponds to case 4, which is “inequality” described in Section 4.3.3. Figure 4.14 shows the simulation results when the bequest share decreases from the benchmark case of 0.5

to 0.3. Here, in order to create a larger diversity in wealth of entrepreneurs, h_{max} is assumed to be $4 \cdot F$ instead of $3 \cdot F$ as shown in Table 4.2.

As the equilibrium wage increases soon after the entry of FDI, some poor entrepreneurs cannot continue running their own businesses. The exit of poor entrepreneurs leads to an increase in labor supply and a decrease in labor demand, resulting in a wage decrease. Steady-state wage is 10.6% lower than that in the case of no FDI firm (Figure 4.14.A). The increase in labor supply is illustrated in Figure 4.14.B. However, although some poor entrepreneurs' children have no other chance but become workers, others are rich enough that the loss in profit does not prevent them from continuously leaving the next generation an amount of bequest larger than the setup cost F. Therefore, the worker share in Figure 4.14.B converges to 98.7% but not 100% as in the case "underdevelopment trap." The wealth at the steady state of these rich entrepreneurs and other workers is illustrated in Figure 4.14.D. Compared to the case of no FDI firm, the steady-state wealth of workers after the entry of FDI firms decreases by 10.6% while that of entrepreneurs increases by 17.2%. In the economy, 98.7% of agents share the same wealth, thus the Gini coefficient in Figure 4.14.C still shows a downward trend as it becomes more equal. However, the fact that entrepreneurs, consisting only 1.3% of the population, holding nearly 30% wealth of the whole country, shows that inequality becomes more serious in this case.

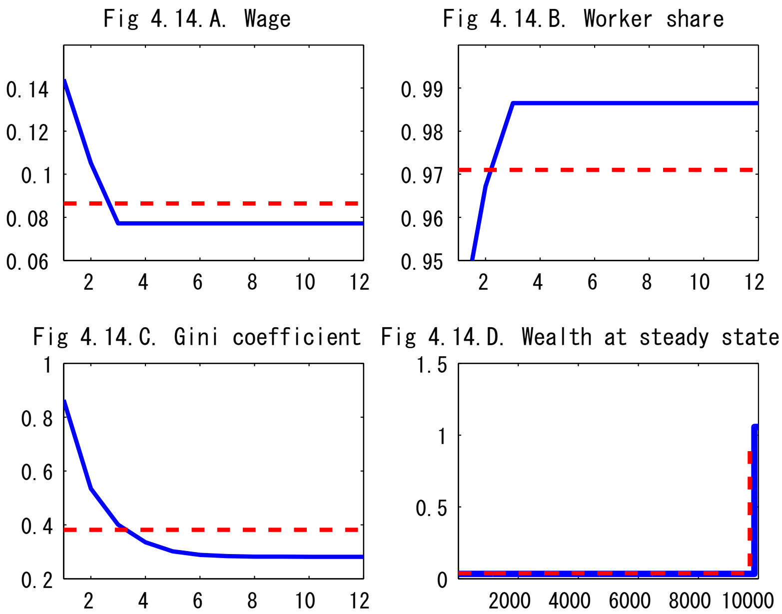

Figure 4.14

4.5 Conclusions

The purpose of this chapter is to examine the changes in terms of wealth distribution in response to the entry of FDI firms. The chapter introduces a model of wealth distribution in the presence of an imperfect capital market and analyzes the impact of FDI firms. The main assumption regarding FDI firms is that they are sufficiently creditworthy, unlike the domestic firms with which they compete, such that they do not face any borrowing constraints.

Against this background, we used the model developed to derive the transition of wealth and labor corresponding to the entry of FDI firms. Through this analytical computation, the chapter is the first to describe how the entry of FDI firms can explain (in)equality in domestic wealth. Their entry could promote equality by giving a "big push" to move workers out of a "poverty trap" so that all domestic agents become equal with respect to wealth and job selection. Alternatively, FDI firms may cause the economy to fall into an "underdevelopment trap", whereby all domestic agents have no choice other than to work for FDI firms. On the other hand, the entry of FDI firms could also widen the gap between the rich and the poor, i.e., it could cause inequality by redistributing domestic wealth to make the richest agents better off if they survive the competition with FDI firms. We also identified four factors affecting the impact of FDI firms on the economy, namely, setup costs, bequest motives, global interest rates, and home country productivity. More specifically, a lower cost in starting a new business, a more altruistic population, a higher global interest rate, and a greater productivity of the home country could promote wealth equality.

Appendix 4.A. Discussion on the existence and stability of the steady state

Regarding the existence and stability of the steady state, let us start with the simplest case in which there are only two groups of agents. In each group, the agents are identical in terms of initial wealth. The initial amounts of wealth in these two groups are designated h_E^0 and h_L^0; h_E^0 and h_L^0 are larger and smaller than the setup cost, F, respectively. Under the labor market clearing condition and the profitability constraint, the solution for the following equation is unique:

$$[1 - G_t(F)]l(w_t) = G_t(F) \Rightarrow l(w_t) = \frac{G_t(F)}{1 - G_t(F)}, w_t \geq w^*$$

. The left-hand side of the above equation is a monotonic decreasing function of wage, w_t, while the right-hand side is constant; thus, a unique equilibrium wage can always be found. Furthermore, there are only two groups of identical agents. Thus, there is no flow from one pool of agents to another, otherwise there will be no worker or entrepreneur. In brief, under the profitability constraint, the labor market clearing condition will determine the equilibrium wage but cannot change the population composition of this economy.

Simulations of more complicated cases where agents no longer have identical initial wealth can be performed. Specifically, we run simulations that combine 1,000 random ranges from "nearly zero" to F fluctuating around the initial wealth of workers, h_L^0, and 1,000 random ranges from F to $100 \cdot F$ fluctuating around the initial wealth of entrepreneurs, h_E^0. Using the same settings as in Section 4.4.1, the simulations show that the steady state is always reached and there is no change in the composition of workers and entrepreneurs. Accordingly, this system has a solution, and it is unique and stable.

Appendix 4.B. Some extra simulation results

FDI firms are assumed to enter during the economy at the steady state. This is the steady state of the case of no FDI firm. As discussed in Section 4.3.3, under this situation, only case 1 and case 3 happen. The results for these two cases are shown in Figure 4B.1 and Figure 4B.2. Each figure has four panels named A to D. In panels A, B, and C, the horizontal axes indicate time. The solid lines show the transition path of wage, worker share, and Gini coefficient in response to the entry of FDI firms at time 1. The dotted lines illustrate the steady state level of wage, worker share, and Gini coefficient when FDI firm does not exist in the economy. On the other hand, Panel D shows the wealth at steady state of all agents in the economy in both cases: with and without FDI firms. All agents in the economy are ordered from poorest to richest along each of the horizontal axes. The solid line shows the case of the entry of FDI firms, while the dotted line illustrates the steady state of the case where there is no FDI firm.

Case1: Poverty trap

The simulation results are described in Figure 4B.1. This benchmark case corresponds to case 1, the "poverty trap" described in Section 4.3.3.

Figure 4B.1.A shows the wage schedule. As the solid line lies above the dotted line, wage is found to increase as soon as FDI firms enter and then remain unchanged starting at the second period. The increase in wage following the entry of FDI firms is consistent with Proposition 4.1. However, after increasing in just one period, wage remains unchanged from the second period. This is because the benchmark case illustrates the poverty trap where there is no switching from workers to entrepreneurs or vice versa. When there is no change in the composition of the labor supply and demand, wage takes a constant value, which is equal to the steady-state value.

Figure 4B.1.B shows no change in the worker share compared to that at the steady state before FDI firms entered. The worker share is 94.6%.

Due to the increase in wage, workers become richer while entrepreneurs become poorer. The results of the change in agents' wealth and the unchanged composition of the population can be seen in Figure 4B.1.D. The wealth of the workers increases by 8.9% while that of the entrepreneurs decreases by 14.1%.

Finally, Figure 4B.1.C shows a reduction in the Gini coefficients, representing a greater equality in this economy. The increase in the wealth of workers and the decrease in that of entrepreneurs lead to the improvement in economic equality.

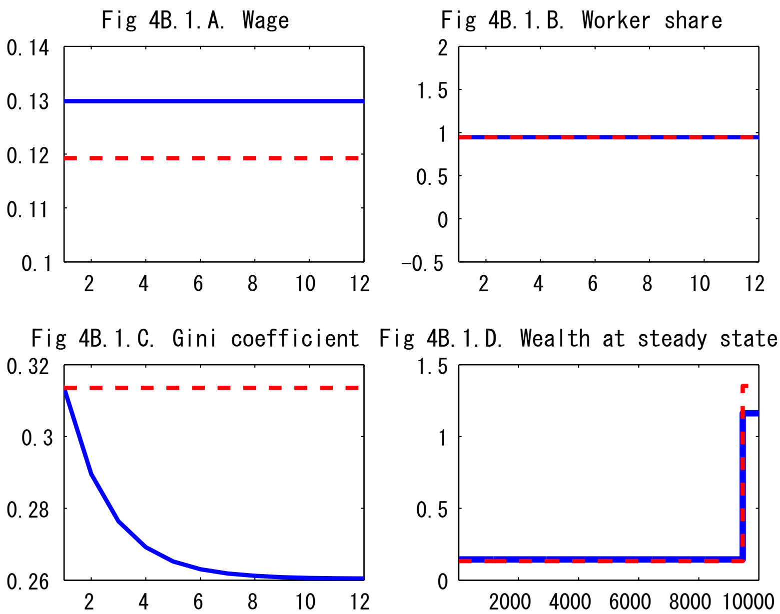

Figure 4B.1

Case 3: Underdevelopment trap case

This case corresponds to case 3 in Section 4.3.3, referred to as the "underdevelopment trap", in which the bequest share decreases from the benchmark case of 0.5 to 0.3. The results are illustrated in Figure 4B.2.

As Proposition 4.1 suggests, immediately after the entry of FDI firms, equilibrium wage increases by 15.5% (Figure 4B.2.A). Due to the increase in the equilibrium wage, profit of all entrepreneurs decreases. In this case, the decrease in profit due to the entry of FDI firms along with the lower inheritance causes children of entrepreneurs to become poorer. They are eventually unable to continue their businesses. Here, all of the entrepreneurs are poor and they have no choice other than becoming workers for FDI firms. As a result, worker share becomes 1 as shown in Figure 4B.2.B. The abundance in labor supply leads to a decline in wage. Figure 4B.2.A shows a reduction in wage from the second period. Wage at the steady state drops to less than a half of what it was at the time when FDI firms entry the economy.

As the economy becomes completely equal, Figure 4B.2.C shows the convergence of Gini coefficient to zero. However, this is an equality in which every agent is poor. As shown in Figure 4B.2.D, the wealth at steady state of all agents in the economy is the same, at a very low level. This level is 42.8% lower than the wealth of workers in the case of no FDI firm.

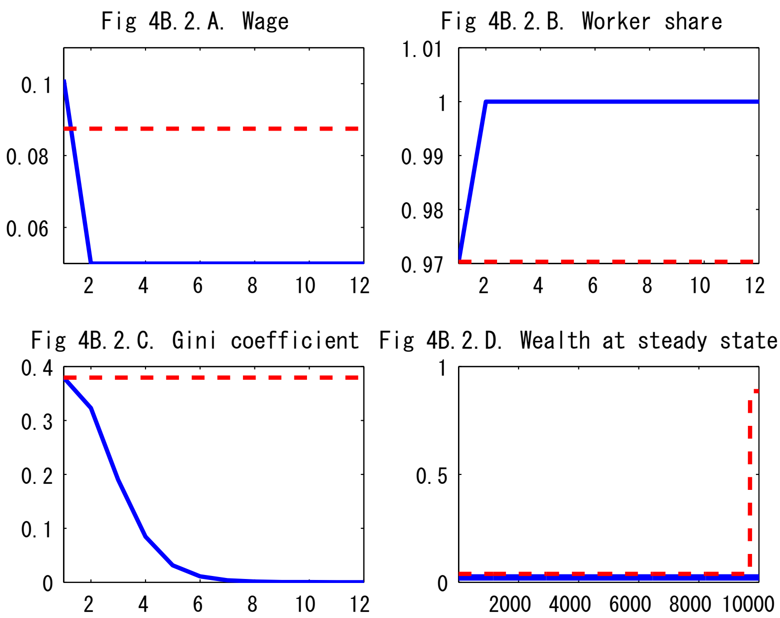

Figure 4B.2

Chapter 5

Conclusion

This dissertation seeks to analyze the effects of international economic policies on income inequality and economic development. The three main issues addressed in this dissertation are described as follows. First, I discuss the optimal infant industry protection policies when a country initiates the process to join the World Trade Organization (WTO). I propose a framework to derive the optimal dynamic path of tariffs to protect infant industries during the process of joining the WTO. Then, I apply this model to numerically analyze the Vietnamese motorcycle industry, an example of an infant industry in a country starting to join the WTO. Second, I examine how trade openness affects wage inequality in trading countries. To evaluate this research question, I derive a new version of a two-country general equilibrium trade model with monopolistic competition. The model is analyzed under the assumption that firms are allowed to choose different types of technologies endogenously. Third, I examine how the entry of Foreign Direct Investment (FDI) firms affects domestic household wealth distribution. I develop a framework in which I examine the changes in domestic wealth distribution that emerges as a response to the entry of FDI firms, given the introduction of borrowing constraint caused by credit market imperfections.

The conclusions drawn from the three major research issues discussed above are described as follows. First, under some plausible scenarios, the optimal dynamic path of tariffs to protect infant industries when a country initiates the process to join the WTO can be upward sloping.

This contrasts with conventional wisdom, which suggests that a country in this situation should reduce the tariff rate gradually so that it converges to its long-run rate at the terminal date of protection. A numerical analysis applied to the Vietnamese motorcycle industry, a typical infant industry in a country joining the WTO, confirms such a pattern. Second, by introducing the realistic assumption of endogenous technology choice, almost all the effects on wage inequality in trading countries, both domestically and internationally, are found to be partially absorbed. Conversely, if a firm only utilizes a standard constant technology, the effect on wage inequality is amplified. This amplification is also examined by calibration using data from 52 countries. Third, the entry of FDI firms can cause different scenarios of wealth in(equality), depending on the specifics of a country, such as the cost of starting a new business, the bequest motive, the global interest rate, and home country productivity. Specifically, entry of FDI firms can promote wealth equality. This is possible when every agent in the economy becomes better off as the poorer members of society move out of the poverty trap thanks to the entry of FDI firms. On the other hand, equality can also be an “underdevelopment trap” - an equality where everyone is poor, whereby all domestic agents have no choice other than to work for FDI firms, with a relatively low wage. In contrast, the entry of FDI firms may widen the disparity between the rich and poor, leading to greater inequality in wealth distribution. It does this by redistributing wealth to make the richest agents who survive competition with FDI firms better off.

The contribution of this dissertation is threefold. First, I construct three theoretical models to examine the mechanisms behind the impact of international economic policies on income inequality and economic development. These theoretical models are developed under more realistic assumptions. These assumptions are: (i) time limit for protection of infant industry in Chapter 2, (ii) endogenous technology choice in Chapter 3, and (iii) the appearance of FDI firms as an additional foreign factor in domestic labor market in Chapter 4. Second, I have calibrated these theoretical models to reflect real-world outcomes. In Chapter 2, calibration using actual data of the Vietnamese motorcycle industry offers precise policy prescription for the protection process. Thanks to this, the model and methodology can be generalized to other countries and industries. Third, the results obtained from the dissertation challenge conventional wisdom and deepen our understanding of the role of international economic policies. Using theoretical models developed with realistic assumptions and calibrated using actual data, this dissertation helps us understand different channels through which international economic policies can shape economic development and income distribution. Understanding these effects comprehensively will help policy makers come up with optimal trade policies, adopt suitable development strategies, and better address income inequality.

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