General-equilibrium studies on frictional unemployment, technology adoption, and international trade

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- U_i utility in country i
- X_i composite good of the manufacturing sector in country i
- $d_i(\omega)$ demand for a variety ω in country i
- $p_i(\omega)$ price of a variety ω produced in country i
- ϱ parameter for a Cobb-Douglas utility function
- σ elasticity of substitution between any two varieties
- E total consumption expenditure
- P_i price index in country i
- φ firm productivity
- $R_i(\varphi)$ firm's revenue with productivity φ in country i
- $\pi_i(\varphi)$ firm's profit with productivity φ in country i
- f fixed cost
- F^t fixed cost for using t technology
- F^X fixed cost for exporting
- w_i wage rate in country i
- $\bar{w}$ average wage rate
- $\hat{w}$ wage perceived as fair for workers

- l_i employment level of a firm in country i
- u_i unemployment rate in country i
- $\mathcal{W}$ preference of a labor union
- γ bargaining power of a labor union
- β bargaining power of an individual worker
- $\tilde{w}$ average labor income
- $\mathcal{S}$ number of job seekers
- V_i total number of vacancies in country i
- v number of vacancies posted by one firm
- M_i number of jobs created between job seekers and vacancies in country i
- m matching efficiency
- α_i labor market tightness in country i
- c cost of providing one vacancy
- r_i capital rent in country i
- ϵ worker effort level
- q the output of a firm
- χ fairness parameter of workers
- e the cost of effort for a worker
- $\mathcal{L}_i$ population in country i
- N_i the number of varieties in country i
- K_i capital endowment in country i
- K total capital endowment in the world

- τ iceberg trade costs
- ϕ trade freeness
- Y_i national income of region i
- μ elasticity of matching with respect to the number of job seekers
- θ_i labor share in country i
- k_i capital share in country i
- Wel_i^t real income of t-group worker in county i
- Z skill level of a worker
- Z_i skill threshold in country i
- Ψ productivity of one unit of labor in low-tech technology
- C_i^t unit cost of a firm producing with technology t in country i
- W_i expected wage income of a worker in country i
- n_i^t share of exporters in firms using technology t in country i
- r_i capital rent in country i
- r_i^t expectable unit capital cost paid by a t-tech firm in country i
- $(r_i^t)^D$, $(r_i^t)^X$ expectable unit capital cost paid by an exporter and a non-exporter using technology t.
- N_i^t mass of firms using technology t in country i
- $\mathcal{R}_i$ intra-country inequality in country i
- RW_i^t real wage for t-group workers in country i
- Rr_i real capital rent in country i
- $\text{pGDP}_{i,t}$ GDP per capita of country i in year t

- $\tau_{i,j,t}$ trade cost from region j to region i in year t, in a tariff-equivalent form (share of CIF prices)
- $\text{tar}_{i,t}$ the average tariff of country i in year t
- $\text{INF}_{i,t}$ value of infrastructure investment of country i in year t
- $\text{FTA}_{i,j,t}$ a dummy variable which equals one if the two countries, i and j, are in the same free trade area in year t

Chapter 1

Introduction

1.1 Backgrounds and research objects

It is well documented that trade policies have impacted labor markets substantially with the development of economic globalization. During the last two decades, unemployment problems have become one of the major topics of theoretical research in spatial economics. Unemployment in a frictional labor market is largely explored using a Diamond–Mortensen–Pissarides-type (DMP) search and matching model, in which a matching function is used to describe how employment is determined by the numbers of job seekers and job vacancies. Nevertheless, in the existing studies of trade models with unemployment due to job search and matching, it is not sufficiently clear how the features of the labor market affect industrial agglomeration with globalization.

In this thesis, we construct a two–factor (labor and capital) trade model with a DMP matching process. Specifically, DMP focuses on frictions due to costly search and pairwise matching. Job seekers and job vacancies have difficulties locating each other, resulting in the match's failure. In this study, we clarify that job-matching elasticity is crucial for determining the configuration of economic geography.

In recent decades, new trade theory (NTT) allows us to study the details of globalization when trade costs are intermediate. In light of the fact that exporters have a higher productivity than non-exporters, trade liberalization leads to intra-industry resource allocation, which also greatly impacts the labor market. The seminal paper of Melitz (2003) makes it possible to examine international trade with firm heterogeneity, starting the so-called new new trade theory. A number of studies also investigate how productivity heterogeneity impacts the income inequality in international trade. For instance, incorporating fair wages into an NTT model, Egger and Kreickemeier (2012) illustrate that unemployment and wage inequality are hump shaped with respect to trade freeness. Manasse and Turrini (2001), Monte (2011), Sampson (2014), and Furusawa, Konishi and Tran (2020) focus on the effect of trade integration on wage inequality in their respective models. Their researches all come to the result that the opening of international trade cause a larger income inequality.

On the other hand, we observe that globalization in recent decades also brings out higher international capital mobility. Over the last 20 years, the world's foreign direct investment (FDI) inward stock increased from 644 billion in 1998 to 1.43 trillion in 2017 (UNCTAD 1999, 2018). However, to the best of our knowledge, few general equilibrium studies theoretically clarify how capital mobility affects income inequality and welfare.

In this thesis, we investigate the impact of capital mobility on technology adoption and income inequality in globalization. Our study combines technology selection into a trade model with capital. We suppose that a recent new technology allows production at a lower unit production cost relative to the older one. Consequently, reducing transport costs will increase firms' incentive to adopt the new technology, causing labor relocation from the old technology to the new. Our results show that the impact of capital mobility on inequality is also related to the population size differential. Moreover, we explore how globalization impacts welfare in various exporting statuses.

Furthermore, we empirically estimate the economic impact of trade cost reduction when transportation infrastructure is improved, using a computable general equilibrium (CGE) model. China launched an ambitious strategy known as the Belt and Road Initiative (BRI) in 2013 with an objective to promote regional economic growth and integration. The initiative was implemented primarily through massive investment in transportation infrastructure development among the Belt and Road countries to improve transportation connectivity and reduce trade costs.

While the BRI was endorsed by more than 130 countries, skepticism and opposition also exist. Some scholars, for instance, Chellaney (2017), argued that the BRI is essentially a neocolonial strategy that China aims to take over assets and natural resources and to expand its military and naval presence through the practice of debt-trap diplomacy to fund the initiative's infrastructure projects. However, other scholars, such as Singh (2020), held a different view, who believed that China provides unconditional financing opportunities for the countries that face hostility from the U.S. and its allies to develop infrastructure systems. As a result, it remains unclear to what extent the investment from China has affected the economic performance of different partner countries.

To clarify this question, we provide an in-depth assessment of BRI investment in transportation infrastructure. Different from previous studies, the regional economic impact was evaluated through CGE simulations based on the actual investment data obtained from various sources. In addition, both the change in intra-regional and inter-regional trade costs as a result of BRI transportation infrastructure investment was estimated.

1.2 Overview of our study

This thesis investigates the issues of frictional unemployment, technology adoption, and international trade by employing the general equilibrium models. It includes three parts. The first part consists of a research paper of Li and Zeng (2021) and a book chapter by Li and Zeng (2020). In this study, we clarify the effects of matching elasticity in the labor market and the bargaining power of workers on industrial location in the presence of internationally mobile capital. Our analysis reveals that a stronger industrial agglomeration force is generated if the elasticity of matching with respect to job vacancies is larger and/or the labor's bargaining power is stronger.

The second part consists of a working paper by Li and Zeng (2021), "Technology selection, income inequalities, and capital mobility". To investigate the impact of capital mobility, we introduce worker heterogeneity into the framework of Takahashi, Takatsuka, and Zeng (2013). We assume capital and immobile labor as two production factors. The inequality is generated by the characteristics of technologies and the skill heterogeneity of workers, as in Yeaple (2005). The differences between this paper and Yeaple (2005) are the asymmetry between two countries and one more production factor — capital. We compare the results derived from the internationally immobile capital case and the internationally mobile capital case. We find that the market size differential is critical in determining exporting status and technology selection. Our results show that when the market size differential is small, more (resp. less) firms using new technology in the larger (resp. smaller) country when capital is mobile across countries. Intuitively, capital tends to relocate in the larger market in globalization, amplifying the larger country's advantage. Contributing to the previous welfare studies, We find that the decreasing trade cost may lead to a loss in real income in different exporting statuses.

The third part consists of a research paper of Chen and Li (2021). We develop a detailed evaluation framework that allows us to assess the economic impacts of investment in BRI transportation infrastructure projects from China. Based on the data obtained from various sources, including American Enterprise Institute (AEI), the World Bank, and the Organisation for Economic Co-operation and Development (OECD), the influence of trade cost change as a response to transportation infrastructure investment is estimated by different regions. The indirect economic impacts of transportation infrastructure are evaluated using the Global Trade Analysis Project (GTAP) model by implementing the shock of trade cost reduction, which is caused by improved infrastructure connectivity.

The objective of this study in the third part is to provide a comprehensive assessment of the economic impact of infrastructure investment in the transportation sector under the BRI. Based on the data obtained from various sources, the influence of trade cost change as a response to transportation infrastructure investment is estimated by different regions. The indirect economic impacts of transportation infrastructure are evaluated using the Global Trade Analysis Project (GTAP) model by implementing a shock of trade cost reduction, which is caused by improved infrastructure connectivity and reduced transportation.

Our findings reveal that BRI transportation infrastructure investment has an overall positive effect among the Belt and Road countries, which is consistent with previous studies, such as Itakura (2014) and Zhai (2018). However, the impacts were found to vary substantially among different countries and regions.

The results in the third study are also connected with our theoretical researches. In the theoretical frameworks in this thesis (the first part and the second part), we demonstrate that globalization may generate opposite effects in different countries. Moreover, we also highlight that the capital mobility is a crucial factor for determining the economic impact of the trade cost reduction. The impacts of lower trade barriers are also highly related to market size, international capital legislation, and exporting structure. We also empirical found that the variation of growth rate in GDP and economic welfare are quite dissimilar among different regions. The assessment will help us better understand the economic impacts of transport connectivity and international investment.

1.3 Thesis Outline

The remainder of this thesis is organized as follows.

Chapter 2 provides an integrated overview of recent theoretical studies that link unemployment problems to spatial economics. Furthermore, we examine how matching elasticity and labor bargaining power affect industrial agglomeration in an open economy with frictional labor markets.

In Chapter 3, we investigate the impact of globalization on technology adoption and income inequality in globalization. We also explore how trade costs affect welfare in different workers groups when the heterogeneity of technologies is introduced in a trade model.

Chapter 4 estimates the economic impact of trade cost reduction when transportation infrastructure is improved. Based on the data obtained from various sources, the influence of trade cost change as a response to transportation infrastructure investment is estimated by different regions.

Chapter 5 gives concluding remarks.

Chapter 2

Frictional unemployment, bargaining, and agglomeration

2.1 Introduction

This chapter examines how matching elasticity and labor bargaining power affect industrial agglomeration in an open economy with frictional labor markets. The analysis is based on a footloose capital model of two symmetric regions with a single industry and immobile labor. Unemployment is generated by a Diamond–Mortensen–Pissarides-type search and matching mechanism. We find that the agglomeration force caused by search frictions in the labor market may be strong enough to break the symmetric equilibrium when the matching elasticity with respect to job vacancies is large and/or labor bargaining power is strong. Matching elasticity is crucial for determining the configuration of economic geography.

Moreover, we show that matching elasticity drastically affects the dispersion pattern of industrial locations in trade. More precisely, if the matches are completely determined by the number of job vacancies (i.e., the matching elasticity with respect to vacancies equals one), the spatial equilibrium moves from dispersion to full agglomeration with increasing trade freeness. If the matching process is frictional with job vacancies (i.e., the elasticity is less than one), partial agglomeration could occur when transportation costs are intermediate, and a re-dispersion pattern emerges when trade barriers are low.

Empirical studies find that the range for the matching elasticity with respect to vacancies is quite large. For instance, Borowczyk-Martin, Jolivet, and Postel-Vinay (2013) give a range from 0.33 to 0.84 with various estimating methodologies. In Coles and Petrongolo (2008), the estimated value could be pretty close to 1 under stock-flowing matching with specific filtered data. Fox (2002) reports an estimate of 0.98 in a linear regression model. Blanchard and Diamond (1989, p.31) also propose the possibility that manufacturing firms may have little trouble recruiting workers. Based on their empirical facts, we conclude that both symmetric and asymmetric equilibria are possible in the real world. Hence, our study is meaningful since it provides the theoretical explanation that the industrial agglomeration could be related to the matching elasticity.

Our results are shown by incorporating the job-matching setup of Pissarides (2000) into the footloose capital model of Takahashi, Takatsuka, and Zeng (2013). We consider a single industry in the economic space of two symmetric regions. As examined by Baldwin et al. (2003), industrial production is always evenly distributed in the two regions if workers are fully employed. In contrast, when frictional unemployment is considered, the agglomeration forces are large enough to break the symmetric equilibrium when the matching elasticity with respect to vacancies is large and/or the labor bargaining power is large.

The intuition for the appearance of agglomeration is expressed as follows. Industrial clustering affects the relative capital rent via three channels. First, firms are directly negatively impacted by tough competition. Second, firms may benefit from a larger market since it leads to a higher wage rate and a larger revenue through the home market effect (HME) when the trade barrier is small. Third, a rising firm share reduces the unemployment rate. In other words, a larger firm share results in more effective labor. A larger matching elasticity on job vacancies strengthens the third effect: the employment level becomes substantially higher in the more agglomerated area. In particular, when the elasticity equals one, the competition effect is offset by the labor efficiency effect, leading to full agglomeration when trade costs are small. Partial agglomeration and re-dispersion could emerge if the third effect is weaker than the first one. When the bargaining power is larger, workers are allocated more from firm revenue in the bargaining process, which leads to a larger local market and brings a stronger HME. As a result, agglomeration occurs when the positive HME and labor efficiency effect dominate the negative competitive effect.

A large body of literature has combined new economic geography (NEG) models with the Diamond–Mortensen–Pissarides-type search and matching frictions,[1] leading to varied results. Epifani and Gancia (2005) and Francis (2009) formulate dynamic core–periphery models with mobile job seekers. Our result is consistent with theirs in the sense that the unemployment rate in the core is lower. Developing a core–periphery model with a mobile workforce, vom Berge (2013) finds that both higher and lower unemployment rates are possible when firms are clustered. Yang (2014) considers a two-sector footloose entrepreneur model with matching frictions in the manufacturing sector. He shows that the unemployment rate in the manufacturing sector is lower with firm agglomeration, whereas the regional unemployment rate is higher. Contrary to these existing studies focusing on how regional unemployment and wages interact with economic geography, we highlight the distinctive role of two labor market parameters in industrial agglomeration: bargaining power and matching elasticity. We analytically show that both the matching elasticity on vacancies and the bargaining power of workers function as agglomeration forces.

In NEG models, the agglomeration force is described by the inter-regional mobility of workers. However, it was found that migration responds to the regional labor market disparity very slowly in the real world (Pissarides and McMaster, 1990; Buttner, 2013). Specifically, the adjustment process takes more than 20 years. Furthermore, the interaction between labor market outcomes and international capital flow is empirically supported by Billington (1999), Hisarciklilar, Gultekin-Karakas, and Asici (2014), and Delbecque, Méjean, and Patureau (2014).

Our framework contributes to the literature by revealing a new economic mechanism generating a large differential in income and unemployment even in two symmetric regions when workers are immobile. Ago, Morita, Tabuchi, and Yamamoto (2018) explore the industrial agglomeration by introducing elastic working hours. They show that labor supply elasticity acts as an agglomeration force and that industrial agglomeration occurs without inter-regional migration.[2] In contrast to

[1]Another segment of the literature explores unemployment with the paradigm of fairness preference or efficiency wage in NEG frameworks, e.g., Suedekum (2005), Francis (2007), Egger and Seidel (2008), and Zierahn (2013).

[2]Ago, Morita, Tabuchi, and Yamamoto (2017) construct a trade model with an elastic labor supply to investigate the economic impacts of technological progress. Nevertheless, the symmetric equilibrium is always stable in their framework.

their framework where only labor supply is elastic, our study focuses on the interaction of labor demand and supply in frictional labor markets. Furthermore, Takatsuka and Zeng (2018) find that elastic working hours may lead to reversed HMEs in terms of wages and firm share. Unlike these earlier studies with full employment, this chapter highlights that a large matching elasticity in the labor demand side and a strong bargaining power also generate inter-regional inequalities in employment and income levels.

The bargaining power of workers, which is directly related to labor market policies (Blanchard and Giavazzi, 2003), is commonly regarded as crucial in determining the industrial location and international capital flow. Munch (2003) and Picard and Toulemonde (2003, 2006) theoretically explore this relationship, supporting that bargaining power accelerates the industrial cluster. In the empirical literature, some studies show that less restrictive employment protection rules increase the inflow of foreign direct investment (FDI) (Görg, 2005; Javorcik and Spatareanu, 2005; Olney, 2013), whereas Rodrik (1996) and Kucera (2002) report dissenting opinions that FDI tends to be greater in countries with stronger worker rights. Autor, Kerr, and Kugler (2007) and Storm and Naastepad (2009) also argue that a positive relationship exists between employment protection and capital intensity in the USA and OECD countries, respectively. However, the survey of Brown, Deardorff, and Stern (2013) argues that there is no evidence that multinationals are attracted by lower labor standards. Comparing with previous literature, our model provides a more comprehensive framework to reveal how labor market policies and regulation rules affect capital flow through the industrial clustering force. Our results show that the effect of bargaining power on capital flow is conditional. Specifically, if the matching elasticity is minor, the bargaining power is not able to affect the location of capital for any positive trade cost.

When the matching elasticity on vacancies equals one, our framework degenerates to a model similar to that of Picard and Toulemonde (2006), in which firms fully agglomerate in a single region for small transport costs. Our result is consistent with theirs in the sense that agglomeration force increases with the power of workers by strengthening the HME. Enriching their study by introducing a frictional matching process, our model finds that different industrial distribution patterns emerge when the matching elasticity on vacancies is smaller than one. Furthermore, our framework demonstrates that agglomeration occurs with a strong bargaining power if the merits from a large market compensate for the loss from the competition effect.

Some economists have devoted attention to the re-dispersion of industrial locations and trade costs. They provide different reasons for this phenomenon: the heterogeneity of workers' tastes regarding where they live (Tabuchi and Thisse, 2002), urban congestion costs (Murata and Thisse, 2005; Ottaviano, Tabuchi, and Thisse, 2002), agricultural transport costs (Picard and Zeng, 2005), and directional imbalance in manufacturing transport costs (Takahashi, 2011). Our results reveal a new mechanism for the re-dispersion process in which matching elasticity on vacancies is crucially associated with industrial distribution patterns. More precisely, benefits of the HME vanish gradually when trade freeness is sufficiently high. For a matching elasticity of less than one, re-dispersion evolves with decreasing trade costs due to the negative competition effect.

A few studies, which are also related to our article,[3] have investigated how search unemployment is influenced by international trade. Dutt, Mitra, and Ranjan (2009) present a model of trade with a Ricardian comparative advantage. They find that unemployment and trade openness are negatively related. Introducing search unemployment into Melitz's (2003) trade model, Felbermayr, Prat, and Schmerer (2011) show that trade freeness affects unemployment by changing the average productivity. Helpman and Itskhoki (2010) and Helpman, Itskhoki, and Redding (2010) study searching frictional unemployment with heterogeneous firms and workers. In their model, the opening of trade can either raise or reduce unemployment. In contrast to these previous studies, we demonstrate that trade costs impact the unemployment rate via the channel of endogenous agglomeration. We show that agglomeration may occur when trade costs are intermediate, which leads to a lower unemployment rate in the more agglomerated region.

[3]There is also a growing body of literature on the trade–unemployment relationship within a framework of fair wages or efficiency wages, including Egger and Kreickemeier (2009, 2012) and Davis and Harrigan (2011).

2.2 Existing literature on frictional labor markets

It is well documented that trade policies have impacted labor markets substantially with the development of economic globalization. During the last two decades, unemployment problems have become one of the major topics of theoretical research in spatial economics. This section seeks to review recent theoretical studies that link globalization to labor market outcomes, especially unemployment.

2.2.1 Labor unions

Let us start with the framework of labor unions (or collective bargaining), which is a standard way to introduce involuntary unemployment to international trade models. Due to the existence of bargaining between firms and labor unions, workers claim a wage rate that is higher than the level of labor market clearing.

In this section, we outline the basic model of a closed economy in Eckel and Egger (2009).[4] With horizontally differentiated goods x and a homogeneous good A, preferences of a consumer are given by a Cobb–Douglas utility function:

$$U = X^{\varrho} A^{1-\varrho}, \quad 0 < \varrho < 1,$$

where

$$X = \left[\int_{\omega \in \Omega} x(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}}$$

represents the composite good of the manufacturing sector, Ω is the set of available varieties, and σ denotes the elasticity of substitution between any two varieties. Utility maximization determines the demand for variety ω,

$$d(\omega) = \frac{\varrho E}{P} p(v)^{-\sigma},$$

[4]Blanchard and Giavazzi (2003) develop a one-country model with monopolistic competition in good markets and collective bargaining in labor markets. Mezzetti and Dinopoulos (1991) develop a partial equilibrium model of a domestic unionized firm and a foreign firm. They show that the way bargaining affects the labor employment depends on the form of union: wage oriented or employment oriented.

where $p(\omega)$ is the price of this variety, E denotes total consumption expenditures, and $P \equiv \int_{v \in V} p(v)^{1-\sigma} dv$ represents the price index.

Firms and unions face a three-stage game. At stage one, firms decide whether to enter the market according to their own productivity. If they decide to start production, they need to invest f units of good to set up a plant. At stage two, there is wage bargaining at the firm level. Union activities are assumed to be restricted to a single firm. At stage three, firms choose an employment level and start production. The game is solved through backward induction.

Profit maximization yields the optimal price of a firm with productivity φ:

$$p(\varphi) = \frac{\sigma w(\varphi)}{(\sigma - 1)\varphi},$$

where $w(\varphi)$ is the wage paid by the firm. Then firm revenues and profits are derived as

$$R(\varphi) = \frac{\varrho E}{P} p(\varphi)^{1-\varrho}, \quad \pi(\varphi) = \frac{\varrho E}{\sigma P} p(\varphi)^{1-\sigma} - f.$$

The union preferences can be represented by a Stone–Geary utility function:[5]

$$\mathcal{W}(\varphi) = l(\varphi) \left[w(\varphi) - \bar{w} \right],$$

where $l(\varphi)$ denotes the employment level of the firm. The average labor income is given by $\bar{w} = (1 - u)\tilde{w}$, where $\tilde{w}$ is the average wage rate outside the firm and u represents the unemployment rate. Since firms share identical productivity, $w = \tilde{w}$ holds in the equilibrium. Given $\bar{\pi} = -f$ as the firm's profit if the bargaining breaks down, and $\pi(\varphi)$ as that if an agreement is reached, the solution to the firm–union bargaining problem is determined by maximizing the Nash product:

$$\Omega = W(\varphi)^{\gamma} \left[\pi(\varphi) - \bar{\pi} \right]^{1-\gamma},$$

where $\gamma \in [0, 1]$ is the bargaining power of the labor union. The solution of the maximizing problem is

$$w(\varphi) = \frac{\sigma - 1 + \gamma}{\sigma - 1} \bar{w}. \tag{2.1}$$

[5]Mezzetti and Dinopoulos (1991) and Zhao (1995, 1998) choose a more general form of union preferences and allow for different weights on employment and the excess wage.

Hence, all firms pay the same wage rate in the equilibrium. Substituting $\bar{w} = (1-u)w$ into (2.1), the unemployment rate is solved as

$$u = \frac{\gamma}{\sigma - 1 + \gamma}. \tag{2.2}$$

This result reveals that greater union power leads to higher wages and a higher unemployment rate in autarky. With $\gamma > 0$, unions claim a higher wage rate than the average labor income, which leads to higher labor costs from the firms' perspective.

Eckel and Egger (2009) also consider the case of an open economy with multinational entrepreneurs (MNEs) to study the interaction between union–firm bargaining and foreign direct investment.[6] Firms have two options for serving consumers in the foreign country. They can concentrate production to serve foreign consumers by bearing trade costs (exporters) or set up a second production plant abroad, i.e., become MNEs, with an extra fixed cost F_m. In equilibrium, the most productive firms invest abroad while less productive firms rely on exporting, which is consistent with the standard MNE model of Helpman, Melitz, and Yeaple (2004).

However, the labor market structure changes crucially when the bargaining of multinational firms is taken into account. For an MNE, if an agreement in the wage negotiations with the foreign union is not reached, it can produce in its domestic plant and serve the foreign market by exporting. Hence, compared with local firms, MNEs hold a higher outside option in the bargaining and pay lower wages than exporters. As a consequence, the wage rates are depressed by MNEs, so that the unemployment rate in the open economy with MNEs is lower for $\gamma \in (0, 1)$.

Moreover, the wage bargaining between firms and unions makes multinational activities more attractive, since MNEs have higher fallback profits. Eckel and Egger (2009) also find that a fall in trade costs could increase the share of multinational enterprises when the bargaining power is sufficiently large. By introducing collective bargaining, their model provides a possible explanation for the "apparent puzzle" that the foreign direct investment has surged at a time when trade

[6] In the case of an open economy when MNEs are not allowed, the same results can be derived in (2.1) and (2.2).

costs declined (Lommerud, Meland, and Sørgard, 2003). This phenomenon could not be explained in the traditional model of Helpman, Melitz, and Yeaple (2004).

A few theoretical studies have examined how the bargaining between labor unions and firms affects the endogenous industrial location in NEG frameworks, such as Munch (2003) and Picard and Toulemonde (2006). They demonstrate the union power works as an agglomeration force by amplifying the home market effect in the core. Moreover, they show that bargaining power is a critical parameter to determine the industrial distribution in trade.

2.2.2 Search–matching model

The 2010 Nobel Prize in Economics has been awarded to Peter Diamond, Dale Mortensen, and Christopher Pissarides "for their analysis of markets with search frictions".[7] In a perfectly competitive labor market, firms and workers match costlessly. Thus, any excess labor supply could be absorbed instantaneously by a decreasing wage rate. However, this is not realistic, since labor markets are imperfect in the real world and both unemployed workers and job vacancies coexist. By introducing matching frictions, many economists give an explanation of how labor market tightness and employment structure change in trade.

Following the setting in a search-matching model, firms post vacancies to find workers. The number of jobs created between job seekers ($\mathcal{S}$) and vacancies (V) is determined by the matching function

$$M = m(\mathcal{S}, V),$$

where $m(\cdot)$ is an increasing function of both arguments, concave and homogeneous of degree one.[8] Define the labor market tightness, $\alpha \equiv \mathcal{S}/V$, as the ratio of job seekers and vacancies, the vacancy-filling rate is $M/V = m(\alpha, 1) \equiv m(\alpha)$. Then the unemployed workers are hired at rate $\alpha m(\alpha)$. To hire l workers, firms post $v = l/m(\alpha)$ vacancies, and the cost of providing one vacancy is c.[9]

[7] Diamond (1982), Pissarides (1990), and Mortensen and Pissarides (1994) developed this theory.

[8] Petrongolo and Pissarides (2001) provide some evidence for constant returns in the matching technology.

[9] Generally, vacancy-posting costs are assumed to be paid by a composite good, a homogeneous good, or labor.

2.2.3 Unemployment in asymmetric countries

Search–matching unemployment has also been incorporated into trade models for asymmetric countries with product differentiation. Introducing search and matching frictions into competitive models of international trade, Davidson, Martin, and Matusz (1999) show that labor market turnover (destruction rate and matching efficiency) has important implications in determining the trade pattern. More precisely, the country with the more efficient search technology has a comparative advantage in production in a high-unemployment sector. Moreover, they find that a relatively capital-abundant large country suffers a larger unemployment rate in trade. Dutt, Mitra, and Ranjan (2009) incorporate search-induced unemployment into a trade model with comparative advantage. They show that unemployment and trade openness are negatively related in a Ricardian model. In an H-O model, trade openness increases unemployment in capital-abundant countries and decreases unemployment in labor-abundant countries.

Helpman and Itskhoki (2010) study a two-country two-sector model of international trade with search and matching frictions. As a result, opening to trade leads to a larger aggregate unemployment in the country with lower labor market frictions in the manufacturing sector. Moreover, only the country with lower frictions in its differentiated good sector can benefit from trade.

A few theoretical studies have examined how industrial location and frictional labor market interact with each other in NEG models. Epifani and Gancia (2005) and Francis (2009) formulate dynamic core-periphery models with mobile job seekers. They show that the unemployment rate in the core is lower than that in the periphery since firms earn high profits in the core and induce more new vacancies.[10]

2.2.4 Efficiency wages

The question of why unemployed workers are unable to bid down the wages has been analyzed in published reports for a long time. The efficiency wage theory suggests that the answer is the negative incentive effects of a low wage rate. More precisely, workers' effort depends positively on their wages. On this basis, firms may find it profitable to pay wages in excess of market clearing. Efficiency wage models have also been incorporated into trade models to investigate the labor

[10] vom Berge (2013) and Yang (2014) also develop similar NEG models with matching frictions.

market outcome in globalization.

Fair wage preference

Akerlof (1982) and Akerlof and Yellen (1990) introduce a rent-sharing motive as a determinant of workers' fair wage preferences. In fair-wage-effort approaches, workers have a preference for fairness. If they feel that they get paid less than they ought to, they exert less effort in the work. Worker effort level, ϵ, is a function of the wage they are paid (w) and the wage perceived as fair ($\hat{w}$), such that

$$\epsilon = \min\left\{\frac{w}{\hat{w}}, 1\right\}.$$

This framework postulates a positive relationship between work effort and wage so that the fairness-oriented behavior of workers may lead to involuntary unemployment.

Kreickemeier and Nelson (2006) modify the original model of Akerlof and Yellen (1990) by considering two factors: the skilled worker and the unskilled worker. They show that the competitive advantage between countries arises from country-specific preferences for fairness. In a country with a higher egalitarian preference, relative wages and employment levels of unskilled workers are negatively affected by the fairness preferences in its trading partner. Furthermore, the opening of trade increases unemployment rates in both countries.

Egger and Kreickemeier (2009) develop a model that incorporates fair wage preference and Melitz's firm heterogeneity into a general equilibrium framework. Compared with the matching unemployment models in Section 3, efficiency wage models allow us to analyze wage differentials among identical workers. Following Blanchard and Giavazzi (2003), final output is assumed to be a CES–aggregate of all available intermediate goods. Following Melitz (2003), with marginal labor input l and productivity φ, the output is $q = \varphi l$. Then the profit-maximizing price of a firm with productivity φ is

$$p(\varphi) = \frac{\sigma w(\varphi)}{(\sigma - 1)\varphi\varepsilon}.$$

The fair wage (reference wage) is a weighted average of two factors: the market potential of an employer, which is related to the firm's productivity, and the average labor income $(1-u)\bar{w}$ ($\bar{w}$ denotes the average wage rate). Hence, the reference wage of a firm is a geometric average of the productivity and the expected labor income:

$$\hat{w}(\varphi) = \varphi^{\chi} \left[(1-u)\bar{w}\right]^{1-\chi},$$

where $\chi \in (0,1)$ is interpreted as a fairness parameter of workers.

Profit-maximizing firms have no incentive to pay less than the fair wage. This implies $\epsilon = 1$ and $w(\varphi) = \hat{w}(\varphi)$ in equilibrium. For $\chi = 0$, the model degenerates to the perfect labor market model with full employment. For $\chi = 1$, all firms have identical marginal production costs, i.e., $w(\varphi)/\varphi = 1$.

This model captures how the rent–sharing motive of workers impacts the wage inequality and unemployment in globalization. Egger and Kreickemeier (2009) find that a higher χ leads to a higher unemployment rate and greater wage inequality in a one-country model. Moreover, they predict that opening to trade raises unemployment and wage inequality, since the firms are more productive and more dispersed with globalization. They also illustrate that a decrease in trade costs has a hump-shaped effect on unemployment and wage inequality.

According to their model, a firm's productivity is determined by the ability of its manager. Knowing their own managerial ability, individuals can choose whether to become a manager or a worker. Workers are taken as identical marginal inputs and managers earn the operating profits. Firms run by more able managers have a higher productivity level and make higher profits. The equilibrium manager ability cutoff (φ^*) is characterized by the labor indifference condition

$$(1-u)\bar{w} = \pi(\varphi^*),$$

where $\pi(\cdot)$ represents the firm's profit. Analogously, they show that international trade leads to a higher unemployment rate by increasing the average productivity and wage. Trade also increases both the inequality within the two subgroups (workers and managers) and the inter-group inequality.

When heterogeneity is introduced into the framework of fair wages, the wage inequality exists among firms even if workers are identical. This feature is not observable in the model of frictional matching such as in Felbermayr, Prat, and Schmerer (2011) and Helpman and Itskhoki (2010).

Egger and Seidel (2008) explore an NEG model of efficiency wages. With more fairness preferences, the income differential between skilled and unskilled workers falls. However, the unemployment rate of unskilled workers increases. Moreover, they illustrate that fair wage preferences could force agglomeration.

Efficiency wages and monitoring

Shapiro and Stiglitz (1984) propose another approach of efficiency wages to determine the labor demand and wage rate, providing a technical explanation of how involuntary unemployment appears. Since shirking makes a firm's productivity decline, the firm needs to offer its workers higher wages to eliminate their shirking.

In a Shapiro–Stiglitz efficiency wage model, there are $\mathcal{L}$ identical workers, who dislike exerting effort but enjoy consuming goods. The instantaneous utility function of an individual is given as $U(w, e)$, where e is the cost of effort. Workers' distaste for effort tempts them to shirk. Their shirking will be discovered with a constant probability, which depends on the monitoring technology of firms. Utility takes the following form:

$$U(w,e) = \begin{cases} w & \text{if the worker shirks,} \\ w - e & \text{if the worker exerts effort } e > 0, \\ 0 & \text{if the worker is unemployed.} \end{cases}$$

Matusz (1996) merges a model of monopolistic competition in the production of intermediate goods with the Shapiro–Stiglitz model of efficiency wages. He shows that international trade reduces the unemployment rate, since opening to trade allows for more production.

Davis and Harrigan (2011) introduce heterogeneity in productivity and monitoring technology into the Shapiro–Stiglitz efficiency wage model. Similar to Egger and Kreickemeier (2009), the inter-group inequality of workers also exists here. Heterogeneity in the monitoring ability of firms leads to different wages for identical workers in Davis and Harrigan (2011). More precisely, the firm-specific wages depend inversely on the firm–level relative monitoring abilities. They find that the national unemployment rate is little affected by liberalization with simulations. However, there is a tremendous amount of labor market churning: nearly one-fourth of all "good" jobs (jobs with above-average wages in autarky) are destroyed in trade. Workers are paid less in an open economy, since it becomes harder to survive for firms offer higher wage rates in international trade.

In NEG models with efficiency wages, firms in the more agglomerated region are able to pay higher wages, so that shirking is reduced there, which leads to a lower unemployment rate, as shown in Suedekum (2005) and Zierahn (2013).

2.2.5 Minimum wage

A minimum wage is the lowest remuneration that employers can legally pay their workers. In general, supply and demand models suggest that minimum wage binding leads to losses in aggregate welfare and employment. However, if employees have greater monopsony power in labor markets, a minimum wage can increase the efficiency of the market.

Brecher (1974) first extends the H–O model of an open economy with exogenous wage constraints (minimum wages). Unemployment occurs if and only if the equilibrium wages exceed the level required for full employment. He shows that the level of employment and welfare could be less in trade. Davis (1998) develops an H-O model of trade between two countries, one of which has flexible wages (America), while the other is bound by a minimum wage for unskilled labor (Europe). International trade equalizes factor prices between the flexible-wage and the minimum-wage economies. He shows that a move from autarky to free trade doubles European unemployment.

Abstracting from Heckscher-Ohlin-type reasons for trade, Egger, Egger, and Markusen (2012) formally incorporate minimum wages in an NTT model with heterogeneous firms. They find that a rise in the minimum wage in a country will force inefficient intermediate good suppliers to exit the market, leading to a decline in exports. They show that trade increases the unemployment rate in all countries.

2.3 The Model and Equilibrium

In this section, we explore the industrial location with frictional labor markets by incorporating the job-matching setup of Pissarides (2000) into the footloose capital model of Takahashi, Takatsuka, and Zeng (2013)

2.3.1 Setup

We consider a world of two symmetric regions, $i = 1, 2$, and one manufacturing sector. There are two production factors in this model: immobile labor and mobile capital. For simplicity, each individual is assumed to supply one unit of labor and one unit of capital. The population and capital endowment in region i are $\mathcal{L}_i = K_i = 1$. The total capital endowment in the world is $K = 2$.

The manufacturing sector produces a continuum of varieties under increasing returns to scale in a monopolistic competition market. The utility (U_i) takes the CES form. In region i,

$$U_i = \left[\int_0^N d_i(\omega)^{\frac{\sigma-1}{\sigma}} \mathrm{d}\omega \right]^{\frac{\sigma}{\sigma-1}},$$

where $d_i(\omega)$ represents the demand for a variety ω in region i, N is the number of varieties, and $\sigma > 1$ denotes the elasticity of substitution between any two varieties. The manufacturing price index in region i is given by

$$P_i = \left[\int_0^N p_i(\omega)^{1-\sigma} \mathrm{d}\omega \right]^{\frac{1}{1-\sigma}},$$

where $p_i(\omega)$ is the price of a variety ω in region i. The total demand in region i for a variety produced in region j is

$$d_{ji}(\omega) = \frac{[p_{ji}(\omega)]^{-\sigma}}{P_i^{1-\sigma}} Y_i, \quad i, j = 1, 2\ , \tag{2.3}$$

where Y_i is the national income of region i, and p_{ji} is the price of a variety made in region j and consumed in region i.

2.3.2 Firm's behavior

We assume that all firms and labor are homogeneous. Firm productivity is denoted by φ, which is taken as an exogenous parameter. With labor input l_i, the output of a firm is φl_i. Before starting production, each firm needs a fixed input of capital and a hiring cost paid by capital. After hiring l_i workers, a firm pays a marginal cost of $1/\varphi$ units of labor to start production.

Inter-regional trade is subject to the iceberg cost $\tau > 1$. Specifically, in order to deliver one unit of output to the foreign market, the producer has to manufacture

τ units. Operating revenues of firms in region i from sales in the foreign market are equal to $p_{ij}d_{ij}$, $i \neq j$.

With the assumption of iceberg transportation, the market clearing condition gives

$$d_{ij} = \begin{cases} \varphi l_{ii} & \text{if } i = j \\ \varphi l_{ij}/\tau & \text{if } i \neq j \end{cases},$$

where l_{ij} is the labor input in market j. A firm allocates its output between the domestic and foreign markets to maximize its total revenues, $R_i = p_{ii}d_{ii}+p_{ij}d_{ij}$. To decide how to allocate labor between the two markets, firms equate the marginal revenue of each market.[11] Then, we obtain the labor allocation,

$$\frac{l_{ii}}{l_{ij}} = \frac{1}{\phi}\frac{Y_i}{Y_j}\left(\frac{P_i}{P_j}\right)^{\sigma-1},$$

where $\phi \equiv \tau^{1-\sigma}$ is the trade freeness, ranging from 0 to 1. Let $l_i = l_{ii} + l_{ij}$ be the total labor input of one firm in region i. Then we have

$$l_{ii} = \frac{Y_i P_i^{\sigma-1}}{Y_i P_i^{\sigma-1} + \phi Y_j P_j^{\sigma-1}} l_i, \quad l_{ij} = \frac{\phi Y_j P_j^{\sigma-1}}{Y_i P_i^{\sigma-1} + \phi Y_j P_j^{\sigma-1}} l_i. \tag{2.4}$$

The total revenue of a firm hiring l_i workers is[12]

$$R_i(l_i) = p_{ii}d_{ii} + p_{ij}d_{ij} = \left(1 + \phi\frac{P_j^{\sigma-1}Y_j}{P_i^{\sigma-1}Y_i}\right)^{\frac{1}{\sigma}} P_i^{\frac{\sigma-1}{\sigma}} Y_i^{\frac{1}{\sigma}} (\varphi l_i)^{\frac{\sigma-1}{\sigma}}. \tag{2.5}$$

Differentiating (2.5) with respect to l_i gives the marginal revenue of labor,

$$\frac{\mathrm{d}R_i}{\mathrm{d}l_i} = \frac{\sigma-1}{\sigma}\frac{R_i}{l_i}. \tag{2.6}$$

2.3.3 Matching and unemployment

The labor market is imperfectly competitive due to the existence of search frictions. We assume that all individuals search for jobs in the beginning. Firms

[11] This calculation is for deriving how a firm's revenue is related to the employment level, l_i. Details are given in Appendix A.1.

[12] Details are given in Appendix A.2.

post vacancies in order to start production. The number of matches between job seekers and vacancies has a Cobb-Douglas form,

$$M_i \equiv M(\mathcal{L}_i, V_i) = mV_i^{\mu}\mathcal{L}_i^{1-\mu},$$

where V_i denotes the measure of all vacancies provided by firms, $m \in (0,1)$ is a parameter of matching efficiency. M_i measures jobs created in the matching process in region i. Moreover, $\mu \in [0,1]$ is the elasticity of matching with respect to the number of job vacancies, which is a critical parameter in this study. For $\mu = 1$, the aggregate number of matches in region i depends solely on the number of vacancies. When $\mu = 0$, only the number of job seekers matters in the matching process. Labor market tightness in region i is defined as the ratio of the number of vacancies over the number of job seekers, $\alpha_i \equiv V_i/\mathcal{L}_i$. The matching rate (also called the vacancy-filling rate) for firms is given as

$$\frac{M_i}{V_i} = m\alpha_i^{\mu-1}. \tag{2.7}$$

Thus, the elasticity of the matching rate with respect to the labor market tightness is $\mu - 1$.

Job seekers meet firms at a rate of $M_i/\mathcal{L}_i = \alpha_i M_i/V_i = m\alpha_i^{\mu}$. Then the unemployment rate in region i is a decreasing function of α_i:

$$u_i = 1 - m\alpha_i^{\mu}. \tag{2.8}$$

To recruit l_i workers, a firm located in region i has to provide v_i vacancies, and the cost of providing one vacancy is c units of capital.[13] To each firm, α_i is taken as given, so the number of vacancies provided by a firm is $v_i = \alpha_i^{1-\mu}l_i/m$. The total hiring cost of a firm located in region i is, therefore, $cv_ir_i = c\alpha_i^{1-\mu}l_ir_i/m$. It is worth pointing out that the vacancy-filling rate is a constant m for $\mu = 1$, according to (2.7). In this special case, the number of vacancies posted by firms is irrelevant to the local labor market tightness.[14]

[13]In Appendix A.4, we consider a more general case in which hiring costs are paid by both labor and capital. We show that our results are robust.

[14]We assume that $1 - m\,[2(\sigma-1)/(c\sigma)]^{\mu} > 0$ always holds, so that firms can always match sufficient workers with vacancies and the unemployment rate is non-negative.

2.3.4 Bargaining and optimal vacancy posting

From the viewpoint of firms, the employment level maximizes their profits. The profit of a firm in region i is expressed as

$$\pi_i(l_i) = R_i(l_i) - w_i l_i - \frac{c}{m}\alpha_i^{1-\mu} l_i r_i - r_i. \tag{2.9}$$

Following Stole and Zwiebel (1996), in bargaining, the division of the total surplus R_i from the match satisfies the following "surplus-splitting" rule. We assume that each worker is treated as a marginal worker. Hence, the wage rate is given as

$$w_i = \text{argmax}\ w_i^{\beta} \cdot \left[\frac{\mathrm{d}(R_i - w_i l_i)}{\mathrm{d}l_i}\right]^{1-\beta},$$

where $\beta \in (0,1)$ is the bargaining power of workers. Unemployed workers merely earn capital rents, so the outside option of workers in bargaining is zero. The bargaining solution is then determined by

$$(1-\beta)w_i = \beta\frac{\mathrm{d}(R_i - w_i l_i)}{\mathrm{d}l_i}, \tag{2.10}$$

which is a linear differential equation in l_i. The solution to (2.10) is[15]

$$w_i = \frac{\beta(\sigma-1)}{\sigma-\beta}\frac{R_i}{l_i}. \tag{2.11}$$

Taking α_i, P_i, and Y_i as given, a firm chooses the optimal l_i to maximize profit (2.9). The F.O.C. gives

$$\frac{c}{m}\alpha_i^{1-\mu} r_i = \frac{(1-\beta)(\sigma-1)}{\sigma-\beta}\frac{R_i}{l_i}. \tag{2.12}$$

Thus, the hiring cost equals $[(1-\beta)(\sigma-1)]/(\sigma-\beta)$ of the revenue. According to the zero profit condition, we have

$$r_i = \frac{1-\beta}{\sigma-\beta}R_i. \tag{2.13}$$

[15] Using (2.6), the following differential equation of w_i can be derived from (2.10):

$$\frac{\mathrm{d}w_i}{\mathrm{d}l_i} = \frac{\sigma-1}{\sigma}R_i l_i^{-2} - \frac{w_i}{\beta l_i}.$$

Using (2.5), the general solution to the above equation is $w_i = [\beta(\sigma-1)/(\sigma-\beta)]R_i/l_i + \mathcal{C}l_i^{-1/\beta}$, where $\mathcal{C}$ is a constant coefficient. Since $w_i l_i$ is finite when $l_i \to 0$, we know that $\mathcal{C} = 0$.

Following (2.11), (2.12), and (2.13), a firm allocates its revenue into three kinds of costs with constant ratios in the equilibrium, as shown in Figure 2.1. It is noteworthy that the share of fixed costs becomes $1/\sigma$ when $\beta = 0$, which is known as a general result of CES models without frictional labor market (Lemma 2.1 of Zeng (2021)).

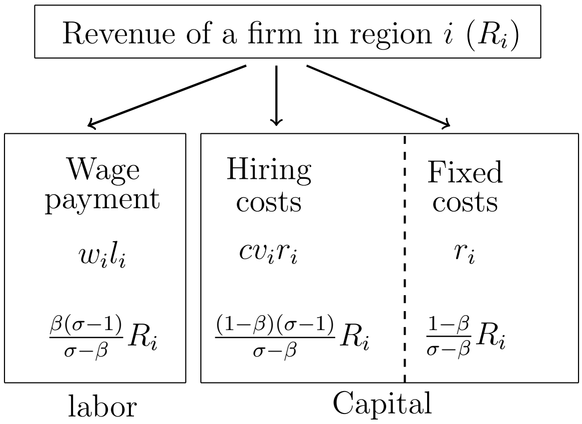


Figure 2.1: Revenue and three kinds of costs

According to (2.12) and (2.13), the amount of capital paid for recruitment and the total capital payment of one firm are calculated as

$$cv_i = \frac{c}{m} \alpha_i^{1-\mu} l_i = \sigma - 1, \tag{2.14}$$

$$r_i + \frac{c}{m} \alpha_i^{1-\mu} l_i r_i = \frac{1-\beta}{\sigma-\beta} R_i + \frac{(1-\beta)(\sigma-1)}{\sigma-\beta} R_i = \frac{\sigma(1-\beta)}{\sigma-\beta} R_i = \sigma r_i.$$

Therefore, each firm employs σ units of capital. The total number of firms in the two regions is $K/\sigma = 2/\sigma$. Meanwhile, the optimal v_i is also determined by (2.14). Let the firm share in region i be k_i, which is also the share of employed capital in region i. For simplicity, we write $k_1 \equiv k$, $k_2 \equiv 1-k$. Since all firms have the same employment level, we get

$$l_i = \frac{(1-u_i)\mathcal{L}_i}{k_i \frac{K}{\sigma}}. \tag{2.15}$$

Combining (2.8) and (2.15) with (2.14), the labor market tightness is solved as

$$\alpha_i = \frac{2(\sigma-1)}{c\sigma} k_i. \tag{2.16}$$

Unlike the dynamic matching process where vacancies meet with the unemployed, the number of job-seekers is exogenously given in this static model, which is independent of the matching elasticity. As a result, the relationship between α_i and k_i becomes linear.[16]

According to (2.11) and (2.12), we can derive how wages are related to the labor market tightness and the capital rent,

$$w_i = \frac{\beta c}{m(1-\beta)} \alpha_i^{1-\mu} r_i. \tag{2.17}$$

Plugging (2.8) and (2.16) into (2.17), the capital rent in region i is written as

$$r_i = \frac{\sigma(1-\beta)}{2\beta(\sigma-1)} \frac{(1-u_i)w_i}{k_i}. \tag{2.18}$$

2.3.5 Simplification

According to equation (2.11), we have

$$p_{ii}\varphi l_{ii} + p_{ij}\frac{\varphi l_{ij}}{\tau} = R_i = \frac{\sigma-\beta}{\beta(\sigma-1)} w_i \left(l_{ii} + l_{ij}\right).$$

Since $p_{ij} = \tau p_{ii}$, the optimal prices of firms are solved as

$$p_{ii} = \frac{\sigma-\beta}{(\sigma-1)\beta} \frac{w_i}{\varphi}, \quad p_{ij} = \frac{\sigma-\beta}{(\sigma-1)\beta} \frac{w_i}{\varphi}\tau, \quad \text{for } i,j = 1,2,\ i \neq j.$$

To simplify the later calculation, we choose the unit of product such that $\varphi \equiv (\sigma-\beta)/[(\sigma-1)\beta]$. Thus, the prices are simplified to $p_{11} = w_1$, $p_{12} = \tau w_1$, $p_{22} = w_2$, and $p_{21} = \tau w_2$. We choose the capital return in region 2 as the numeraire, such that

$$r_2 = \frac{\sigma(1-\beta)}{2\beta(\sigma-1)} \frac{(1-u_2)w_2}{1-k} \equiv 1. \tag{2.19}$$

2.3.6 The short-run equilibrium

In the short-run equilibrium, the mobility of capital is not allowed between the two regions; hence, the firm share k is taken as given in this step. The price indices in

[16] Researches with static matching setups include Helpman and Itskhoki (2010) and Helpman, Itskhoki, and Redding (2010).

the two regions are rewritten as

$$P_1 = \left\{ [kw_1^{1-\sigma} + \phi(1-k)w_2^{1-\sigma}]\frac{K}{\sigma} \right\}^{\frac{1}{1-\sigma}},$$
$$P_2 = \left\{ [\phi k w_1^{1-\sigma} + (1-k)w_2^{1-\sigma}]\frac{K}{\sigma} \right\}^{\frac{1}{1-\sigma}}. \tag{2.20}$$

The national income in region i is

$$Y_i = \mathcal{L}_i \left[\bar{r} + (1-u_i)w_i \right], \tag{2.21}$$

where $\bar{r} = kr_1 + (1-k)r_2$ represents the reward to each capital holder.[17] From (2.18), we have

$$\bar{r} = \frac{\sigma(1-\beta)}{2\beta(\sigma-1)} \left[(1-u_1)w_1 + (1-u_2)w_2 \right]. \tag{2.22}$$

The labor market clearing condition in region 1 is given as

$$(1-u_1)\mathcal{L}_1 = k\frac{K}{\sigma\varphi}(d_{11} + \tau d_{12}). \tag{2.23}$$

When k increases, the labor efficiency in region 1 increases, so the labor supply there rises. This is observed in the LHS of (2.23). On the other hand, the direct effect of an increase in k on d_{11} is through the price index term $P_1^{1-\sigma}$, which is dependent on k and $1-k$. Similarly, the direct effect of k on d_{12} is also dependent on k and $1-k$. Therefore, when k increases, the impact on the labor demand in region 1 (the RHS of (2.23)) is ambiguous. Wages are adjusted to clear two labor markets.

To explore the detail, let the relative wage rate be $w \equiv w_1/w_2$. Substituting (2.3), (2.16), and (2.18) – (2.22) into (2.23), we obtain a wage equation,

$$\mathcal{F}(w) \equiv \mathcal{A}_0(w) + \mathcal{A}_1(w)\phi + \mathcal{A}_2(w)\phi^2, \tag{2.24}$$

[17] As in Baldwin et al. (2003, p.74), a straightforward assumption is imposed here that half of the employed capital in each region belongs to region 1 for any k. This simplifies our analysis of a short-run equilibrium because the capital returns to the owners in the two regions are equal for any k. Note that such an assumption does not change the results regarding a long-run equilibrium.

with

$$\mathcal{A}_0(w) \equiv (1-\beta)\sigma\Big[\Big(\frac{1-k}{k}\Big)^{\mu} - w\Big],$$
$$\mathcal{A}_1(w) \equiv 2(\sigma-\beta)w^{1-\sigma}\Big[\Big(\frac{k}{1-k}\Big)^{1-\mu} - \frac{1-k}{k}w^{2\sigma-1}\Big],$$
$$\mathcal{A}_2(w) \equiv [\beta(\sigma-2)+\sigma]\Big[\Big(\frac{1-k}{k}\Big)^{\mu} - w\Big].$$

This wage equation implicitly gives equilibrium wage rate $w(\phi)$, showing how w responds to trade freeness ϕ. Note that firm share k is given in the short run. The following properties of $\mathcal{F}(w)$ are evident:

$$\frac{\partial \mathcal{F}}{\partial w} < 0, \quad \frac{\partial \mathcal{A}_0}{\partial k} < 0, \quad \frac{\partial \mathcal{A}_1}{\partial k} > 0, \quad \frac{\partial \mathcal{A}_2}{\partial k} < 0.$$

Thus, $\mathcal{F}(w)$ describes how w adjusts the labor market balance of (2.23). A negative value of $\mathcal{F}(w)$ indicates excess demand of labor if the wage rate is w, so the equilibrium wage rate is higher. A rise in k decreases both $\mathcal{A}_0$ and $\mathcal{A}_2$ but increases $\mathcal{A}_1$. The total effect of k on $\mathcal{F}(w)$ and w is ambiguous, which is consistent with our analysis on (2.23).

Now we examine a possible core-periphery structure to show the difference between cases of $\mu < 1$ and $\mu = 1$. Note that the income is positive in the peripheral region because each resident owns one unit of capital. Since the two regions are symmetric, we assume that region 1 is the peripheral region (i.e., $k \to 0$) when industrial agglomeration occurs without loss of generality. It is immediately verified that

$$\lim_{k\to 0} \mathcal{F}(w)|_{\mu<1} = -2\phi(\sigma-\beta)w^{\sigma}, \tag{2.25}$$
$$\lim_{k\to 0} \mathcal{F}(w)|_{\mu=1} = (1-\beta)\sigma - 2(\sigma-\beta)w^{\sigma}\phi + [\beta(\sigma-2)+\sigma]\ \phi^2. \tag{2.26}$$

Accordingly, the equilibrium relative wage is solved as:

$$\lim_{k\to 0} w|_{\mu<1} = 0, \quad \lim_{k\to 0} w|_{\mu=1} = \Big\{\frac{(1-\beta)\sigma + [\beta(\sigma-1)+\sigma-\beta]\phi^2}{2(\sigma-\beta)\phi}\Big\}^{\frac{1}{\sigma}} > 0.$$

The above result reveals a substantial difference between cases of $\mu = 1$ and $\mu < 1$. According to (2.8), (2.15), and (2.16), the optimal employment level of a firm can be expressed as

$$l_i|_{\mu<1} = \frac{m\sigma^{1-\mu}\mathcal{L}_i}{K}\left[\frac{2(\sigma-1)}{c}\right]^{\mu} k_i^{\mu-1}, \quad l_i|_{\mu=1} = \frac{2\mathcal{L}_i m(\sigma-1)}{cK}.$$

Intuitively, vacancies are more difficult to be filled in the agglomerated region if $\mu < 1$. When all firms are located in region 2, the vacancy-posting cost of hiring one unit of worker in region 1 is tiny, according to (2.14) and (2.16). Accordingly, the relative optimal employment level of firms in region 1 approaches infinite, leading to an infinitesimal relative wage there. On the contrary, the vacancy-filling rate is fixed and disconnected from the firm share when $\mu = 1$. As a result, the optimal employment level of a firm keeps constant. Since the wage rate is determined by bargaining, even in the corner distribution, firms need to pay positive wages in region 1 when the employment level is finite. It will be clear in Section 2.4 that the relative wage is crucial for determining whether the full agglomeration occurs.

2.3.7 The long-run equilibrium

In the long run, capital is free to move to the region with a higher capital rent. We use the following dynamics[18] to describe the movement of capital:

$$\dot{k} = \Delta r \equiv r_1 - r_2 = \frac{\sigma(1-\beta)}{2\beta(\sigma-1)}\Big[\frac{(1-u_1)w_1}{k} - \frac{(1-u_2)w_2}{1-k}\Big],$$

where the last equality is from (2.18). Following (2.18) and (2.19), an interior distribution[19] ($k \in (0,1)$) is a long-run equilibrium if

$$\Delta r = wh\frac{1-k}{k} - 1 = 0, \tag{2.27}$$

where $h \equiv (1-u_1)/(1-u_2)$ denotes the relative labor efficiency. Therefore, combining (2.8), (2.16), and (2.27) gives

$$w = \Big(\frac{k}{1-k}\Big)^{1-\mu} \tag{2.28}$$

in an interior long-run equilibrium. Substituting (2.28) into (2.24), we obtain an equation of k displaying how k is related to ϕ.

$$\mathcal{F}^L(k) \equiv \mathcal{B}_0(k) + \mathcal{B}_1(k)\phi + \mathcal{B}_2(k)\phi^2 = 0, \tag{2.29}$$

[18]Since we have only two regions, the stability results derived from this specific dynamics can be generalized to any positive definite dynamics. See Tabuchi and Zeng (2004, p.644).

[19]In Section 3, we show that a corner equilibrium exists if and only if $\mu = 1$. Therefore, here we only focus on the case of $\mu < 1$.

with

$$\mathcal{B}_0(k) \equiv \sigma(1-\beta)\Big(\frac{k}{1-k}-1\Big),$$
$$\mathcal{B}_1(k) \equiv 2(\sigma-\beta)\Big[\Big(\frac{k}{1-k}\Big)^{(1-\mu)(\sigma-1)} - \Big(\frac{k}{1-k}\Big)^{1-(1-\mu)(\sigma-1)}\Big],$$
$$\mathcal{B}_2(k) \equiv [\beta(\sigma-2)+\sigma]\Big(\frac{k}{1-k}-1\Big).$$

Let k^* be the solution of $\mathcal{F}^L(k) = 0$. The asterisk $(*)$ denotes the value in the long-run equilibrium. All endogenous variables are solved as

$$\alpha_1^* = \frac{2(\sigma-1)}{c\sigma}k^*,\ \alpha_2^* = \frac{2(\sigma-1)}{c\sigma}(1-k^*),$$
$$u_1^* = 1-m\left[\frac{2(\sigma-1)k^*}{c\sigma}\right]^{\mu},\ u_2^* = 1-m\left[\frac{2(\sigma-1)(1-k^*)}{c\sigma}\right]^{\mu},$$
$$w_1^* = \frac{2^{1-\mu}c^{\mu}(\sigma-1)^{1-\mu}\beta}{m(1-\beta)\sigma^{1-\mu}}(k^*)^{1-\mu},\ w_2^* = \frac{2^{1-\mu}c^{\mu}(\sigma-1)^{1-\mu}\beta}{m(1-\beta)\sigma^{1-\mu}}(1-k^*)^{1-\mu}. \tag{2.30}$$

It is evident that $k^* = 1/2$ is always a solution of $\mathcal{F}^L(k) = 0$. If this symmetric equilibrium is reached, the labor market tightness in the two regions is not affected by trade costs or bargaining power. Nevertheless, the story is different in an asymmetric equilibrium, i.e., $k^* \neq 1/2$.

Proposition 1 *(i) The unemployment rate and wages are not affected by trade costs in a symmetric equilibrium. (ii) In an asymmetric equilibrium, the unemployment rate is lower in the more agglomerated region. If $\mu < 1$, the wage rate is higher in the more agglomerated region.*

Proposition 1 states that the wage rate and the unemployment rate are directly related to the firm share k. Intuitively, agglomeration brings a higher labor demand and more vacancies, leading to a higher wage rate and employment level in the general case with $\mu < 1$.[20]

[20]For $\mu = 1$, full agglomeration occurs in the asymmetric equilibrium. We discuss the wage rate of this case in Section 2.4.

2.4 Stability

In this section, we turn our attention to the equilibrium stability. Totally differentiating Δr in (2.27) with respect to k, we obtain the stability condition of an interior equilibrium as follows:

$$\left.\frac{\mathrm{d}\Delta r}{\mathrm{d}k}\right|_{k^*} = \left.\frac{\partial \Delta r}{\partial k}\right|_{k^*} + \left.\frac{\partial \Delta r}{\partial w}\frac{\partial w}{\partial k}\right|_{k^*} + \left.\frac{\partial \Delta r}{\partial h}\frac{\partial h}{\partial k}\right|_{k^*} < 0. \tag{2.31}$$

A rising firm share k generates three effects on the relative capital rent. The first term in (2.31) is the direct competition effect, which is always negative. On the other hand, agglomeration also generates positive effects. It leads to a higher wage rate since the labor demand is higher (the second term). In addition, the market advantage is enlarged due to a higher employment level—the labor efficiency effect (the third term). Through these two positive effects, the firm revenue could be improved by a rising firm share.

For a corner equilibrium, the stability conditionis given as

$$\Delta r = wh\frac{1-k}{k} - 1 \begin{cases} < 0 \text{ for } k\to 0, \\ > 0 \text{ for } k\to 1. \end{cases} \tag{2.32}$$

According to (2.30), Δr in a corner equilibrium approaches to infinity for $k\to 0$ and $\mu < 1$. However, $\Delta r|_{k\to 0}$ is finite if $\mu = 1$.

2.4.1 Effect of matching elasticity

Symmetric equilibrium

The stability condition (2.31) at the symmetric equilibrium ($k^* = 1/2$) is simplified as

$$\left.\frac{\mathrm{d}\Delta r}{\mathrm{d}k}\right|_{k=1/2} = -C^M\phi(\mu^B - \mu) < 0,$$

where

$$C^M \equiv \frac{16(\sigma-\beta)(\sigma-1)}{\sigma(1-\beta) + 2(2\sigma-1)\phi(\sigma-\beta) + \phi^2[\beta(\sigma-1)+\sigma-\beta]} > 0,$$

$$\mu^B \equiv 1 - \frac{(1-\phi)[\beta(\sigma-1)+\sigma-\beta]}{4(\sigma-1)\phi(\sigma-\beta)}(\phi-\phi^M),$$

$$\phi^M = \frac{\sigma(1-\beta)}{\beta(\sigma-1)+\sigma-\beta} \in (0,1). \tag{2.33}$$

Thus, we obtain the following result.

Proposition 2 *The symmetric equilibrium is stable if* $\mu < \mu^B$ *and unstable if* $\mu > \mu^B$.

This proposition reveals that the matching elasticity with respect to vacancies can generate an agglomeration force. To examine the mechanism, we calculate three terms of (2.31) in the symmetric equilibrium as follows,

$$\left.\frac{\partial \Delta r}{\partial k}\right|_{k=\frac{1}{2}} = -4, \tag{2.34}$$

$$\left.\frac{\partial \Delta r}{\partial w}\frac{\partial w}{\partial k}\right|_{k=\frac{1}{2}} = \frac{16\phi(\sigma-\beta) - 4\mu\{\phi^2[\beta(\sigma-2)+\sigma] + 2\phi(\sigma-\beta) + (1-\beta)\sigma\}}{\phi^2[\beta(\sigma-2)+\sigma] + 2(2\sigma-1)\phi(\sigma-\beta) + \sigma(1-\beta)}, \tag{2.35}$$

$$\left.\frac{\partial \Delta r}{\partial h}\frac{\partial h}{\partial k}\right|_{k=\frac{1}{2}} = 4\mu > 0. \tag{2.36}$$

The above three terms describe how firm relocation impacts the capital market via three channels: the market competition, the wage rate (or price), and the labor efficiency. The direct competition effect in (2.34) is always negative. Intuitively, it is more difficult for firms to earn higher capital rents when the number of firms increases. Equations (2.35) and (2.36) measure the advantages of a larger market: a higher labor income and more employed workers. The wage effect of (2.35) has an inverted-U shape with respect to ϕ. Thus, the merit of a larger market is strong when trade costs are intermediate. Interestingly, the negative effect in (2.34) is offset by (2.36) if and only if $\mu = 1$.

Unlike in traditional models, such as that of Krugman (1980), the labor supply in our model is an endogenous variable that is equivalent to the number of matching jobs. With constant job seekers in the labor market, vacancies are difficult to be filled in the more agglomerated region. However, with a larger μ, the difficulty is lessened and the employment level is higher in the agglomerated region. Combining (2.16) with (2.7) and (2.8), the relative vacancy-filling rate and employment rate in the regions are expressed as

$$\frac{M_1/V_1}{M_2/V_2} = \left(\frac{k}{1-k}\right)^{-(1-\mu)}, \quad \frac{M_1/\mathcal{L}_1}{M_2/\mathcal{L}_2} = \left(\frac{k}{1-k}\right)^{\mu},$$

which are increasing functions of μ for a given $k > 1/2$. As a consequence, firms benefit in agglomeration when $\mu > \mu^B$, since the positive labor efficiency effect counteracts a large part of the negative effect of market competition. On the contrary, the negative impact of market competition dominates the benefits in clustering when $\mu < \mu^B$, which leads to a stable symmetric equilibrium.

Asymmetric equilibria

First, we show that full agglomeration is possible if and only if $\mu = 1$. We can obtain the following wage equation for the corner short-run equilibrium by rewriting (2.26):

$$\mathcal{F}(w)|_{\mu=1,k\to 0} \equiv (1-\phi)(\phi-\phi^M) + \frac{2\phi(\sigma-\beta)}{\beta(\sigma-1)+\sigma-\beta}(w^\sigma - 1) = 0, \qquad (2.37)$$

where ϕ^M is defined in (2.33). When $\mu = 1$, vacancies are filled at a constant rate, m, which is not affected by clustering. Thus, the recruitment cost to hire one worker is also fixed. Since the wage rate is determined by bargaining, even in this corner distribution, a firm needs to pay positive wages w_1 to relocate to region 1. Equation (2.37) implies that $w < 1$ for $\phi \in (\phi^M, 1)$. Thus, by applying (2.32), we conclude that full agglomeration is sustained for $\mu = 1$ when $\phi \in (\phi^M, 1)$.

However, if $\mu < 1$, the matching process with vacancies is frictional. Vacancies are difficult to be filled in the more agglomerated region. If all firms are located in region 2, the vacancy-posting cost of hiring one unit of worker is tiny. According to (2.25), the relative wage rate w approaches 0 when k approaches 0 for $\mu \in [0, 1)$. This implies that if a firm moves to region 1 at this point, it obtains infinitely large marginal profits but infinitesimal marginal costs. Hence, a corner equilibrium never occurs for $\mu \in [0, 1)$.

As shown in Tabuchi and Zeng (2004), a stable equilibrium exists in such a two-region one-sector model in general. Next, we explore the emergence of endogenous agglomeration when the symmetry breaks.

Lemma 1 *For all* $k \in (0, 1)$, $\mathcal{F}^L(k) = 0$ *has three solutions at most.*

Proof: See Appendix A.3. □

According to Tabuchi and Zeng (2004), there is at least one stable equilibrium for any $\phi \in [0, 1]$. Hence, we conclude that the asymmetric equilibrium is stable if the symmetric equilibrium is unstable. If $\mu < \mu^B$, there is a unique stable equilibrium $k^* = 1/2$. If $\mu > \mu^B$, there are three equilibria, two stable asymmetric equilibria and one unstable symmetric equilibrium.

Let

$$\mu^O \equiv \frac{(2\sigma - 3)(\sigma - \beta) + \sqrt{(1-\beta)\sigma[\beta(\sigma-2)+\sigma]}}{2(\sigma - 1)(\sigma - \beta)},$$

which is the minimal value of μ^B for $\phi \in (0, 1)$. Then we establish the following proposition.

Proposition 3 *(i) If $\mu = 1$, firms are symmetrically distributed in the two regions when $\phi < \phi^M$; full agglomeration occurs when $\phi > \phi^M$. (ii) If $\mu \in (\mu^O, 1)$, there exists a non-empty interval, $[\phi_1^m, \phi_2^m]$, within which partial equilibria could occur and outside which symmetry is sustained. (iii) If $\mu < \mu^O$, the symmetric equilibrium is always stable.*

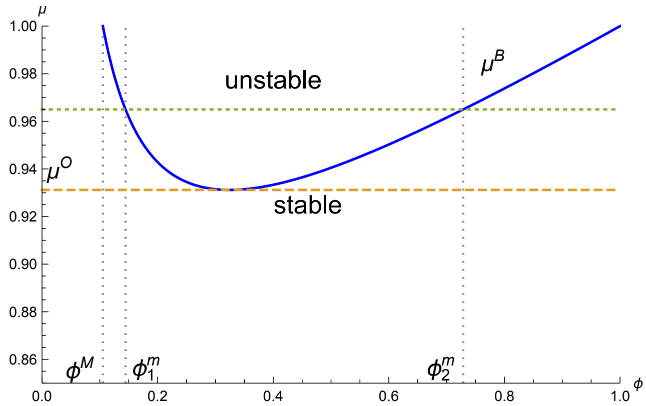


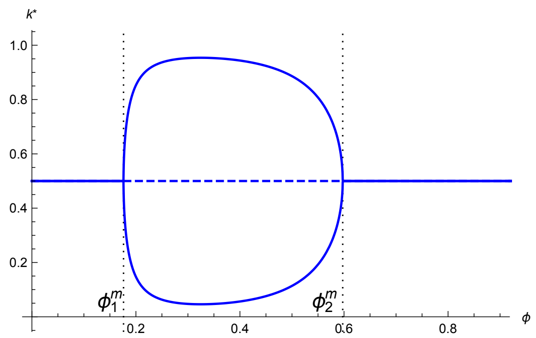
Figure 2.2: Stability of the symmetric equilibrium and μ

Propositions 2 and 3 can also be illustrated by Figure 2.2, which is based on a simulation result with $\sigma = 4$ and $\beta = 0.85$. Curve μ^B is the boundary of μ, above which the symmetric equilibrium is stable and below which the symmetric equilibrium is unstable. Since $\phi\mu^B$ is a quadratic function of ϕ, $\mu^B(\phi) = 0$ has at most two roots in $(0, 1)$. If $\mu < \mu^O$, the symmetric equilibrium is always stable for all $\phi \in [0, 1]$. For $\mu > \mu^O$, the symmetry breaks when $\phi \in (\phi_1^m, \phi_2^m)$, where ϕ_1^m and ϕ_2^m are solutions of $\mu^B(\phi) = 0$. When trade costs are high, markets in the two regions are separated. For a constant μ ($\mu^O < \mu < 1$), as the trade freeness ϕ

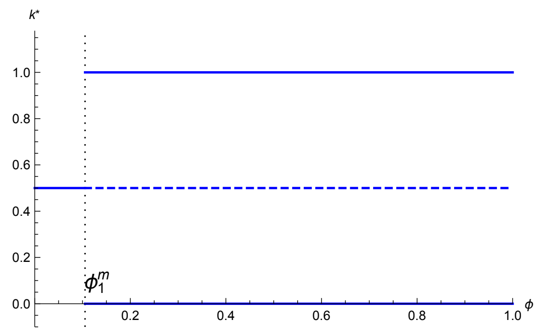
gradually increases, the symmetric pattern is initially stable, then becomes unstable when ϕ reaches ϕ_1^m. As ϕ increases further, it reaches another critical point, ϕ_2^m, after which the symmetric pattern becomes stable again.

When the matches rely solely on vacancies, i.e., $\mu = 1$, firms are not affected by competition in the market with clustering, as shown in (2.36) and (2.34). The agglomeration force is strong enough to avoid a process of re-dispersion when ϕ is large. In this case, our model degenerates to a model similar to that of Picard and Toulemonde (2006), in which the equilibrium moves from dispersion to a core–periphery pattern when trade costs fall. Since full agglomeration is rare in the real world, it is interesting to find that a full agglomeration is replaced by a partial one as long as $\mu < 1$. In this more realistic situation, we observe a process of "dispersion–agglomeration–re-dispersion" with an increasing ϕ if μ is not too small. However, when the matching elasticity on vacancies is sufficiently low, i.e., $\mu < \mu^O$, the symmetric industry distribution never breaks. This result is consistent with that of Krugman (1980), where the labor supply depends on the labor endowment instead of job vacancies.

Figure 2.3 plots the completely different dispersion patterns of industrial location for $\mu < 1$ and $\mu = 1$. We have chosen the following parameters for this simulation: $\sigma = 4$ and $\beta = 0.85$. The stable equilibria are indicated by solid lines and unstable equilibra by dashed ones.



(a) $\mu = 0.95$



(b) $\mu = 1$

Figure 2.3: Three equilibria and trade costs

2.4.2 Effect of bargaining power

In the following part, we illustrate how bargaining power influences the location of inter-regional capital via the channel of industrial agglomeration. To examine the effect of bargaining power on stability, we rewrite the stability condition as

$$\left.\frac{\mathrm{d}\Delta r}{\mathrm{d}k}\right|_{k=1/2} = C^B(\beta - \beta^B) < 0,$$

where

$$C^B \equiv \frac{4\left[4(1-\mu)(\sigma-1)\phi + (\sigma-1)\left(1-\phi^2\right) + (1-\phi)^2\right]}{\phi^2[\beta(\sigma-2)+\sigma] + 2(2\sigma-1)(\sigma-\beta)\phi + (1-\beta)\sigma} > 0,$$

$$\beta^B \equiv 1 - \frac{2(\sigma-1)\phi[\phi^B - \phi]}{4(1-\mu)(\sigma-1)\phi + (\sigma-1)(1-\phi^2) - \sigma(1-\phi)^2},$$

$$\phi^B \equiv 1 - 2(1-\mu)(\sigma-1).$$

Proposition 4 *The symmetric equilibrium is stable for $\beta < \beta^B$ and unstable for $\beta > \beta^B$.*

Proposition 4 demonstrates that the bargaining power of workers also acts as an agglomeration force. According to the revenue allocation pattern illustrated in Figure 2.1, the share of wage payment in firm revenue is $[\beta(\sigma-1)]/(\sigma-\beta)$, which increases with β. Thus, a larger β amplifies consumption in the local market.[21] In fact, (2.35) shows that the positive effect of expanding markets increases with β. We conclude that the symmetric equilibrium breaks when $\beta > \beta^B$ because the HME from a market with larger consumption is sufficiently beneficial. For a smaller bargaining power, workers have less influence in the bargaining process. The symmetric equilibrium is more likely to be stable with small bargaining power, which is consistent with the traditional model of Krugman (1980).

Let

$$\beta^O \equiv \frac{2\sigma\left\{2(1-\mu)[(1-\mu)(\sigma-1)-1] + \sqrt{(1-\mu)(\sigma-1)[1-(1-\mu)(\sigma-1)]}\right\}}{4(1-\mu)[(1-\mu)(\sigma-1)-1] + \sigma - 1},$$

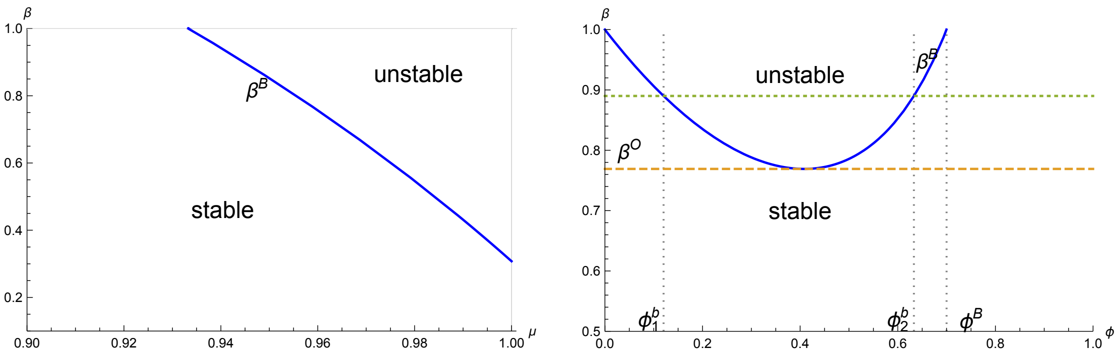
which is the minimal value of β^B for $\phi \in (0,1)$. We can derive the following conclusion, which is similar to (ii) in Proposition 3.

[21] More wage payment with a larger β also implies higher labor costs. Since the two regions have the same β, labor is more expensive in both regions with a larger β.

Corollary 1 *(i) The symmetric equilibrium is always stable for any $\beta \in (0,1)$ if $\phi^B < 0$. (ii) β^B takes a value smaller than one and has a minimal value β^O for $\phi \in (0,1)$ if $\phi^B > 0$. The symmetric equilibrium is always stable for all $\phi \in [0,1]$ if $\beta < \beta^O$ whereas the symmetry breaks for $\phi \in (\phi_1^b, \phi_2^b)$ if $\beta > \beta^O$, where ϕ_1^b and ϕ_2^b are solutions of $\beta^B(\phi) = 0$.*

Corollary 1 implies that the role of the bargaining power in economic geography is also highly related to the matching elasticity. This new finding extends the result of Picard and Toulemonde (2006). If μ is sufficiently small such that $2(1-\mu)(\sigma-1) > 1$ (i.e., $\phi^B < 0$) holds, we have $\beta^B > 1$, implying that the bargaining power cannot change firms' location for any trade cost. It is because the benefits from the HME and the labor efficiency effect cannot dominate the loss from the higher market competition. Specifically, competition in the vacancy-filling process is tough enough to hinder agglomeration. However, if $2(1-\mu)(\sigma-1) < 1$, β^B is smaller than one when $\phi < \phi^B$.

Two panels of Figure 2.4 plot the cutoff curves β^B, showing how the stability is related to μ and ϕ via the bargaining power β (with parameter $\sigma = 4$). Figure 2.4(a) illustrates that the symmetry is unstable if (β, μ) is located above the curve of β^B. It implies that both β and μ work as agglomeration forces. In Figure 2.4(b), the curve of β^B is U-shaped and crosses the horizontal line $\beta = 1$ twice, at 0 and ϕ^B. This happens when $\phi^B > 0$. Otherwise, β^B is an increasing function of ϕ that is always larger than 1.



(a) β^B with μ ($\phi = 0.6$) (b) β^B with ϕ ($\mu = 0.95$)

Figure 2.4: The effect of β on stability

From Figure 2.2 , showing the μ^B curve, we observe that there is only one critical break point of trade costs, ϕ^M of (2.33), when $\mu = 1$. This ϕ^M decreases with bargaining power β as illustrated in Figure 2.5, which is plotted with parameter $\sigma = 4$. The result of a positive correlation between agglomeration and bargaining power is consistent with the arguments of Picard and Toulemonde (2006, p.680).

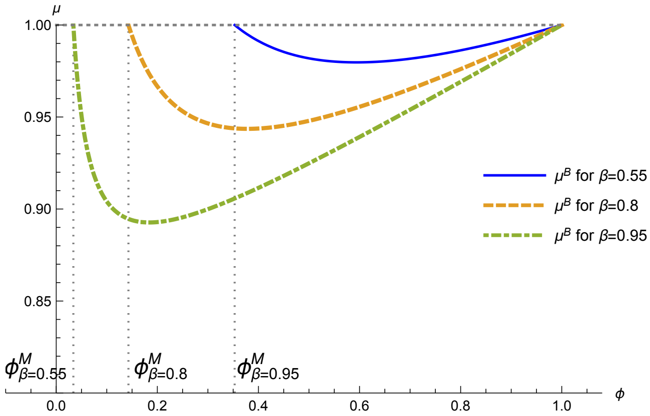


Figure 2.5: Loci of μ^B and ϕ^M with different values of bargaining power

In this chapter, we demonstrate that the features of the labor market affect the location of international capital in two dimensions: amplifying the HME through the bargaining power and improving the employment level through the matching elasticity. Assuming that region 1 is the peripheral region, Figure 2.6 shows that the HME is stronger with a higher bargaining power if agglomeration occurs. The simulation is conducted with parameters $\sigma = 4$, $\mu = 0.95$, $\phi = 0.6$, $c = 0.3$, and $m = 0.9$. Our result indicates that a larger bargaining power generates opposite effects if the symmetry breaks. The regional differential in industrial location expands with a higher bargaining power. In the literature, the correlation between labor market regulation and FDI is reported to be negative (Görg, 2005; Javorcik and Spatareanu, 2005; Olney, 2013), irrelevant (Brown, Deardorff, and Stern, 2013), or positive (Rodrik, 1996; Kucera, 2002). Our theoretical study provides an economic mechanism leading to the observed mixed facts.

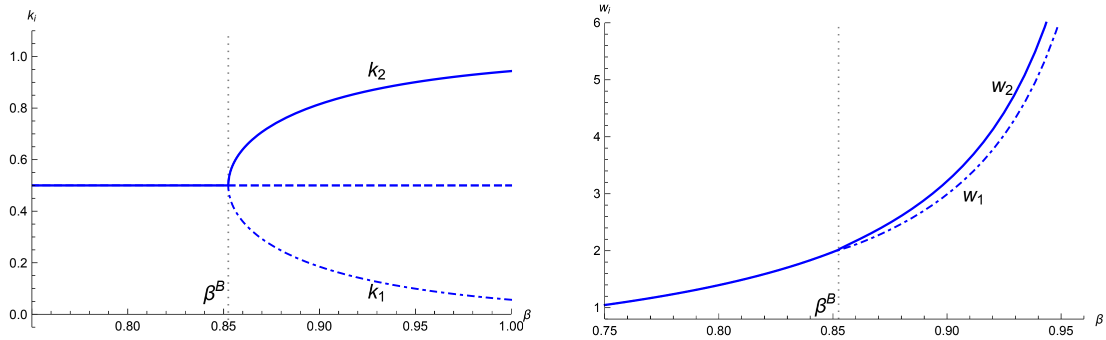


Figure 2.6: The effects of β on firm location and wages

2.5 Welfare

We use real income to measure the welfare of employed workers and unemployed workers as follows:

$$\text{Wel}_i^E = \frac{w_i + r_i}{P_i}, \quad \text{Wel}_i^U = \frac{r_i}{P_i}.$$

Then, we are able to make the following conclusions. (i) In the symmetric equilibrium, the welfare of both employed workers and unemployed workers decreases with trade costs. (ii) If an asymmetric equilibrium occurs, both employed workers and unemployed workers are better off in the more agglomerated region. Their proofs are given in Appendix A.5.

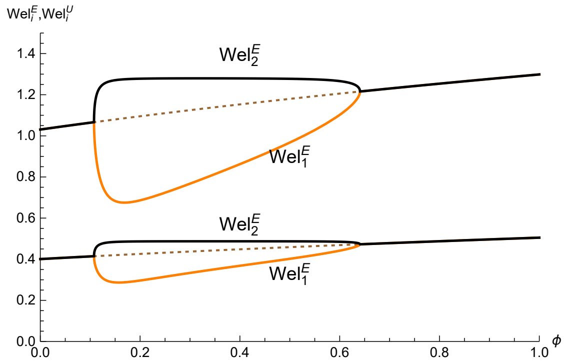


Figure 2.7: Real wages and trade freeness

In Figure 2.7, we depict how real incomes change with trade freeness, using the following parameters: $\sigma = 4$, $\beta = 0.9$, and $\mu = 0.95$. We assume that region 2 is the more agglomerated region when symmetry breaks. Individuals benefit from a larger market via the following channels. First, firms provide more vacancies, which lead to a higher employment level in the more agglomerated region. Second, the wage rate is higher because there is a higher labor demand in the larger market. Finally, since domestic products are not subject to trade costs, the price index is lower in the more agglomerated region. Both employed and unemployed individuals are better off when there are more local varieties, whereas workers in the less agglomerated region suffer from the outflow of capital.

We now examine how bargaining power and matching elasticity impact the total real incomes of employed and unemployed workers in two regions, defined as

$$\text{TW} = \frac{\left[(1-u_1)w_1 + r_1\right]\mathcal{L}_1}{P_1} + \frac{\left[(1-u_2)w_2 + r_2\right]\mathcal{L}_2}{P_2}.$$

According to Proposition 4, the symmetric equilibrium is stable when β is small enough. The total real income in the symmetric equilibrium is simply

$$\text{TW}\Big|_{k=1/2} = \Big(\frac{1}{\beta} - \frac{1}{\sigma}\Big)\alpha_s^{\mu}\frac{2m\sigma}{(\sigma-1)}\Big(\frac{1+\phi}{\sigma}\Big)^{\frac{1}{\sigma-1}}, \tag{2.38}$$

where $\alpha_s \equiv \alpha_i\big|_{k_i=1/2} = (\sigma-1)/(c\sigma)$ is the labor market tightness of (2.16) in the symmetric equilibrium.

Equation (2.38) shows the immediate relationship between welfare and bargaining power. The total welfare decreases with β. At first glance, this result seems contradictory to the fact that a small bargaining power reduces the wage rate of workers. However, it is correct because the prices of varieties decrease so that price indices in the two regions rise. In addition, although lower worker bargaining power leads to higher firm profits, the profits are returned to all residents in the form of capital rent in our general-equilibrium model. Meanwhile, it is noteworthy that the total welfare is infinitely large when $\beta \to 0$. Accordingly, a larger β may break the symmetric distribution of firms, but the total welfare in the asymmetric equilibrium cannot be higher than the case of symmetric equilibrium for a small β.

Equation (2.38) also tells us that the relationship between welfare and matching elasticity depends on the labor market tightness α_s. The total welfare increases with μ if and only if $\alpha_s > 1$. Intuitively, the matching elasticity impacts the total welfare through the channel of employment level. If the vacancy-posting cost c is sufficiently small, the number of vacancies exceeds the number of job seekers in the equilibrium, i.e., $\alpha_s > 1$. In this case, the matching rate of (2.7) increases with the matching elasticity on vacancies, which improves social efficiency. In contrast, when the number of vacancies is smaller than the number of job seekers, the total social welfare is reduced by an increasing unemployment rate of (2.8) with a larger μ.

The above results contrast with those of Hosios (1990), who shows that the matching is efficient when the bargaining power equals the matching elasticity. Basically, this is because the owners of firm profit and labor income are separated in the partial equilibrium model of Hosios. The tradeoff between the owners is optimally balanced when $\beta = \mu$ in his setup.

Chapter 3

Technology selection, income inequalities, and capital mobility

3.1 Introduction

We observe that globalization in recent decades also brings out higher international capital mobility. Over the last 20 years, the world's foreign direct investment (FDI) inward stock increased from 644 billion in 1998 to 1.43 trillion in 2017 (UNCTAD 1999, 2018). However, the outbreak of COVID-19 has severely disrupted the global economy and greatly shocked the international stock market. As global economic activity will need time to recover after the COVID-19 pandemic (Fernandes 2020; McKibbin and Fernando 2020), attracting financing is becoming even more challenging given the uncertainty of foreign investments. Given the uncertain nature of the global investment in the post-COVID-19 era, we theoretically explore the income inequalities and welfare with a model with capital mobility and heterogeneous technologies.

This chapter analyzes the effect of international trade on skill selection and income inequalities in a large or small country. Suppose that there are two different technologies and workers vary in their skills. Technology threshold plays a role to select workers according to their skill. Since the wage income differs by technologies, the result of skill selection is closely related to wage distribution. The workers with higher skills are hired in firms using high (more productive) technology. Workers employed by low technology are regarded as the low-skilled group, and their labor incomes are relatively low inside a country.

Existing theoretical literature has predicted the link between trade liberalization and skill selection. Acemoglu (2003) argues that trade opening increases the possibility of adopting superior technologies. Egger and Kreickemeier (2012) show that international trade leads to a skill selection of the firms into export status. Manasse and Turrini (2001), Monte (2011), Sampson (2014), Furusawa, Konishi, and Tran (2020) focus on the effect of trade integration on wage inequality in their respective models. Their researches all come to the result that trade costs cause the change in skill selection. Some workers who were initially employed at low technology start to work at the more productive exportable technology with a reduction in trade costs. However, the internationally immobile capital assumption in the literature does not fit the real world since FDI plays a significant role. Thus we consider both the cases of internationally immobile capital the internationally mobile capital to analyze the impact of trade costs on skill selection. By comparing these two cases, we find that capital mobility affects skill selection only if the population differential between the two countries is sufficiently small. Moreover, we find that trade liberalization may lead to a lower welfare when the fixed cost is small and the capital market is opening.

Our framework is mainly based on Takahashi, Takatsuka, and Zeng (2013), who assume mobile capital and immobile labor as two production factors. This study adds worker heterogeneity into their model. The heterogeneity is generated by the characteristics of competing technologies and the skill heterogeneity of workers, as in Yeaple (2005). The differences between our work and Yeaple (2005) are the asymmetry between two countries and one more production factor — capital.

This study considers two competing technologies, a high (new) technology with higher productivity and a low (traditional) technology. This assumption follows Yeaple (2005), who supposes two different technologies to produce differentiated goods. The new technology needs a lower marginal cost than the old technology. A worker with a higher skill level has a comparative advantage in high technology relative to a worker of a lower skill level. The adoption of firms with different technologies results in firm heterogeneity. Setting two different technologies allows us to examine the technology threshold. The change in the technology threshold affects wage distribution.

Our result reveals that capital mobility does not affect intra-country inequality if the population differential is sufficiently large. It can be explained by the incentive for exporting. The small country always has a stronger incentive to participating in the foreign market since the large market is more attractive. If the foreign market is larger, more resources are reallocated to exporting firms after the opening of trade. Then all high-tech firms in the small country export, and the skill selection threshold decreases rapidly. However, the threshold value remains constant in the large country since only parts of high-tech firms choose to export when trade starts. On the contrary, when the population differential is small, there is a stage that the threshold values decrease relatively mildly in both countries. Capital mobility affects the skill selection only if the trade pattern is in that stage. Since the skill selection cutoff directly determines the intra-country inequality, we conclude that capital mobility affects the income inequality for a small population differential.

This chapter also explores how real incomes from labor markets and capital markets change in international trade. We find that, when capital is mobile across countries and the fixed cost for exporting is small, trade may lead to a lower real total income. When capital is internationally mobile, the large country attracts a more-than-proportionate share of capital after the opening of trade, due to the existence of HME. However, the capital share in the large country falls when low-tech firms in the small country start exporting. With capital inflow, real labor income increases, whereas real capital income decreases. Exploring by numerical simulations, we find that the individuals in the small country bear a loss in trade when the fixed cost for exporting is sufficiently small. With a small barrier for fixed input in foreign markets, the home market effect is stronger when trade starts. As a result, the welfare in the small country could decrease after the opening of trade and capital mobility. Similarly, the welfare in the large country could decrease when trade barriers are sufficiently low. In that stage, low technology in the small country is exportable, and the merit of HME is weakened, which could lead to a loss in the large country.

3.2 The model

The world economy consists of two countries $i \in \{1, 2\}$ having the same physical geographical constraints except for their population. The share of labor in country

i is denoted by θ_i. Assuming that country 1 is larger, we use the following notations: $\theta_1 = \theta \in (1/2, 1)$, $\theta_2 = 1 - \theta$. Each individual is assumed to supply labor and one unit of capital inelastically. The population in this economy is normalized to 1, without loss of generality. Then the total amount of capital also equals 1.

3.2.1 Demand

The economy has only one manufacturing sector producing differentiated goods. Each firm in the sector produces a distinct variety. The preference of a representative consumer located in country $i \in \{1, 2\}$ is described by

$$U_i = \left[\int_{\omega \in \Omega_i} d_i(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}},$$

where $\sigma > 1$ represents the elasticity of substitution between two manufactured varieties, Ω_i is the set of varieties consumed in country i, and $d_i(\omega)$ is the demand for a typical variety $\omega \in \Omega_i$. The manufacturing price index in country $i = 1, 2$ is given by

$$P_i = \left[\int_{\omega \in \Omega_i} p_i(\omega)^{1-\sigma} d\omega \right]^{\frac{1}{1-\sigma}}, \quad \text{for } i \in \{1, 2\}.$$

The Marshallian demand in country i for a variety made in country j is

$$d_{ji} = \frac{p_{ji}^{-\sigma}}{P_i^{1-\sigma}} Y_i, \quad \text{for } i, j \in \{1, 2\}, \tag{3.1}$$

where Y_i is the national income of country i and p_{ji} is the price of this variety.

3.2.2 Production and technology

The setup in production follows Yeaple (2005). Workers are heterogeneous by their skill level, which is indexed by Z. A larger value of Z corresponds to a higher skill level. We assume that Z is drawn by a uniform distribution:

$$G(Z) = Z, \quad Z \in [0, 1]. \tag{3.2}$$

Suppose two competing technologies produce varieties, a traditional (low) technology (L) and a new (high) technology (H) with higher productivity. To produce a distinct variety, each firm needs a fixed input of capital denoted by F^t,

$t \in \{H, L\}$, and a marginal input of labor. The fixed cost for technology H is higher: $F^H > F^L$.

The output of a worker with skill level Z and employed in technology t is denoted by $\varphi^t(Z)$. We assume that the workers employed by technology L have the same efficient labor, whereas the efficiency of workers employed by H is related to their ability. More specifically,

$$\varphi^t(Z) = \begin{cases} \Psi & \text{if } t = L, \\ Z & \text{if } t = H, \end{cases} \tag{3.3}$$

where $\Psi \in (0, 1)$ is an exogenously given constant. A worker with a higher skill is more productive if employed in a firm using technology H.

Let $w_i(Z)$ be the wage distribution in country i. By employing a worker with skill level Z, the unit cost of a firm producing with technology t is

$$C_i^t = w_i(Z)/\varphi^t(Z).$$

According to Yeaple (2005), there exists a skill threshold value Z_i in country i such that workers with a skill $Z < Z_i$ (resp. $Z > Z_i$) are hired by firms with technology L (resp. H). The worker with skill level Z_i is indifferent between working in L or H. Given the skill threshold Z_i, the unit cost of H firms is

$$C_i^H = C_i^L \frac{\varphi^L(Z_i)}{\varphi^H(Z_i)} = C_i^L \frac{\Psi}{Z_i}. \tag{3.4}$$

Given the unit cost C_i^t, the wage distribution can be expressed as

$$w_i(Z) = \begin{cases} C_i^L \Psi & \text{if } Z < Z_i, \\ \Psi C_i^L Z / Z_i & \text{if } Z > Z_i. \end{cases}$$

The wages of workers working in firms with the technology L are the same inside one country, while the labor incomes of workers employed by H firms increase with the skill level Z. In this study, we refer to the workers in country i with an ability level lower than Z_i low-skilled, workers with a skill level higher than Z_i high-skilled.

Combining (3.2) – (3.4), the expected wage income of a worker in country i is

$$W_i = W_i^L + W_i^H = C_i^L \frac{\Psi\left(1 + {Z_i}^2\right)}{2Z_i}, \tag{3.5}$$

where

$$
\begin{aligned}
W_i^L &\equiv C_i^L \int_0^{Z_i} \varphi^L(Z)dG(Z) = C_i^L \Psi Z_i, \\
W_i^H &\equiv C_i^H \int_{Z_i}^1 \varphi^H(Z)dG(Z) = C_i^L \frac{\Psi\left(1-{Z_i}^2\right)}{2Z_i}.
\end{aligned}
\tag{3.6}
$$

The total labor income of workers employed by technology t in country i equals $W_i^t \theta_i$.

3.2.3 Exporting

Exporting incurs both variable and fixed costs: iceberg transport costs $\tau \geq 1$ and F^X units of capital. Accordingly, the profit of a firm using technology t located in country i is

$$
\pi_i^t = \begin{cases} p_{ii}^t x_{ii}^t - C_i^t x_{ii}^t - F^t \left(r_i^t\right)^D & \text{for non-exporting firms,} \\ p_{ii}^t x_{ii}^t + p_{ij}^t x_{ij}^t - C_i^t(x_{ii}^t + \tau x_{ij}^t) - \left(F^t + F^X\right)\left(r_i^t\right)^X & \text{for exporting firms,} \end{cases}
$$

where $(r_i^t)^D$ and $(r_i^t)^X$ are the unit capital costs paid by non-exporting and exporting firms, respectively. By the constant-markup property of a CES setup, the optimal prices for the domestic and exporting markets:

$$
p_{ii}^t = \frac{\sigma}{\sigma - 1} C_i^t, \quad p_{ij}^t = \frac{\tau\sigma}{\sigma-1} C_i^t. \tag{3.7}
$$

If both exporters and non-exporters exist, according to the zero-profit condition, the expectable capital rents of exporting and non-exporting firms are derived as

$$
(r_i^t)^D = \frac{C_i^t x_{ii}^t}{(\sigma-1)F^t}, \quad (r_i^t)^X = \frac{C_i^t(x_{ii}^t + \tau x_{ij}^t)}{(\sigma-1)(F^t+F^X)}. \tag{3.8}
$$

Combining (3.1) and (3.7) with (3.8), we have

$$
\frac{(r_i^t)^X}{(r_i^t)^D} = \left(1 + \phi \frac{Y_i {P_j}^{1-\sigma}}{Y_j {P_i}^{1-\sigma}}\right) \frac{F^t}{F^X + F^t}, \tag{3.9}
$$

where $\phi = \tau^{1-\sigma} \in (0,1)$ is the so-called trade freeness. Capital is assumed to be mobile across firms so it is invested into firms paying higher returns. The capital rent in country i is thus $r_i = \max_t\{(r_i^t)^D, (r_i^t)^X\}$. We temporarily assume that both technologies are applied in either country, whose condition (3.11) will be given later. Whether a firm with technology t in country i exports is determined as follows:

$$\frac{(r_i^t)^X}{(r_i^t)^D}\begin{cases} > 1 & \text{all } t \text{ firms export,} \\ = 1 & \text{no difference between exporting or not,} \\ < 1 & \text{no } t \text{ firm exports.} \end{cases}$$

When the exporting barrier is sufficiently large,[1] firms do not serve the foreign market since $(r_i^t)^X < (r_i^t)^D$. According to $(r_i^H)^D = (r_i^L)^D$, (3.1), and (3.8), we can derive the technology cutoff in autarky:

$$Z_i = \left(\frac{F^H}{F^L}\right)^{\frac{1}{\sigma-1}} \Psi. \tag{3.10}$$

Both technologies are profitable from export if exporting barriers are sufficiently small.[2] According to $(r_i^H)^X = (r_i^L)^X$, we can derive the cutoff as

$$Z_i = \left(\frac{F^H + F^X}{F^L + F^X}\right)^{\frac{1}{\sigma-1}} \Psi,$$

by use of (3.1) and (3.8) again. Note that the above expressions are independent of r_i. Therefore, we can conclude that trade costs or capital mobility have no impact on skill threshold if two technologies have the same barriers in exporting. In this study, we assume that the following condition holds,

$$\Psi^{\sigma-1} < \frac{F^L}{F^H} < 1. \tag{3.11}$$

Assumption (3.11) ensures the following inequalities:

$$\left(\frac{F^H + F^X}{F^L + F^X}\right)^{\frac{1}{\sigma-1}} \Psi < \left(\frac{F^H}{F^L}\right)^{\frac{1}{\sigma-1}} \Psi < 1,$$

so that both technologies are active in the economy.

Denote the share of exporters in firms using technology t in country i by n_i^t. Given the asymmetry in market size (population), we show that only the following five exporting stages are possible when trade costs fall.

[1] The specific condition is given in Section 3.3.1.

[2] The specific condition is given in Section 3.3.4.

- Stage I: no firm exports, i.e., $n_1^L = n_2^L = n_1^H = n_1^H = 0$.
- Stage II: all H firms in country 2 export, a part of H firms in country 1 export. Firms with technology L are not exportable. Namely, $n_1^L = n_2^L = 0$, $n_1^H = 1$, $n_1^H \in (0,1)$ is endogenously determined in the equilibrium;
- Stage III: in both countries all H firms export, whereas all L firms serve their domestic markets only. Namely, $n_1^L = n_2^L = 0$, $n_1^H = n_2^H = 1$.
- Stage IV: all H firms and a part of L firms in country 2 export, while all L firms in country 1 are non-exporter. Namely, $n_1^H = n_2^H = 1$, $n_1^L = 0$, $n_2^L \in (0,1)$.
- Stage V: all H firms in two countries export, all L firms in country 2 export. The share of exporting L firms in country 1 is endogenously determined. Namely, $n_1^L = n_1^H = n_2^L = 1$, $n_1^L \in (0,1]$.

If two countries are symmetric as in Yeaple (2005), the market structure evolves in Stage I – III – V when trade barriers fall. However, if the countries are asymmetric, we can observe two new exporting statuses: Stages II and IV In the next section, we explore the equilibrium in various stages. In Section 3.3.4, we prove that only the five stages described above are possible and discuss when these stages appear.

3.3 Equilibrium

The national income of country i is

$$Y_i = \theta_i \left(r_i + W_i \right).$$

The price index in country i is

$$P_i = \left[N_i^H \left(p_{ii}^H \right)^{1-\sigma} + N_i^L \left(p_{ii}^L \right)^{1-\sigma} + N_j^H n_j^H \left(p_{ji}^H \right)^{1-\sigma} + N_j^L n_j^L \left(p_{ji}^H \right)^{1-\sigma} \right]^{\frac{1}{1-\sigma}}, \tag{3.12}$$

where N_i^t (N_j^t) represents the mass of firms using technology t in country i (j) and n_i^t and n_i^t are the share of exporting firms. The labor market clearing conditions give

$$N_i^t\left(x_{ii}^t + \tau n_i^t x_{ij}^t\right) = \frac{\theta_i W_i^t}{C_i^t}, \quad \text{for } i, j \in \{1,2\},\ i \neq j. \tag{3.13}$$

Since capital rents are identical inside a country, the labor inputs in two technologies are proportional to their capital inputs:

$$\frac{N_i^H\left(F^H + F^X n_i^H\right)}{N_i^L\left(F^L + F^X n_i^L\right)} = \frac{W_i^H}{W_i^L} = \frac{1 - {Z_i}^2}{2Z_i^2}, \tag{3.14}$$

where the second equality is from (3.6). We choose the marginal input of the low technology in country 2 as the numeraire so that $C_2^L = 1$.

To explore the impact of international capital mobility, we discuss two different cases one by one as follows.

Case A: internationally immobile capital

When capital is limited to be invested domestically, the amount of capital input in a country is equal to its endowment:

$$N_i^H\left(F^H + n_i^H F^X\right) + N_i^L\left(F^L + n_i^L F^X\right) = \theta_i. \tag{3.15}$$

Equations (3.14) and (3.15) give the masses of firms:

$$N_i^L = \frac{2\theta_i {Z_i}^2}{\left(F^L + F^X n_i^L\right)\left(1 + {Z_i}^2\right)}, \quad N_i^H = \frac{2\theta_i\left(1 - {Z_i}^2\right)}{\left(F^H + F^X n_i^H\right)\left(1 + {Z_i}^2\right)}. \tag{3.16}$$

Meanwhile, the ratio of capital rents in two countries equals the ratio of expected wage:

$$\frac{\theta_1 r_1}{\theta_2 r_2} = \frac{\theta_1 W_1/(\sigma-1)}{\theta_2 W_2/(\sigma-1)} \Rightarrow \quad \frac{r_1}{r_2} = \frac{W_1}{W_2} = \frac{C_1^L(1 + {Z_1}^2)Z_2}{C_2^L(1 + {Z_2}^2)Z_1}. \tag{3.17}$$

Case B: internationally mobile capital

When capital is freely mobile across countries, the capital rents in two countries are equal, such as

$$r_1 = r_2 = \frac{\theta W_1 + (1-\theta)W_2}{\sigma - 1} \equiv r.$$

In the capital market, the total input is equal to the total capital endowment:

$$\sum_{i=1,2} N_i^H(F^H + F^X n_i^H) + N_i^L(F^L + F^X n_i^L) = 1. \tag{3.18}$$

Due to the CES setup, the total fixed cost and the total wage payment of all t firms in country i satisfies

$$N_i^t \left(F^t + F^X n_i^t\right) r = \frac{\theta_i W_i^t}{\sigma - 1}.$$

Then we have

$$\frac{N_1^L \left(F^L + F^X n_1^L\right)}{N_2^L \left(F^L + F^X n_2^L\right)} = \frac{\theta W_1^L}{(1-\theta) W_2^L}.$$

By the use of the above equation, (3.14) and (3.18), the masses of firms in Case B are solved as

$$\begin{aligned} N_i^L &= \frac{2\theta_i C_i^L Z_i}{(F^L + n_i^L F^X)\left(\theta_i C_i^L \frac{1+Z_i{}^2}{Z_i} + \theta_j C_j^L \frac{1+Z_j{}^2}{Z_j}\right)}, \\ N_i^H &= \frac{\theta_i C_i^L \frac{1-Z_i{}^2}{Z_i}}{(F^H + n_i^H F^X)\left(\theta_i C_i^L \frac{1+Z_i{}^2}{Z_i} + \theta_j C_j^L \frac{1+Z_j{}^2}{Z_j}\right)}. \end{aligned} \tag{3.19}$$

3.3.1 Stages I: autarky

In Case B, we have $C_1^L = C_2^L$ in Stage I due to the capital mobility. Plugging (3.10) and $n_i^t = 0$ into (3.16) and (3.19) respectively, we solve that the masses of firms in the two cases are the same as follows:

$$N_i^L\Big|_{\text{Stage I}} = \frac{2\theta_i M (F^H/F^L)^{\frac{2}{\sigma-1}} \Psi^2}{F^L[1 + (F^H/F^L)^{\frac{2}{\sigma-1}} \Psi^2]}, \quad N_i^H\Big|_{\text{Stage I}} = \frac{2\theta_i M[1 - (F^H/F^L)^{\frac{2}{\sigma-1}} \Psi^2]}{F^H[1 + (F^H/F^L)^{\frac{2}{\sigma-1}} \Psi^2]}.$$

In fact, the trade balance implies that there is no international capital flow in autarky even though the global capital market is open.

The equilibria of the two cases are entirely the same in Stage I. Accordingly, the capital rent in each country is $r_i = W_i/(\sigma - 1)$ in both cases. Then the following equation holds in Stage I:

$$\left.\frac{Y_i P_j{}^{1-\sigma}}{Y_j P_i{}^{1-\sigma}}\right|_{\text{Stage I}} = \frac{\theta_i (W_i + r_i)}{\theta_j (W_j + r_j)} \frac{N_j^H \left(p_{jj}^H\right)^{1-\sigma} + N_j^L \left(p_{jj}^L\right)^{1-\sigma}}{N_i^H \left(p_{ii}^H\right)^{1-\sigma} + N_i^L \left(p_{ii}^L\right)^{1-\sigma}} = \left(\frac{C_i^L}{C_j^L}\right)^{-\sigma}.$$

According to (3.9), we find that $(r_i^H)^X/(r_i^H)^D = 1$ if $F^X/\phi = F^H$. Note that two countries never start trade if $F^X \geq F^H$. Therefore, we assume that $F^X < F^H$ subsequently. At $\phi = F^X/F^L$, H firms have no difference between exporting or not.[3] For $\phi < F^X/F^H$, no firms export since the expectable capital return is lower. When ϕ rises a little from F^X/F^H, if no other firm exports in both countries, investing in an exporting H firm will lead to higher returns. Meanwhile, L firms are still not profitable to export at this point.

For $\phi > F^X/F^H$, (some) H firms in two countries have an incentive to export. Thus, trade evolves into another stage. In the following subsection, we explore the market when exportable H firms and non-exportable L firms coexist. (Stages II, III, and IV)

3.3.2 Stages II – IV: Exportable high technology

In the equilibrium, capital rents are identical inside a country. If exporting H firms and non-exporting L firms co-exist, $(r_i^H)^X = (r_i^L)^D$. Arranging (3.8) with (3.1), (3.4), and (3.7) gives the ratio of capital rents under the two technologies (exportable H and non-exportable L) in country i

$$\frac{(r_i^H)^X}{(r_i^L)^D} = \frac{1 + \phi \frac{Y_j {P_i}^{1-\sigma}}{Y_i {P_j}^{1-\sigma}}}{F {Z_i}^{1-\sigma}} = 1, \quad \text{for} \quad i, j \in \{1, 2\},\ i \neq j, \tag{3.20}$$

where $F \equiv \Psi^{\sigma-1}(F^H + F^X)/F^L$. Using (3.20) in two countries to eliminate $Y_j {P_i}^{1-\sigma}/(Y_i {P_j}^{1-\sigma})$, we get

$$\left(F {Z_i}^{1-\sigma} - 1\right)\left(F {Z_j}^{1-\sigma} - 1\right) = \phi^2. \tag{3.21}$$

This equality holds in Stages II, III, and IV.

Also, the ratio of the capital rents in two countries is equal to the ratio of revenues. Since L firms serve domestic markets merely,

$$\frac{r_1}{r_2} = \frac{r_1^L}{r_2^L} = \left(\frac{p_{11}^L}{p_{22}^L}\right)^{1-\sigma} \frac{Y_1 P_2^{1-\sigma}}{Y_2 P_1^{1-\sigma}} = \left(\frac{C_1^L}{C_2^L}\right)^{1-\sigma} \frac{Y_1 P_2^{1-\sigma}}{Y_2 P_1^{1-\sigma}}. \tag{3.22}$$

[3] In autarky, two countries are separated when capital is internationally immobile. When they just begin to trade (i.e, $\phi = F^X/F^H$), we can calculate that $C_1^L/C_2^L = 1$ in Case A by substituting (3.10) and $\phi = F^X/F^H$ into (3.24).

Using(3.17), (3.5), and (3.22), we solve the following equation in Case A:

$$\left(\frac{C_1^L}{C_2^L}\right)^{1-\sigma}\frac{Y_1P_2^{1-\sigma}}{Y_2P_1^{1-\sigma}}=\frac{W_1}{W_2}=\frac{C_1^L(1+{Z_1}^2)Z_2}{C_2^L(1+{Z_2}^2)Z_1}.$$

Plugging the above equation in (3.20) solves for C_1^L in Case A:

$$(C_1^L)^A=\left[\frac{\left(F{Z_2}^{1-\sigma}-1\right)(1+{Z_2}^2)Z_1}{\phi\left(1+{Z_1}^2\right)Z_2}\right]^{\frac{1}{\sigma}}. \tag{3.23}$$

The capital rents are identical across countries with international mobile capital. Then C_1^L in Case B is solved by combining $r_1/r_2=1$ with (3.22) and (3.20):

$$(C_1^L)^B=\left(\frac{FZ_2^{1-\sigma}-1}{\phi}\right)^{\frac{1}{\sigma-1}}. \tag{3.24}$$

Using the labor market clearing condition (3.13), we can derive another equation as follows to solve the equilibrium in Case A:

$$\begin{aligned}\mathcal{J}^A(Z_1,Z_2,n_1^H,n_2^L)\equiv&\frac{\theta\left(1-{Z_1}^2\right)Z_2}{(1-\theta)\left(1-{Z_2}^2\right)Z_1}\left(1-\frac{F^L{Z_1}^{\sigma-1}\Psi^{1-\sigma}}{F^H+F^Xn_1^H}\right)(C_1^L)^A\\&-\left(F{Z_2}^{1-\sigma}-1\right)\left[\frac{1}{F{Z_2}^{1-\sigma}}+\frac{2{Z_2}^2F^Ln_2^L}{\left(1-{Z_2}^2\right)(F^L+F^Xn_2^L)}\right]\\=&0.\end{aligned} \tag{3.25}$$

Similarly, rewriting the labor market clearing condition gets the equation to pin down the equilibrium in Case B:

$$\begin{aligned}\mathcal{J}^B(Z_1,Z_2,n_1^H,n_2^L)\equiv&\theta\left[\frac{1+{Z_1}^2}{Z_1}+\sigma\left(\frac{F^L\Psi^{1-\sigma}{Z_1}^{\sigma-1}}{F^H+F^Xn_1^H}-1\right)\frac{1-{Z_1}^2}{Z_1(1-\theta)}\right](C_1^L)^B\\&-\theta\frac{1+{Z_2}^2}{Z_2}+\sigma\left(F{Z_2}^{1-\sigma}-1\right)\left(\frac{2F^Ln_2^LZ_2}{F^L+F^Xn_2^L}+\frac{1-{Z_2}^2}{F{Z_2}^{2-\sigma}}\right)\\=&0.\end{aligned} \tag{3.26}$$

In the above two equations, $(C_1^L)^A$ and $(C_1^L)^B$ are determined by (3.23) and (3.24), respectively. In these three stages, $n_2^H=1, n_1^L=0$.[4] All other endogenous variables can be expressed through (Z_1,Z_2,n_1^H,n_2^L).

[4]In Section 3.3.4, we demonstrate that only Stages II, III, and IV are possible for $F^X/\phi\in(F^L,F^H)$. Hence, n_2^H and n_1^L cannot take other values in that range.

Stage II: a part of H firms export

In Stage II, all H firms in country 2 export. Meanwhile, non-exporting H firms exist in country 1, i.e., $(r_1^H)^D = (r_1^L)^D$. Thus, Z_1 does not change. Using (3.20), we solve the following variables in Stage II:

$$Z_1 = \left(\frac{F^H}{F^L}\right)^{\frac{1}{\sigma-1}} \Psi, \quad Z_2 = \left(\frac{FF^X}{F^H\phi^2 + F^X}\right)^{\frac{1}{\sigma-1}}, \quad n_2^L = 0 \tag{3.27}$$

Another endogenous variable n_1^H in the two cases is determined by substituting (3.27) into (3.25) and (3.26), respectively. In Case $S \in \{A, B\}$, n_1^H is solved by the following implicit function.

$$\mathcal{J}^S(n_1^H)\big|_{(3.27)} = 0. \tag{3.28}$$

Stage III: all H firms export, no L firm exports

In Stage III, all firms using technology H export whereas no L firms export, i.e., $n_1^H = n_2^H = 1$, $n_1^L = n_2^L = 0$. Equations (3.21) and the following equation solve the equilibrium with internationally immobile capital,

$$\mathcal{J}^A(Z_1, Z_2)\big|_{\{n_1^H=1,\ n_2^L=0\}} = 0 \tag{3.29}$$

of which the solution is denoted by $\{Z_1^*, Z_2^*\}$.

By the use of (3.21) and the following equation, we can solve the variables $\{Z_1, Z_2\}$ in Case B: internationally mobile capital,

$$\mathcal{J}^B(Z_1, Z_2)\big|_{\{n_1^H=1,\ n_2^L=0\}} = 0 \tag{3.30}$$

We use $\{Z_1^\sharp, Z_2^\sharp\}$ to denote the solution. Note that $\{Z_1^*, Z_2^*\}$ and $\{Z_1^\sharp, Z_2^\sharp\}$ are only mathematical solutions to (3.29) and (3.30), respectively, which are not necessarily the values in the equilibrium path. We have the following intermediate results.

Lemma 2 *(i)* $\partial Z_1^*/\partial\phi < 0$, $\partial Z_2^*/\partial\phi < 0$.

(ii) $Z_2^* < \left(\frac{F}{1+\phi}\right)^{\frac{1}{\sigma-1}} < Z_1^*$.

Proof See Appendix B.1. □

Lemma 3 *For $\sigma > 3/2$,*[5] *the following properties hold.:*

(i) $\partial Z_1^\sharp/\partial\phi < 0$, $\partial Z_2^\sharp/\partial\phi < 0$;

(ii) $Z_2^\sharp < \left(\frac{F}{1+\phi}\right)^{\frac{1}{\sigma-1}} < Z_1^\sharp$.

Proof See Appendix B.2. □

Stage IV: a part of L firms in country 2 export

In Stage IV, all H firms in two countries and a part of L firms in country 2 export. According to $(r_2^H)^X = (r_2^L)^X$, Z_2 does not change with respect to ϕ. Using (3.20), we solve the following variables in Stage IV,

$$Z_1 = \left(\frac{FF^X}{F^X + F^L\phi^2}\right)^{\frac{1}{\sigma-1}}, \quad Z_2 = \left(\frac{F^H + F^X}{F^L + F^X}\right)^{\frac{1}{\sigma-1}}\Psi, \quad n_1^H = 1. \tag{3.31}$$

In Case $S \in \{A, B\}$, another endogenous variable n_2^L in the two cases is determined by the following implicit function.

$$\mathcal{J}^S(n_2^L)\big|_{(3.31)} = 0. \tag{3.32}$$

3.3.3 Stage V: both technologies are exportable in two countries

In Stage V, both technologies are exportable in two countries,

$$Z_1 = Z_2 = \left(\frac{F^H + F^X}{F^L + F^X}\right)^{\frac{1}{\sigma-1}}\Psi \equiv \hat{Z}.$$

Since only a part of L firms in country 1 export, (3.20) still holds for $i = 1$ in Stage V. Then we have

$$\phi\frac{Y_2{P_1}^{1-\sigma}}{Y_1{P_2}^{1-\sigma}} = F\hat{Z}^{1-\sigma} - 1.$$

Using the above equation and

$$\frac{r_1}{r_2} = (C_1^L)^{1-\sigma}\frac{Y_1/{P_1}^{1-\sigma} + \phi Y_2/{P_2}^{1-\sigma}}{Y_2/{P_2}^{1-\sigma} + \phi Y_1/{P_1}^{1-\sigma}},$$

[5] We make this assumption to simplify our proofs. For $\sigma \in (1, 3/2)$, same results can be observed from simulations.

we can solve C_1^L in Stage V of the two cases:

$$(C_1^L)^A|_{\text{Stage V}} = \left[\frac{\phi(F^L+F^X)}{F^L\phi^2+F^X}\right]^{\frac{1}{\sigma}}, \quad (C_1^L)^B|_{\text{Stage V}} = \left[\frac{\phi(F^L+F^X)}{F^L\phi^2+F^X}\right]^{\frac{1}{\sigma-1}}.$$

In Case A, the equilibrium is solved by the following implicit function, which is rewritten from the labor market clearing condition:

$$\begin{aligned}\mathcal{L}^A(n_1^L) \equiv & \frac{2\theta\hat{Z}^2}{F^L+F^Xn_1^L} - \frac{1+\hat{Z}^2}{F^L} + \frac{2(1-\theta)\phi\hat{Z}^2\left[(C_1^L)^A\right]^2}{F^L+F^X} \\ & + \frac{(1-\hat{Z}^2)\Psi^{\sigma-1}}{(F^H+F^X)\hat{Z}^{\sigma-1}}\left\{\theta+(1-\theta)\phi\left[(C_1^L)^A\right]^{\sigma-1}\right\},\end{aligned}$$

In Case B, we can derive another equation from the labor market clearing condition to solve n_1^L,

$$\mathcal{L}^B(n_1^L) \equiv \mathcal{Q}_1(n_1^L) + \mathcal{Q}_0 = 0, \tag{3.33}$$

where

$$\begin{aligned}\mathcal{Q}_0 \equiv & \frac{(C_1^L)^B-1}{F^L}\left(1+\hat{Z}^2\right)\theta - \frac{\sigma\phi}{\theta}\left[(C_1^L)^B\right]^{\sigma-1}\left[\frac{2\hat{Z}^2}{F^L+F^X}+\frac{(1-\hat{Z}^2)\Psi^{1-\sigma}}{(F^H+F^X)\hat{Z}^{1-\sigma}}\right], \\ \mathcal{Q}_1(n_1^L) \equiv & \frac{(\sigma-1)(C_1^L)^B+1}{F^L}(1+\hat{Z}^2) - 2\sigma\hat{Z}^2\left\{\frac{(C_1^L)^B}{F^L+F^Xn_1^L} - \frac{\phi\left[(C_1^L)^B\right]^{\sigma-1}}{F^L+F^X}\right\} \\ & - \frac{\sigma(1-\hat{Z}^2)\Psi^{1-\sigma}\left[(C_1^L)^B - \phi\left[(C_1^L)^B\right]^{\sigma-1}\right]}{(F^H+F^X)\hat{Z}^{1-\sigma}}.\end{aligned}$$

3.3.4 Conditions for various stages

In this section, we demonstrate that only the five stages described in Section 3.2.3 are possible. We also discuss the boundaries for various stages.

For $\phi \in (F^X/F^H, F^X/\sqrt{F^HF^L})$, there exist a threshold of $\tilde{\theta}^S$, which can be explicitly solved by

$$\mathcal{J}^S(\theta)\big|_{\{(3.27),\ n_1^H=1\}} = 0, \quad S \in \{A, B\}.$$

We can solve another threshold value, $\underline{\phi}^S$, which is the solution of

$$\mathcal{J}^S(\phi)|_{\{(3.27),\ n_1^H=1\}} = 0, \quad S \in \{A, B\}.$$

Note the variables here are different from that of (3.25) and (3.26). For $\phi \in (F^X/\sqrt{F^H F^L}, F^X/F^L)$, there exist a threshold of $\hat{\theta}^S$, which can be explicitly solved by

$$\mathcal{J}^S(\theta)\big|_{\{(3.31),\ n_2^L=0\}} = 0, \quad S \in \{A, B\}.$$

We have

$$\tilde{\theta}^S|_{\phi=F^X/\sqrt{F^H F^L}} = \hat{\theta}^S|_{\phi=F^X/\sqrt{F^H F^L}}.$$

The boundary of Stages III and IV, $\overline{\phi}^S$, is the solution of

$$\mathcal{J}^B(\phi)|_{\{(3.31),\ n_2^L=0\}} = 0, \quad S \in \{A, B\}.$$

Again, the variables here are different from that of (3.25) and (3.26).

Proposition 5 *Suppose that $F^X < F^L$ and $\sigma > 3/2$. When trade freeness increases from 0 to 1 in Case $S \in \{A, B\}$,*

(i) if $\theta > \theta^S_{\phi=F^X/\sqrt{F^H F^L}}$, trade evolves in Stage I $\to$ II $\to$ IV $\to$ V;

(i) if $\theta < \theta^S_{\phi=F^X/\sqrt{F^H F^L}}$, trade evolves in Stage I $\to$ II $\to$ III $\to$ IV $\to$ V.

Proof See Appendix B.4 □

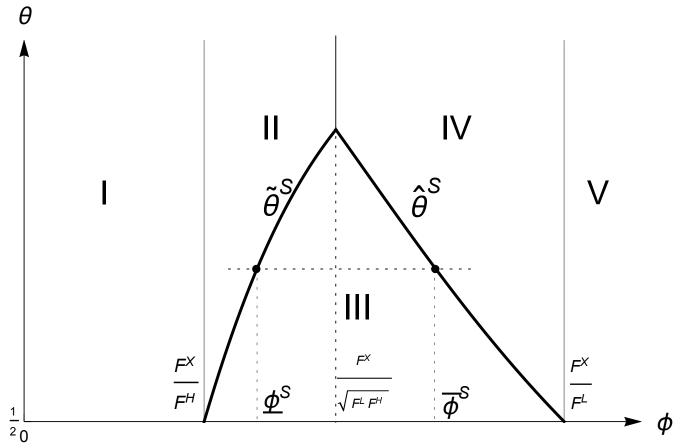
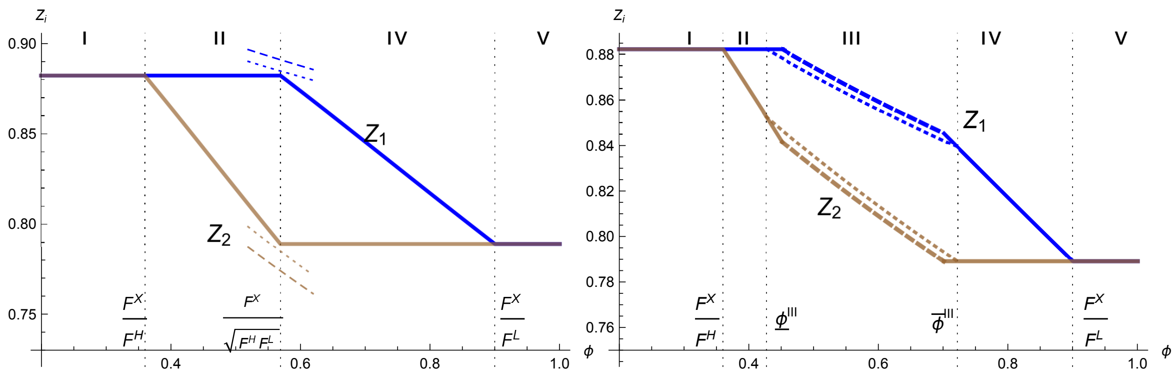


Figure 3.1: Trade patterns with θ and ϕ ($\phi < F^X/F^L$)

Figure 3.1 depicts the conditions for various exporting statuses. Stage III happens when (ϕ, θ) locates below the loci of $\tilde{\theta}^S$ and $\hat{\theta}^S$. If the two countries have a large difference in their market size, the trade pattern is II – IV when trade costs fall. On the contrary, if the differential in market size is relatively small, the trade pattern evolves in Stages II – III – IV with the increasing trade freeness. The boundaries for Stage II → III and Stage III → IV are $\underline{\phi}^S$ and $\overline{\phi}^S$ in Case S, respectively.

In Figure 3.2, we show the loci of Z_i with decreasing trade costs with the following parameters: $\sigma = 4$, $F^L = 1$, $F^H = 2.5$, $F^X = 0.9$, and $\Psi = 0.65$. The dashed lines denote the loci of Z_1^* and Z_2^*. The grid lines are the boundaries among stages in Case B. The dotted lines represent the curves of $Z_1^\sharp$ and $Z_2^\sharp$. As shown in Figure 3.2 (a), when the population size differential is significant, Stage III is inactive. In Stage II, only Z_2 is falling with trade costs. In Stage IV, only Z_1 is impacted by trade costs. When the population size differential is relatively small, Stage III appears, as illustrated in Figure 3.2 (b). Both Z_1 and Z_2 decrease with trade freeness and no L firms export in Stage III. When the capital market is open, the loci of Z_i change from dashed lines to dotted lines. Compared with Case A, Z_1 is smaller, whereas Z_2 is larger in Case B.



(a) $\theta = 0.8$ (b) $\theta = 0.65$

Figure 3.2: Z_i and trade freeness

3.4 Capital share

When capital is immobile across countries, the capital share of country i is equal to the share of endowment θ_i. Denoting the capital share of country 1 in Case B

by k, we have

$$\frac{kr}{(1-k)r} = \frac{\theta W_1}{(1-\theta)W_2} \quad \Rightarrow k = \frac{\theta(W_1/W_2)}{(1-\theta)+\theta(W_1/W_2)}.$$

Then we have the following conclusion to show how the capital share are relocated with decreasing trade costs.

Proposition 6 *In Stage II, $\partial k/(\partial\phi) > 0$. In Stage IV, $\partial k/(\partial\phi) < 0$.*

Proof

$$\frac{\partial k}{\partial \phi} = \frac{\partial k}{\partial(W_1/W_2)}\frac{\partial(W_1/W_2)}{\partial\phi} = \frac{(1-\theta)\theta}{\left[\theta(\frac{W_1-W_2}{W2})+1\right]^2}\frac{\partial(W_1/W_2)}{\partial\phi}.$$

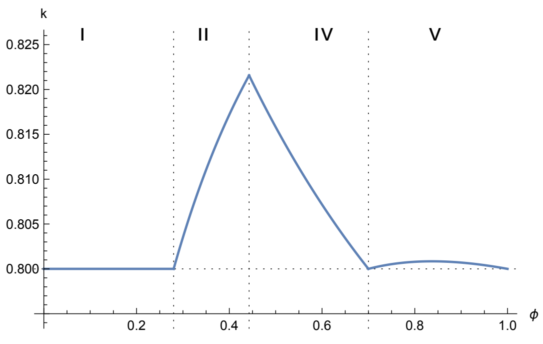
Equations (3.5), (3.24), and (3.28) pin down W_1/W_2. In Stage II, we have $\phi \in (F^X/F^H, F^X/\sqrt{F^H F^L})$. Then we calculate that

$$\left.\frac{\partial\log(W_1/W_2)}{\partial\phi}\right|_{\text{Stage II}} = \frac{F^H\left(\frac{4Z_2{}^2}{Z_2{}^2+1}-1\right)\phi^2+F^X}{(\sigma-1)\phi\left(F^H\phi^2+F^X\right)} > 0.$$

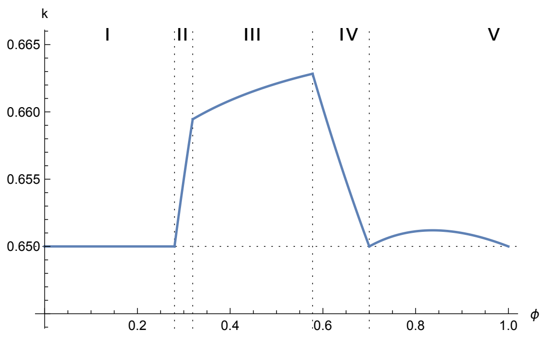
Similarly, by using $\phi \in (F^X/\sqrt{F^H F^L}, F^X/F^L)$, we have the following inequality in Stage IV,

$$\left.\frac{\partial\log(W_1/W_2)}{\partial\phi}\right|_{\text{Stage IV}} = -\frac{F^L\left(3-\frac{4}{1+Z_1{}^2}\right)\phi^2+F^X}{(\sigma-1)\phi\left(F^L\phi^2+F^X\right)} < 0.$$

□



(a) $\theta = 0.8$, $F^X = 0.7$



(b) $\theta = 0.65$, $F^X = 0.7$

Figure 3.3: k and trade freeness

When two countries start trade (Stage II), the large country attracts a more-than-proportionate share of capital. In Stage IV, some L firms located in the small country are exporters, which weakens the agglomeration force of the large market. As a result, the home market effect declines gradually in Stage IV and vanishes at $\phi = F^X/F^L$. Figure 3.3 shows the loci of k with $\sigma = 4$, $F^L = 1$, $F^H = 2.5$, and $\Psi = 0.68$. In Stage II, capital flows into the large market when trade costs increase. It flows back to the small country in Stage IV, since firms using L technology start exporting and the advantage of the large market diminish gradually.

3.5 Intra-country inequality of labor income

Intra-country inequality of labor income is measured by the ratio of the average incomes of workers, which is determined as

$$\mathcal{R}_i \equiv \frac{C_i^H \int_{Z_i}^1 \varphi^H(Z)\mathrm{d}Z}{\Psi C_i^L} = \frac{1 - {Z_i}^2}{2Z_i}.$$

Hence, the labor income inequality inside a country is directly determined by the skill selection. Since capital mobility affect the skill selection only in Stage III, we have the following result.

Corollary 2 *Assume $F^X < F^L$ and $\sigma > 3/2$. Capital mobility impacts the skill selection as well as the intra-country wage inequality only if the population difference is small, i.e., $\theta < \tilde{\theta}^B|_{\phi = F^X/\sqrt{F^H F^L}}$. It has impacts in the range of $\phi \in (\underline{\phi}^B, \overline{\phi}^B)$.*

Under these conditions, the opening of capital markets will increase $\mathcal{R}_1$, whereas $\mathcal{R}_2$ decreases.

Proof See Appendix B.3. □

This corollary implies that whether capital mobility affects labor inequality is also related to the market size. When the populations are sufficiently different, firms located in the small region always have a strong incentive to participate in the large market, whereas firms in the large country do not. Then, capital mobility changes the exporting firms' share merely, which does not influence the production.

On the contrary, when the asymmetry is slight, there exists a stage where all H firms have an advantage in exporting in both two countries. In this stage, the falling speed of Z_i with respect to the increasing trade freeness is relatively mild. Since the production is enlarged (resp. shrinks) in the large (resp. small) country after the capital market's opening in stage III, the skill selections are also changed.

3.6 Welfare

In the previous section, we show that Stages II and IV are distinctively different from previous literature with symmetric markets, such as Yeaple (2005). Next, we focus on the welfare of low- and high-skilled workers in these two stages.

3.6.1 Real wages

We firstly investigate how the real incomes from labor markets are changed in trade. We use the average labor income over the price index to measure the real wage for the skilled worker. Then the real wages are expressed as

$$\mathrm{RW}_i^L = \frac{\Psi C_i^L}{P_i}, \quad \mathrm{RW}_i^H = \frac{\Psi C_i^L}{Z_i}\frac{1+Z_i}{2P_i}.$$

Proposition 7 *Suppose that capital is immobile (Case A) and $F^L < F^X/\phi < F^H$. (i) Trade costs do not change the real labor income of low-skilled workers in two countries. (ii) RW_1^H keeps constant in Stage II and increases with trade freeness in Stage IV. (iii) RW_2^H increases with trade freeness in Stage II and keeps constant in Stage II.*

Proof The real wage is related to the demand function in (3.1). Since non-exporting L firms exist for $F^L < F^X/\phi < F^H$,

$$p_{ii}^L d_{ii}^L = \frac{(p_{ii}^L)^{1-\sigma}}{P_i^{1-\sigma}} Y_i \;\Rightarrow\; \frac{(p_{ii}^L)^{\sigma-1}}{P_i^{\sigma-1}} = \frac{Y_i}{p_{ii}^L d_{ii}^L} = \frac{\sigma\theta_i r_i}{\sigma F^L r_i} = \frac{\theta_i}{F^L}.$$

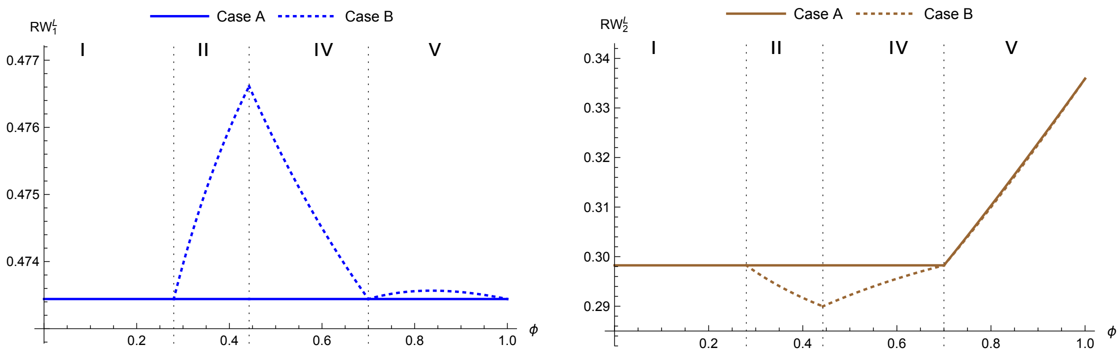
Then the real wage in Stages II, III, and IV are

$$\mathrm{RW}_i^L = \frac{\sigma-1}{\sigma}\Psi\left(\frac{\theta_i}{F^L}\right)^{\frac{1}{\sigma-1}}, \quad \mathrm{RW}_i^H = \frac{\sigma-1}{\sigma}\Psi\left(\frac{\theta_i}{F^L}\right)^{\frac{1}{\sigma-1}}\frac{1+Z_i}{2Z_i}.$$

Combining above equations with (3.27) and (3.31), we can prove this proposition.

□

In Case A, capital is reallocated inside a country when trade begins. Trade affects the real wage for low-skilled workers via price index in country 2. It impacts both nominal labor income and price index in country 1. In Stages II, III, and IV, the mass of firms located in the small country decreases since all H firms pay additional exporting costs. Meanwhile, the varieties increases since individuals are able to consume foreign productions. As a result, the price index keeps constant in the small country and increases at the same rate with C_1^L in the large country when capital is immobile across countries. Consequently, the real wages for low-skilled workers in Case A are also independent of trade costs when non-exporting L firms exists. According to (3.4), the high-skilled workers earn higher wages when skill selection is lower. Hence, the average real wage of the high-skilled group is improved if Z_i falls with decreasing trade costs.



(a) RW$_1^L$ (b) RW$_2^L$

Figure 3.4: Real wage of low-skilled workers and trade freeness

Proposition 8 *Suppose that $F^L < F^X/\phi < F^H$ and the capital is mobile (Case B). When trade costs fall, we have the following results.*

(i) The real wage of low-skilled workers in the large (resp. small) country rises (resp. falls) in Stage II and falls (resp. rises) in Stage IV.

(ii) The real wage of high-skilled workers in the large country rises in Stage II.

(iii) High-skilled workers in the small country gain higher real wage in Stage IV.

Proof The real wage in Case B are

$$\mathrm{RW}_i^L = \frac{\sigma-1}{\sigma}\Psi\left\{\frac{[\theta_i+(\sigma-1)k_i]\,M}{\sigma F^L}\right\}^{\frac{1}{\sigma-1}}, \quad \mathrm{RW}_i^H = \mathrm{RW}_i^L\frac{1+Z_i}{2Z_i}. \tag{3.34}$$

Combining above equations with Proposition 6, we can prove this proposition. □

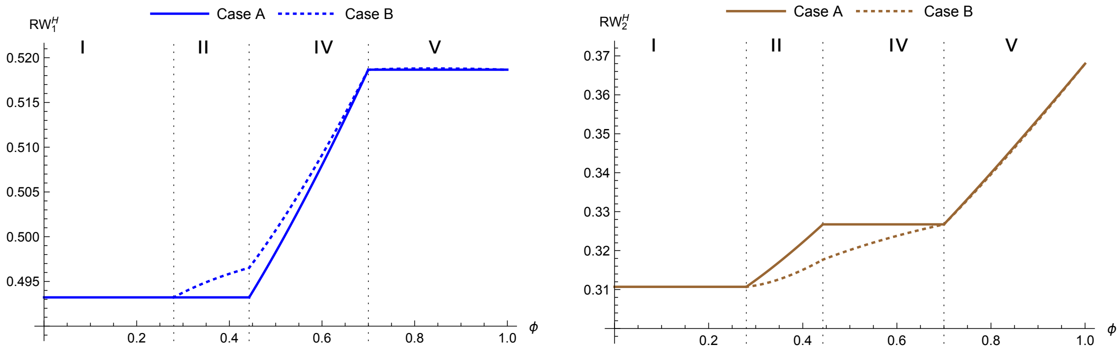
This proposition shows that when capital is internationally mobile, workers in the large country gain higher real labor incomes due to the HME. For low-skilled workers, their real wages are affected by the price index. The price index is directly determined by the capital share. In Case B, the price index in country i can be rewritten as

$$P_i = \left\{\frac{[\theta_i+(\sigma-1)k_i]\,M}{\sigma F^L}\right\}^{\frac{1}{1-\sigma}} p_{ii}^L.$$

In proposition 6, we have shown that the large country attracts a more-than-proportionate capital share. Consequently, the real price for domestic L variety decreases in the small country in Stage II. On the other hand, low-skilled workers in the small country are negatively impacted by higher prices of domestic H varieties and importing goods. With the opening of trade, the mass of firms located in the small country decreases, and the number of importing varieties increases due to the capital outflow. As a result, the price index increases, and low-skilled workers in the small country suffer a loss in Stage II.

The real labor incomes for high-skilled workers are related to both capital share and skill threshold. Our results show that the trends are various: both decreasing and increasing curves can be observed. With an open international capital market, all workers in the large country gain higher real labor income in Stage II since there are more local varieties and cheap importing goods. Meanwhile, high-skilled workers in the small country are still possible to benefit in the labor market when trade starts, since the skill threshold decreases, leading to higher productivity. Similarly, a falling real wage for high-skilled workers in the large country is also possible.

Figures 3.4 and 3.5 depict how trade freeness affects the real wage for low- and high-skilled workers, respectively. We use the following parameters for simulations: $\sigma = 4$, $F^L = 1$, $F^H = 2.5$, $F^X = 0.7$, $\Psi = 0.68$, and $\theta = 0.8$. The grid lines are the boundaries among stages in Case B. When foreign capital investment is prohibited (Case A) and trade barriers are not too small ($F^X/\phi < F^L$), only high-skilled workers earn more real labor income in trade. Capital mobility leads to a higher real labor income in country 1 but a lower one in country 2.



(a) RW_1^H

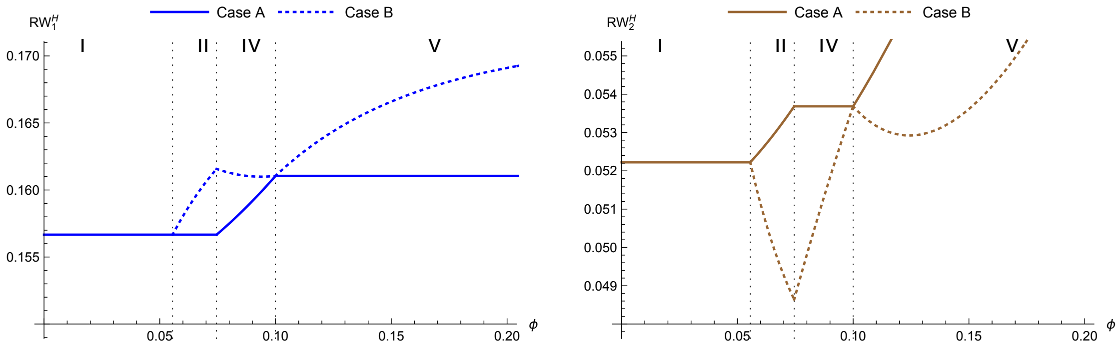
(b) RW_2^H

Figure 3.5: Average real wage of high-skilled workers and trade freeness

Figure 3.6 shows that the real wages of high skilled workers could also be decreasing functions of the trade freeness. The parameters for simulations are: $\sigma = 2$, $F^L = 1$, $F^H = 1.8$, $\Psi = 0.28$, $F^X = 0.1$, and $\theta = 0.75$. In simulations, we find the following results in Case B.

Result 1 *In Stage II,* $\mathrm{d}RW_2^H/(\mathrm{d}\phi) < 0$ *if* F^X *is sufficiently small. In Stage IV,* $\mathrm{d}RW_1^H/(\mathrm{d}\phi) < 0$ *if* F^X *is sufficiently small.*

These results from simulations reveal that lower trade costs may lead to a loss in real wage for high-skilled workers when fixed costs for the foreign market are small. The intuition is explained as follows. According to (3.34), the ratio of the average labor income between high- and low-skilled workers is $(1 + Z_i)/(2Z_i)$, which is a decreasing function of Z_i. From (3.27), we can derive that the $\mathrm{d}\left[(1 + Z_2)/(2Z_2)\right]/(\mathrm{d}\phi)|_{\text{Stage II}}$ is smaller when F^X is smaller. It implies that the change in the advantage of high-skilled workers with falling trade costs is mild if F^X is small. Intuitively, when the foreign market fixed cost is small, more firms are willing to select the exporting H technology, which leads to a lower Z_2 with the opening of trade. Then the advantage for high-skilled workers is also shirked if F^X is small. For high-skilled workers in the small country, the average labor income is smaller if Z_i is larger for a given C_i^L. Hence, the benefit of skill threshold



(a) RW_1^H (b) RW_2^H

Figure 3.6: Decreasing real wage of high-skilled workers with trade freeness

improvement does not compensate for the loss in a decreasing capital share when F^X is small in Stage II. Similarly, RW_1^H could be smaller with falling trade costs in Stage IV if F^X is small.

3.6.2 Real capital rents

Then we investigate the real income from capital markets in two countries. We use Rr_i to denote the real capital rent in the country i, which equals the capital rent over the price index. In Case A, we have

$$\mathrm{Rr}_1 = \frac{W_1}{(\sigma-1)P_1}, \quad \mathrm{Rr}_2 = \frac{W_2}{(\sigma-1)P_2}.$$

In Case B, the real capital rents are written as

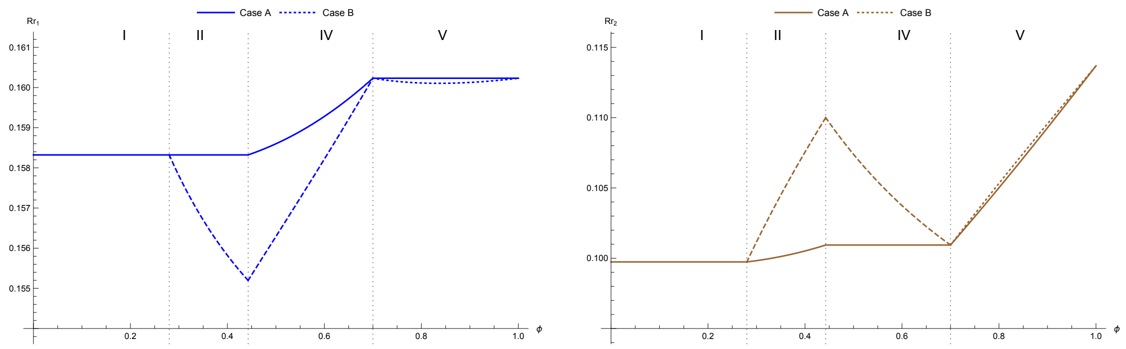
$$\mathrm{Rr}_1 = \frac{\theta W_1 + (1-\theta)W_2}{(\sigma-1)P_1}, \quad \mathrm{Rr}_2 = \frac{\theta W_1 + (1-\theta)W_2}{(\sigma-1)P_2}.$$

We can prove that in Case A, the real capital rent in country 2 increase in Stage II and remain constant in Stage IV. In the previous subsection, we show that the price index in country 2 is not affected by the trade costs in Stages II – IV when capital is internationally immobile. Hence, the real capital rent in the small country increases in Stage II due to the improvement of productivity. Similarly, the real capital rent in country 1 increase in Stage IV and keep constant in Stage II.

When the capital market is fully open (Case B), we have the following results from simulations.

Result 2 *Assume that capital is mobile across country (Case B). In Stage II, when the trade freeness rises, Rr_1 is decreasing and Rr_2 is increasing. In Stage IV, when the trade freeness rises, Rr_1 is increasing and Rr_2 is decreasing.*

From simulations, we find that the real capital rent in the large country is lower in Case B. The result is the opposite in the small country. If capital is mobile across countries, more capital is invested into the large market since its nominal return is higher. As a result, the real capital rents decrease with the capital inflow. Figures 3.7 depicts the real capital rents in two countries with the following parameters for simulations: $\sigma = 4$, $F^L = 1$, $F^H = 2.5$, $F^X = 0.7$, $\Psi = 0.68$, and $\theta = 0.8$. In Stage IV, the home market effect is weakened since the small country has exportable L firms. Although the large market still attracts a more-than-proportionate capital share, the ratio falls steadily in Stage IV. The real capital rent also decreases in country 2 since capital flows back to the small market.



(a) Rr_1 (b) Rr_2

Figure 3.7: Real capital returns with trade freeness

3.6.3 Real income

Next, we examine how trade barriers affect the total welfare in a country. The real income of a $t \in (L, H)$ type worker in country i is denoted by Wel_i^t, which is equal to the sum of real labor income and real capital income of an individual:

$$\mathrm{Wel}_i^t = \mathrm{RW}_i^t + \mathrm{Rr}_i.$$

We can derive how the real income change with trade costs in Case A.

Proposition 9 *Suppose that $F^L < F^X/\phi < F^H$ and capital is immobile across countries (Case A). When trade costs fall, (i) the real incomes of low- and high-skilled workers in the large country keep constant in Stage II and rises in Stage IV; (ii) the real incomes of low- and high-skilled workers in the small country keep constant in Stage II and rises in Stage IV.*

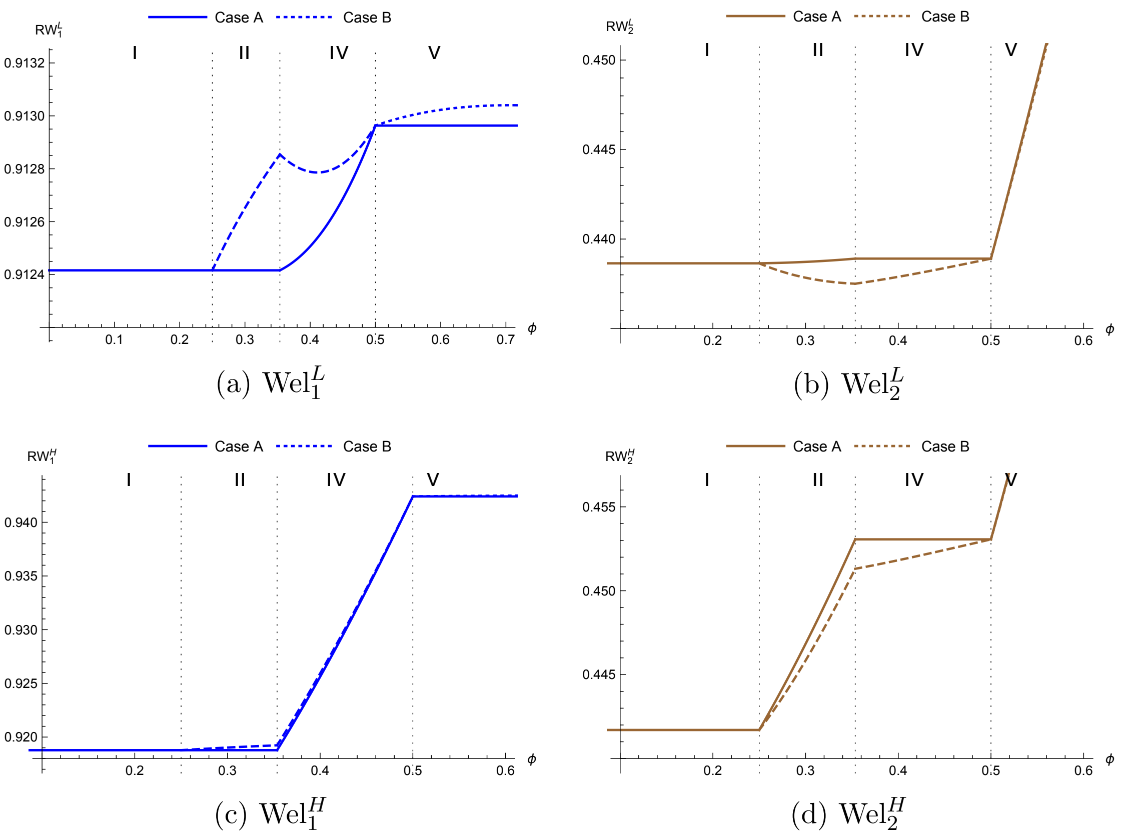
When capital is internationally immobile, trade costs affect real income via the skill threshold. All individuals can benefit from trade when the national productivity is higher (lower skill threshold). The large country and the small country gain higher welfare in Stages IV and II, respectively. Higher trade freeness never causes a loss in welfare in two countries.

Considering international mobile capital, we observe that trade may hurt real income in different stages. The results from simulations are summarized as follows.

Result 3 *Supposing that $F^L < F^X/\phi < F^H$ and capital is mobile across countries (Case B), we have the following results by simulations. (i) In Stage II, $\partial Wel_1^L/(\partial\phi) > 0$. (ii) In Stage IV, $\partial Wel_2^L/(\partial\phi) < 0$. (iii) In Stage II, $\partial Wel_2^L/(\partial\phi)$ and $\partial Wel_2^H/(\partial\phi)$ are negative if F^X is sufficient small. (iv) In Stage IV, $\partial Wel_1^H/(\partial\phi)$ and $\partial Wel_1^H/(\partial\phi)$ are decreasing functions of F^X.*

Unlike the results in Case A, our results reveal that trade liberalization may reduce welfare. When fixed costs for exporting are small, the real incomes in the small (resp. large) country are more likely to decrease with trade freeness in Stage II (resp. IV), as shown in Figure 3.8. The parameters for simulations are $\sigma = 4$, $F^L = 1$, $F^H = 2$, $\Psi = 0.78$, $F^X = 0.5$, and $\theta = 0.85$.

We have demonstrated that the low-skilled workers gain a higher real wage but a lower real capital return when the capital share increases. With a smaller F^X, the difference of skill selection between the two countries is also smaller. Consequently, the real wage effect dominates the real capital income effect for a small F^X.



(a) Wel_1^L (b) Wel_2^L

(c) Wel_1^H (d) Wel_2^H

Figure 3.8: Welfare and trade freeness

Chapter 4

Economic impact of transportation infrastructure investment

4.1 Introduction

The Belt and Road Initiative (BRI), as a global development strategy of China, has received increasing attention since its implementation in 2013. The objective of this strategy is to facilitate economic and cultural exchange and integration among different countries in Asia, Africa, the Americas, Middle East, and Europe to achieve coordinated regional development. One key focus of BRI is to promote infrastructure development through a consistent pace of investment. The ultimate goal is to establish an "international community with shared interests, destiny, and responsibility" through an interconnected infrastructure system and trade cooperation (Zhang, 2018).

The number of BRI participating countries has increased substantially since its deployment. The trend of infrastructure investment in the transport sector in BRI countries is illustrated in Figure 4.1. It shows that during 2014 – 2018, the investment in transportation infrastructure from China has increased substantially. In addition, it is expected that the world's infrastructure investment is likely to reach $1.3 trillion by 2027 (Morgan Stanley, 2018).[1] These investments will fa-

[1]The estimate was predicted in the pre-COVID-19 era. However, one should note that the

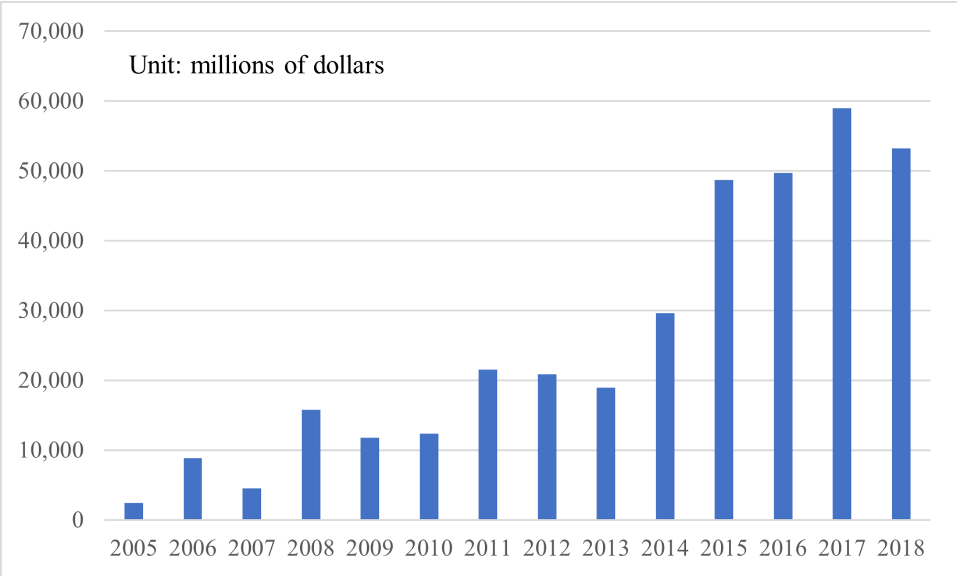
cilitate the development of a wide range of infrastructure systems, such as transportation, oil and gas pipelines, telecommunication, and power system (American Enterprise Institute, 2018). According to the China Global Investment Tracker of the American Enterprise Institute, during 2014 – 2020, there are 58 records of outward direct investment of $40.4 billion in the transport sector under the strategy of BRI. These investments were mainly from China's state-owned enterprises, such as China Communications Construction and China Railway Construction. Meanwhile, 304 construction contracts related to the transportation sector were signed during the period. Key investors include China Railway Construction, China Energy Engineering, China Railway Engineering, and Power Construction Corporation of China.

To promote regional trade flow and economic development, the BRI consists of two main strategies: the development of surface physical infrastructure, which refers to the "belt," and an improvement of maritime transportation, known as "maritime silk road." Specifically, the following land infrastructure corridors were planned[2]: (1) the New Eurasia Land Bridge Economic Corridor, which connects Western China with countries, such as Kazakhstan, Russia, and Western Europe; (2) the China–Mongolia–Russia Economic Corridor, (3) China–Central Asia–Western Asia Economic Corridor, which connects Western China with Turkey; (4) China–"Indochina Peninsula," which links China with Southeast Asian countries, such as Cambodia, Laos, Myanmar, Viet Nam, and Thailand; (5) China–Pakistan, Economic Corridor.

While the BRI was endorsed by more than 130 countries, skepticism and opposition also exist. Some scholars, for instance, Chellaney (2017), argued that the BRI is essentially a neocolonial strategy that China aims to take over assets and natural resources and to expand its military and naval presence through the practice of debt-trap diplomacy to fund the initiative's infrastructure projects. However, other scholars, such as Singh (2020), held a different view, who believed

COVID-19 is likely to a long-lasting influence on infrastructure investment. On one hand, the pandemic may slow down the investment in short-term due to the requirement of social distancing and a temporary suspension of project. On the other hand, infrastructure investment may experience a substantial growth in the recovery period as a response of government stimulus spending.

[2]The Bangladesh–China–India–Myanmar Economic Corridor, which was originally proposed in 2015 by China, was dropped from the list of corridors in 2019, due to the opposition of India.



Source: American Enterprise Institute.

Figure 4.1: BRI related investment in transportation sector

that China provides unconditional financing opportunities for the countries that face hostility from the U.S. and its allies to develop infrastructure systems. As a result, it remains unclear to what extent the investment from China has affected the economic performance of different partner countries.

The objective of this study is to provide a comprehensive assessment of the economic impact of infrastructure investment in the transportation sector under the BRI. Based on the data obtained from various sources, including American Enterprise Institute (AEI), the World Bank, and the Organisation for Economic Co-operation and Development (OECD), the influence of trade cost change as a response to transportation infrastructure investment is estimated by different regions. The indirect economic impacts of transportation infrastructure are evaluated using the Global Trade Analysis Project (GTAP) model by implementing a shock of trade cost reduction, which is caused by improved infrastructure connectivity and reduced transportation. The assessment helps us better understand the economic impacts of the BRI investment in transportation infrastructure.

4.2 Literature Review

Despite the massive and rapid investment and project implementation, the empirical understanding of the economic impact resulting from transportation infrastructure investment in BRI remains unclear. Part of the reason is due to the complexity of measurement at such a large geographic scale. The following review focuses on the generic evaluations of the economic impact of infrastructure and the specific evaluations of transportation infrastructure projects in BRI.

4.2.1 Economic impacts of infrastructure

Traditionally, the role of infrastructure in economic growth and regional development was evaluated through the change in connectivity and accessibility of the markets as a response to infrastructure development (Lall, 2007; Francois and Manchin, 2013; Chong et al., 2019). Moreover, the improvement of infrastructure quality could improve the productivity of existing firms and facilitate the formation of new firms (Puga, 2002). Stough and Rietveld (1997) revealed that infrastructure is critical for foreign firms to determine their location, which hence, may indirectly promote the growth of the regional economy. From the perspective of New Economic Geography, infrastructure improvement leads to a reduction in transportation costs, which may facilitate an industrial agglomeration and change in the total demand in the markets. For instance, Chen et al. (2016) found that rail infrastructure investment in China has stimulated the growth of the economy through increased demand and output expansion. Using a spatial panel model, Chen and Haynes (2014) pointed out that surface transportation infrastructure in the US northeast corridor generates positive spillover effects on regional GDP.

A number of studies have also confirmed that the improvement of transportation infrastructure has been a major factor in reducing international trade costs (Limao and Venables, 2001; Donaldson, 2018). Brooks and Hummels (2009) pointed out that infrastructure construction plays an important role in trade expansion in Asia. The development of transportation infrastructure through the BRI is likely to have a significant impact on reducing shipment time and trade costs (de Soyres et al., 2020). Their study revealed that shipment time and trade costs have reduced by $1.7 - 3.2\%$ and $1.5 - 2.8\%$ due to transport infrastructure development in BRI countries, respectively.

In addition, scholars also found that the impact of trade on labor markets is likely to be substantial in globalization, as shown in Chapter 2. In that chapter, we investigated how globalization impacts labor market outcomes with different paradigms of unemployment when productivity heterogeneity is considered. According to Melitz (2003), trade liberalization can facilitate the efficiency of intra-industry resource allocation, which thus may increase the labor demand and wage rate. For instance, through integrating the job-matching theory with the Melitz model, Felbermayr et al. (2011) revealed that trade liberalization could lower unemployment and raise real wages since active firms tend to be more productive and thus are likely to search for workers more intensively. However, other scholars, such as Egger and Kreickemeier (2009, 2012), indicated that the unemployment rate is higher under trade liberalization since firms may offer higher wages, which may lead to lower labor demand. As a result, it remains unclear to what extent the improvement of the trade environment (e.g., a reduction in trade cost and trade liberalization) may affect the macro-economy.

4.2.2 The impact of BRI investment

Many empirical studies have confirmed that transport infrastructure projects in the BRI countries promote greater regional and inter-regional connectivity and international trade (Chan, 2018, Sheu and Kundu, 2018, Wang et al., 2020). Some scholars, such as Villafuerte et al. (2016), Zhai (2018), and Mukwaya and Mold (2018), assessed the economic impact of infrastructure development in belt and road countries using various methods, including both econometric analysis and computable general equilibrium (CGE) analysis. As the state-of-the-art impact assessment tool, CGE has been extensively adopted for the economic impact evaluation of BRI-related policies. Table 4.1 summarizes the relevant studies using CGE analysis. For instance, Mukwaya and Mold (2018) revealed that the reduction in trade margin as a result of BRI investment contributes to a $0.4 - 1.2\%$ growth of the economy in East Africa. Tsigas and Yuan (2017) evaluated the economy-wide impact of China's overseas investment in the iron and steel sector under BRI. Based on the assumption that the cost of capital for Chinese iron and steel firms would decrease by 50% due to the influence of BRI, their analysis revealed that economic welfare would increase by $4.78 million in Kazakhstan.

Although these studies provided some initial efforts to disclose the economic impact of BRI-related investment, one major limitation of these studies is that nearly all the CGE simulations were conducted based on hypothetical scenarios and the magnitude of shocks. For instance, Villafuerte et al. (2016) analyzed the economic impact of infrastructure by assuming that the shocks to the economy were driven by a reduction in trade margin at a unified rate across all regions. Their findings showed that a 25% reduction in international road transport margin and a 5% reduction in sea transport margin would lead to an overall positive effect on GDP growth in Asia. Similarly, Zhai (2018) evaluated the impact of infrastructure investment of BRI by assuming the investment growth rate is identical across all the regions. Also, Yang et al. (2020) estimated the effect of infrastructure investment on total factor productivity (TFP) enhancement and trade cost reduction. A significant difference between their research and ours is that they assumed three scenarios where the infrastructure investment demand gap can be fulfilled to certain degrees. Their results showed that BRI would generate a significant benefit to the world economy.

Table 4.1: Studies on the impact of BRI and trade using CGE analysis

Papers	Method	Data	Shock	Result/Contribution
Mukwaya and Mold (2018)	CGE	GTAP 10, 5 Eastern African countries	a 10% decline in trade margin due to BRI	A positive impact from BRI on East Africa is confirmed
Villafuerte et al. (2016)	CGE	GTAP 9a, 17 regions	a unified rate of trade cost reduction	Examined the size of trade and growth nationally and regionally.
Zhai (2018)	CGE	GTAP 9	a unified rate of investment growth	BRI has a positive impact on the world economy
Tsigas and Yuan (2017)	CGE	GTAP 9, 5 Central Asian countries	a cost reduction for Chinese iron and steel firms by 50 %.	Kazakhstan's welfare increases by $42.8 million.
Yang et al. (2020)	CGE	GTAP9, 16 regions	TFP enhancing & trade costs reducing	Most regions' economic growth, welfare, and trade are promoted
Ramasamy and Yeung (2019)	econometric analysis	bilateral trade 2008-2014		Trade gains from improvements in trade facilitation are uneven.
Wang et al. (2020)	econometric analysis	65 BRI countries from 2007 to 2016		Transport infrastructure plays a positive role in promoting economic growth
de Soyres et al., (2019)	econometric analysis	GTAP 10		GDP increased by 3.4 % among participating countries
Herrero and Xu (2017)	econometric analysis & simulation exercise	Exports in 2014	a unified rate of trade cost reduction	E.U. member states would benefit less. Asia would benefit more.

Source: Authors' summary.

Overall, while a plethora of studies have attempted to evaluate the economic impact of transportation infrastructure, there is still a lack of understanding of the economic impacts of infrastructure investment in BRI based on realistic scenarios and data. In addition, it remains unclear to what extent the economic benefits of transportation infrastructure vary among different BRI countries. To fill these research gaps, our study provides a comprehensive assessment of the economic impact of BRI transportation infrastructure investment from an ex-post perspective, based on the actual investment data collected from various data sources. Our objective is to provide, for the first time, a more realistic view of the impacts of China's BRI investment on the economy and welfare of the member countries. The CGE assessment enables us to capture various impacts in different countries and regions. Furthermore, we also assess the different effects from both intra-regional and inter-regional trade cost reductions, as well as the short-run versus the long-run effects. Such an evaluation enables us to gain a closer understanding of the impact of the BRI transportation infrastructure investment on the integration of regional markets in globalization.

4.3 Data

Our assessment focuses on 42 Eurasian countries, which are the primary member countries of the BRI. As illustrated in Table 4.2, the assessment includes six regions: 15 countries in Central and West Asia, 11 Central and East European nations, 3 Eastern European non-EU member countries, 13 South and Southeast Asian countries, China, and the rest of the world. The rationale of such aggregation is based on data availability, which does not reflect any geopolitical consideration.

Table 4.2: Classifications of regions and economies under BRI

Region (No. of countries)	Economies in BRI projects
Central and West Asia (15)	United Arab Emirates (UAE), Armenia, Azerbaijan, Bahrain, Egypt, Georgia, Iran, Kazakhstan, Kyrgyzstan, Kuwait, Mongolia, Oman, Qatar, Saudi Arabia, Turkey
Central and East Europe (11)	Bulgaria, Czech, Estonia, Croatia, Hungary, Lithuania, Latvia, Poland, Romania, Slovakia, Slovenia
Non-EU countries in East Europe (3)	Belarus, Russian Federation, Ukraine

Table 4.2: Classifications of regions and economies under BRI

Region (No. of countries)	Economies in BRI projects
South and Southeast Asia (13)	Bangladesh, Brunei Darussalam, Indonesia, Sri Lanka, Cambodia, Lao PDR, Malaysia, Nepal, Pakistan, Philippines, Singapore, Thailand, Viet Nam
China (1)	P.R. China
Rest of the World (1)	All the rest of the countries in the world

Source: Authors' classification.

The data in this study covers the period 2006 – 2018. Specifically, the trade cost data were collected from the World Bank UNESCAP Trade Costs Database[3]. The dataset provides estimates of symmetric bilateral trade costs by sectors for 208 countries, which was calculated using the Inverse Gravity Framework. Other variables, such as GDP, population, the quality index of transportation infrastructure, tariff, and the exchange rate of different countries, were collected from the World Bank Open Data Website.

The data of transportation infrastructure investment were obtained from both the World Bank Open Data[4] and OECD[5]. Although the scale of the data is somewhat different between the two sources, they are still relevant. Specifically, the OECD data provides detailed statistics of transport infrastructure investment in countries in Central and West Asia, Central and East Europe, non-EU countries in East Europe, and China. The data of the World Bank is more detailed for South and Southeast Asian countries. Hence, the OECD data was adopted to estimate the trade cost elasticity among countries in Central and West Asia, Central and East Europe, non-EU countries in East Europe, and China. Meanwhile, the World Bank data was adopted to estimate the elasticity of the trade costs among the South and Southeast Asian countries and other regions.

In addition, we also introduced a dummy variable to capture the effect of the free trade agreement (FTA) on the change in trade cost, the data of which was collected from the Regional Trade Agreement Database offered by the World Trade

[3] https://www.unescap.org/resources/escap-world-bank-trade-cost-database
[4] https://data.worldbank.org/indicator/IE.PPI.TRAN.CD
[5] https://data.oecd.org/transport/infrastructure-investment.htm

Organization[6]. The variable is coded as one if a bilateral FTA was established between two countries in year t.

4.4 Methodology

The impact assessment is implemented in two steps. In step one, the elasticity of trade cost is estimated using regression analysis. Then, the level change in trade cost in different regions is calculated based on the estimated trade cost elasticity and the volume of actual transportation investment. In step two, the changes in trade cost in different regions were adopted as the impact drivers for the CGE simulation. The macroeconomic outcomes as a result of the CGE shocks of trade cost change among BRI countries are then summarized and compared.

4.4.1 Estimation of Trade Cost Change

Step 1: Estimating Elasticity of Trade Cost

The elasticity of trade cost change as a response to transportation infrastructure investment is estimated through the following regression[7] model, following Francois et al. (2009):

$$\begin{aligned} \ln \tau_{i,j,t} =& \beta_0 + \beta_1 \ln \mathrm{pGDP}_{i,t} + \beta_2 \ln \mathrm{pGDP}_{j,t} + \beta_3 \ln \mathrm{tar}_{i,t} + \beta_4 \ln \mathrm{tar}_{j,t} \\ &+ \beta_5 \ln \mathrm{INF}_{i,t} + \beta_6 \mathrm{INF}_{j,t} + \mathrm{FTA}_{i,j,t} + \varepsilon_{i,j,t}, \end{aligned} \tag{4.1}$$

where i and j represent region i and j, and t denotes the time period. In the regression model, $\tau_{i,j,t}$ denotes the trade cost from region j to region i in year t, which is expressed in a tariff–equivalent form (share of CIF prices), $\ln \mathrm{pGDP}_{j,t}$ represents the logged GDP per capita of the country in region j, $\mathrm{tar}_{i,t}$ denotes tariff in region i, and $\mathrm{INF}_{i,t}$ represents the value of infrastructure investment. The elasticity of trade cost with respect to transportation infrastructure investment in country i (country j) is denoted as β_5 (β_6). FTA_{ij} is a dummy variable which equals one if the two countries are in the same free trade area, otherwise $\mathrm{FTA}_{i,j,t}$ was equal to zero. The estimated results are summarized in Table 4.3.

[6] http://rtais.wto.org/UI/PublicMaintainRTAHome.aspx

[7] The potential issue of endogeneity may exist in this gravity model structure. An important future extension of this model is to test the model by introducing lagged dependent variables.

The regression results show that the estimated coefficient of transportation infrastructure investment on intra-regional trade cost varies substantially among different O.D. pairs. The average trade cost elasticity based on the estimate of all samples is -0.04, suggesting that a 1% increase in transportation infrastructure investment is associated with a 0.04% reduction in trade cost, ceteris paribus. In terms of the intra-regional trade cost elasticity, only the estimate of the Central and East Europe was found to be statistically significant, with a slightly higher value of -0.047. The insignificant estimate of other regions may be due to various reasons, such as the lack of sufficient data to capture significant variations. Hence, we assume that the intra-regional elasticities of trade cost for the remaining regions, such as Central and East Europe, Central and West Asia, non-EU countries in East Europe, and China, are equal to the value of the overall estimate based on the OECD data. The elasticities of trade cost between South and Southeast Asia and other regions are equal to the overall estimate based on the World Bank dataset.

Regarding the bilateral inter-regional elasticities of trade cost, the results show that the estimated coefficients vary substantially among different regions. Similarly, for those regions with insignificant estimates, we also assume that the elasticity is equal to the mean value estimated based on the overall sample dataset.[8] The final elasticities of trade cost adopted for the analysis are summarized in Table 4.4.

[8]This also applies to the trade cost elasticity between Central and East Europe and non-EU countries in East Europe , as a positive estimate was found in this case. Such a result could be attributed to the limitation of data.

Table 4.3: Regression results of trade cost elasticity estimation

Estimation of intra-regional trade cost elasticity						
Region i	All regions (OECD)	All regions (World Bank)	Central and East Europe	Central and West Asia	Non-EU countries in East Europe	South and Southeast Asia
$\ln \text{pGDP}_i$	−0.366***	−0.234***	−0.839***	0.27	−0.436	−0.272***
	(−18.705)	(−9.650)	(−11.190)	−0.858	(−0.692)	(−4.662)
$\ln \text{INF}_i$	−0.040***	−0.038***	−0.047***	−0.035	0.052	0.011
	(−7.220)	(−5.022)	(−2.619)	(−0.480)	−0.567	−0.636
$\ln \text{tar}_i$	−0.027	−0.082***	−0.298	−0.045	0.476**	−0.153*
	(−1.632)	(−3.434)	(−1.145)	(−0.647)	−2.229	(−1.793)
FTA	−0.544***	−0.572***		−0.489***		−0.358***
	(−25.688)	(−15.967)		(−3.904)		(−5.675)
constant	9.364***	8.222***	13.924***	3.100*	6.046	7.476***
	−41.955	−29.395	−15.361	−1.722	−1.314	—11.394
R-squared	0.321	0.299	0.127	0.16	0.654	0.311
No. of obs.	3012	854	886	90	14	156

Estimation of inter-regional trade cost elasticity										
Region i	Central and East Europe	Central and East Europe	Central and East Europe	Central and West Asia	Central and West Asia	China	South and Southeast Asia	South and Southeast Asia	South and Southeast Asia	South and Southeast Asia
Region j	Central and West Asia	Non-EU countries in East Europe	China	Non-EU countries in East Europe	China	Non-EU countries in East Europe	Central and East Europe	Central and West Asia	Non-EU countries in East Europe	China
$\ln \text{pGDP}_i$	0.299***	–0.359**	–0.375***	–0.439***	–0.487***	0.36	–0.102	–0.167**	–0.195**	–0.271***
	–3.95	(–2.098)	(–3.853)	(–2.797)	(–3.564)	–0.726	(–1.130)	(–2.512)	(–2.141)	(–3.390)
In INF_i	0.016	0.127***	–0.046**	0.044	–0.051*	0.058	–0.022	–0.057**	–0.052*	–0.033
	–1.062	–3.972	(–2.476)	–1.32	(–1.821)	–0.294	(–0.754)	(–2.450)	(–1.682)	(–1.136)
In tar_i	-0.34	–0.308	–0.129	–0.022	0.070***	0.1	–0.125	–0.395***	–0.283**	–0.02
	(–1.647)	(–0.551)	(–0.438)	(–0.941)	–3.374	–0.18	(–0.899)	(–4.041)	(–2.115)	(–0.154)
In pGDP_j	-0.691***	–0.34	0.252	0.801***	0.066	0.004	0.119	–0.384***	0.003	0.285
	(–6.978)	(–0.670)	–0.44	–3.364	–0.173	–0.007	–0.579	(–4.268)	–0.019	–1.292
$\ln \text{INF}_j$	-0.015	–0.023	–0.193	–0.266***	0.158	–0.229**	–0.109***	–0.088***	–0.003	–0.009
	(–0.629)	(–0.307)	(–0.691)	(–7.731)	–0.801	(–2.869)	(–3.301)	(–3.458)	(–0.141)	(–0.264)
$\ln \text{tar}_j$	0.209***	–0.131	–0.245	0.329**	0.66	0.671***	3.895***	–0.112***	0.068	0.892
	–9.471	(–0.368)	(–0.334)	–2.269	–0.819	–4.006	–4.803	(–2.783)	–0.505	–0.758
FTA_{ij}	0.134			0.002						–0.18
	–1.397			–0.028						(–1.422)
constant	8.618***	9.871**	13.048***	5.495***	4.748	3.478	4.424*	14.418***	8.365***	3.489
	–10.5	–2.146	–3.52	–3.299	–1.242	–0.894	–1.934	–14.474	–5.892	–0.85
R-squared	0.499	0.138	0.29	0.727	0.901	0.957	0.622	0.527	0.235	0.458
No. of obs.	378	204	113	78	42	24	26	106	54	43

Source: Authors' calculation.

Table 4.4: Estimated elasticities of trade cost as a response to the change in transportation infrastructure investment from China

Region of Origin (i)	Region of Destination (j)	Type	Coef. i	Coef. j
Central and East Europe	Central and West Asia	inter-region	–0.040	–0.040
Central and East Europe	Non-EU countries in East Europe	inter-region	–0.040	–0.040
Central and East Europe	China	inter-region	–0.046	–0.040
Central and West Asia	Non-EU countries in East Europe	inter-region	–0.040	–0.266
Central and West Asia	China	inter-region	–0.051	–0.040
China	Non-EU countries in East Europe	inter-region	–0.040	–0.229
South and Southeast Asia	Central and East Europe	inter-region	–0.038	–0.109
South and Southeast Asia	Central and West Asia	inter-region	–0.057	–0.088
South and Southeast Asia	Non-EU countries in East Europe	inter-region	–0.052	–0.038
South and Southeast Asia	China	inter-region	–0.038	–0.038
Central and East Europe	Central and East Europe	intra-region	–0.047	–0.047
Central and West Asia	Central and West Asia	intra-region	–0.040	–0.040
Non-EU countries in East Europe	Non-EU countries in East Europe	intra-region	–0.040	–0.040
South and Southeast Asia	South and Southeast Asia	intra-region	–0.038	–0.038

Source: Authors' calculation.

Step 2 Calculating Transportation Infrastructure Investment in BRI

The assessment involves various developing countries, among which the data quality and availability can be a major issue. Our study uses data obtained from different sources. Our assessment focuses on the Chinese overseas investment in transportation infrastructure-related projects.[9]

Specifically, we first estimated the transportation infrastructure investment in the base year of 2013, the year when the BRI was launched. It was estimated based on the information collected from the Asian Development Bank (ADB).[10] In addition, given that the future need of transportation infrastructure investment is expected to account for 34.5% of the total infrastructure investment in Asia

[9] The key data of infrastructure investment was obtained from the China Global Investment Tracker (CGIT) database. It contains investment and construction transactions over $100 million. The investments were mainly from the Chinese corporate sources, and no trade, lending or bond transactions were included (Scissors, 2020).

[10] For instance, given that infrastructure investment from 2010-2014 accounts for 4.8% of GDP in South Asia, 2.6% of GDP in Southeast Asia, 2.9% of GDP in Central and West Asia, respectively, the ratios were adopted for the calculation of the transportation infrastructure investment in 2013. The data is obtained from `https://www.adb.org/node/228891`.

(ADB, 2015)[11], the volume of transportation infrastructure investment in Asian countries in 2013 can be estimated through the following equation:

$$\text{INF}_{m,2013} = \text{GDP}_{m,2013} \times r_{\text{INF}} \times r_{\text{tran}} \tag{4.2}$$

where r_{INF} denotes the ratio of infrastructure investment over GDP and r_{tran} denotes the ratio of investment in transportation over the total infrastructure investment. The data on transportation infrastructure investment in European countries were collected from OECD.[12] Hence, the growth of investment in transportation infrastructure in country m (r_m^{increase}) in the period 2014 – 2020 can be calculated as follows:

$$r_m^{\text{increase}} = \frac{\sum_t^{2014-2020} \text{INF}_{m,t}^{\text{BRI}}}{\text{INF}_{m,2013}} \tag{4.3}$$

where $\text{INF}_{m,t}^{\text{BRI}}$ represents the investment of infrastructure in the transportation sector. The specific investment in the transportation sector was obtained from the China Global Investment Tracker (CGIT) database from AEI.[13] In the end, the growth rates of transportation infrastructure investment from Chinese corporations through BRI projects among different countries are summarized in Table 4.5. In the case where the estimated ratio is surprisingly high, for instance, if the value of trade cost reduction is smaller than −100%, we assume that the corresponding reduction in trade cost is equivalent to −100%, which indicates that the trade margin between the two countries approximately equals to zero.

Table 4.5: The growth of transportation infrastructure investment from the Chinese corporation through BRI projects among different countries

ID	Country	Investment of transportation in 2013 (million $)	Investment of transportation in BRI 2014-2020 (million $)	Increasing ratio with BRI investment
1	Bangladesh	2,484	860	0.35

[11] `https://data.adb.org/dataset/infrastructure-needs-asia-and-pacific`

[12] `https://data.oecd.org/transport/infrastructure-investment.htm`

[13] The CGIT database provide both statistics of Chinese investment both by the actual investment and construction contracts. The former was adopted for the assessment. More details could be found at `https://www.aei.org/china-global-investment-tracker/`.

Table 4.5: The growth of transportation infrastructure investment from the Chinese corporation through BRI projects among different countries

ID	Country	Investment of transportation in 2013 (million $)	Investment of transportation in BRI 2014-2020 (million $)	Increasing ratio with BRI investment
2	Indonesia	8,185	5,030	0.61
3	Sri Lanka	1,231	1,870	1.52
4	Cambodia	137	2,450	17.94
5	Lao PDR	107	4,170	38.93
6	Malaysia	2,900	390	0.13
7	Pakistan	3,829	1,620	0.42
8	Philippines	2,547	400	0.16
9	Singapore	2,759	800	0.29
10	Thailand	3,770	1,870	0.50
11	Viet Nam	1,536	440	0.29
12	Belarus	863	160	0.19
13	Russian Federation	73,660	1,340	0.02
14	United Arab Emirates	3,903	610	0.16
15	Azerbaijan	742	270	0.36
16	Kazakhstan	2,368	560	0.24
17	Turkey	9,583	690	0.07
	Weighted Average	7,095	1,384	0.195

Note: The summary was calculated based on raw data from the CGIT database of AEI.

Source: Authors' calculation.

4.4.2 GTAP Model

The Global Trade Analysis Project (GTAP) model was adopted for the regional economic impact assessment. The model consists of 44 regions and 57 economic sectors. Hence, the analysis was adopted for an ex-post assessment of the transportation infrastructure investment in the 17 countries by Chinese corporations in the period 2014 – 2020.

The GTAP Model was developed by Hertel (1997). It is a static and multi-regional CGE model that has been widely adopted to evaluate the economic impact of international trade policies. The model was developed based on Walras's general equilibrium theory, and it has been extended to provide a realistic representation of international trade given the introduction of transportation margin and saving institutions (Mukhopadhyay and Thomassin, 2010). The GTAP model was developed primarily based on two sets of simultaneous equations. The first set represents the behavioral equations that were developed based on the microeconomic theory. The second set of equations measures the accounting relationships among different agents (consumers, producers, government, and the Rest of the World). Hence, the linkages were primarily developed based on macroeconomic theory. As Rose (1995) indicated, CGE models have advantages in that their modeling structure reflects multi-sectoral details. In addition, CGE models reflect an inter-dependency of various components, such as factor inputs, behavioral content, a reflection of the actions of prices and markets, non-linearities, and incorporation of explicit constraints (Wei et al., 2018).

The GTAP 9 database was adopted for the CGE analysis. The data represents the world economy, and it has been extensively used for various impact assessments of global economic issues. The database also consists of information on import shares and tariff rates between partner countries. In this study, we evaluated the economic impact of trade margin reduction as a response to transportation infrastructure investment, focusing on the 43 BRI participant countries.

Given that the economic impacts of transportation infrastructure investment are likely to be different due to the various assumptions on the closure rule, our CGE analysis was conducted using both the short-run and the long-run closure rules[14] to capture the various effects. Specifically, the short-run closure rule, also known as the Keynesian rule, assumes wage is fixed while labor supply and demand are determined endogenously. The exogenous shocks can lead to a change in labor supply, which are adjusted until factor supply equals again at the initial wage. Conversely, the long-run closure rule, which is also known as the neoclassical rule, assumes full employment given that wage is determined endogenously. Although both closure rules present two extreme scenarios, such a comparative analysis helps us gain a clearer understanding of the economic impacts of the investment

[14]The definitions for short-run and long-run in Chapter 4 are different from those in Chapter 2. In Chapter 2, capital mobility is not allowed in the short run. Then the capital share is taken as a given in the short-run equilibrium. The capital is allowed to be invested in the region with higher capital returns. Hence the capital share is endogenously solved in the long-run equilibrium.

under different assumptions. Moreover, the real-world impacts tend to be a mix with both scenarios. The detailed discussions of the different sets of modeling institutions, including production, household, government, and foreign trade, can be seen from Hertel (1997) and Wei et al. (2018). The GTAP Model enables us to analyze the economic impact measured in real GDP change, employment change, and the change in welfare. More precisely, economic welfare in our model reflects the level of disposable income necessary to get to the new level of utility. Hence, the model enables us to evaluate to what extent the transportation infrastructure investment from China has affected the welfare change in various BRI countries.

4.5 Simulation Results

The investment in transportation infrastructure among 17 BRI countries during 2014 – 2020 has increased by 19.5% on average from its base level. It is also clear that the level of investment amount and the associated economic impacts (GDP and economic welfare) are quite uneven among different regions. We summarize the short- and long-run simulation results in Tables 4.6 and 4.7, respectively.

We consider three scenarios in our study to compare the different economic impacts generated by intra-regional, inter-regional, and combined trade costs reduction. In the scenario of intra-region, we observe that the real GDP is lower in 16 countries in the long run. In addition, 23 countries experience a loss in economic welfare. Specifically, most countries in Central and West Asia and Non-EU countries in East Europe are negatively influenced by the intra-regional trade costs reduction both in the long-run and short-run equilibrium, as shown in Figure 4.2(a) and (d). Such outcomes may reflect the spillover effects (e.g., trade competition) from the improved transportation system among other regions. In particular, the impact of transportation infrastructure investment on intra-regional trade costs was found negligible in Central and East Europe.

In the scenario of inter-regional impact, 28 countries have positive real GDP growth. The results suggest that transportation infrastructure investment tends to significantly reduce inter-regional trade costs, which may generate an overall positive impact on the BRI countries' economies. However, such impacts are found quite uneven among the BRI countries, especially among South and Southeast Asia countries. For instance, Cambodia and Lao PDR experienced the most consider-

Table 4.6: Simulation results of the short-run economic impact of infrastructure investment

Region	Aver. invest-ment growth	Output Indicator	Precent change in real GDP			Welfare change per capita		
			Intra-regional impact	Inter-regional impact	Com-bined impact	Intra-regional impact	Inter-regional impact	Com-bined impact
Central and West Asia	0.06	Aver.	–0.0002	0.0011	0.0009	–0.018	0.6388	0.6208
		Agg.	–0.0001	0.0022	0.0021	–0.0048	0.3343	0.3295
		Median	0	0.0009	0.001	–0.0401	0.4418	0.2691
		Max.	0.001	0.01	0.01	1.0272	3.1074	2.8516
		Min.	–0.001	–0.0088	–0.009	–0.3531	–0.1745	–0.1671
South and South-east Asia	4.7	Aver.	0.1202	0.0527	0.1729	2.9483	–0.5581	2.3902
		Agg.	0.0204	–0.0051	0.0153	0.674	–0.3602	0.3138
		Median	0.012	–0.0048	0.006	0.2366	–0.2509	0.0111
		Max.	1.078	0.5532	1.322	19.0532	1.925	20.1588
		Min.	–0.012	–0.0307	-0.027	–0.5452	–5.0672	–0.8132
Non-EU countries in East Europe	0.07	Aver.	–0.001	0.0032	0.002	–0.0648	0.1851	0.1203
		Agg.	–0.0008	–0.0002	–0.0009	–0.0928	–0.0422	–0.135
		Median	–0.001	–0.0002	–0.001	–0.0748	–0.0233	-0.1248
		Max.	0	0.0148	0.014	–0.0182	0.7927	0.7745
		Min.	–0.002	–0.005	–0.007	–0.1014	–0.214	–0.2888
Central and West Europe	0	Aver.	–0.0004	0.0018	0.0017	–0.0006	0.39	0.3894
		Agg.	–0.0004	0.0012	0.0008	–0.0682	0.2707	0.2024
		Median	–0.001	0.0013	0.001	–0.0876	0.2432	0.1247
		Max.	0.006	0.006	0.012	1.0007	1.0006	2.0013
		Min.	–0.001	–0.0002	–0.001	–0.2266	0.0365	–0.0715
PRC	0	Agg.	–0.002	0.0221	0.02	–0.0219	0.2522	0.2306

Source: Authors' summary.

Table 4.7: Simulation results of the long-run economic impact of infrastructure investment

Region	Aver. invest-ment growth	Output Indicator	Percent change in real GDP			Welfare change per capita		
			Intra-regional impact	Inter-regional impact	Com-bined impact	Intra-regional impact	Inter-regional impact	Com-bined impact
Central and West Asia	0.06	Aver.	0.00009	0.00023	0.00032	0.0003	0.3763	0.3765
		Agg.	0.00015	0.00035	0.00051	0.0165	0.1451	0.1618
		Median	0.00000	0.00012	0.00011	–0.0090	0.2237	0.1665
		Max.	0.00098	0.00286	0.00293	0.5461	2.0000	1.8419
		Min.	–0.00016	–0.00354	–0.00336	–0.2190	-0.1331	–0.1251
South and South-east Asia	4.70	Aver.	0.01440	0.02887	0.04327	1.0936	–0.3586	0.7360
		Agg.	0.00254	0.00196	0.00451	0.1899	–0.1741	0.0159
		Median	0.00074	0.00009	0.00086	0.0818	–0.1039	0.0309
		Max.	0.11254	0.19785	0.31039	7.0000	0.5415	7.5538
		Min.	–0.00021	–0.00147	–0.00074	–0.5025	-2.0577	–0.7718
Non-EU countries in East Europe	0.07	Aver.	0.00002	0.00168	0.00170	–0.0006	0.0834	0.0828
		Agg.	0.00004	0.00053	0.00056	–0.0034	0.0444	0.0410
		Median	0.00004	0.00046	0.00051	–0.0018	0.0648	0.0629
		Max.	0.00006	0.00487	0.00493	0.0106	0.2316	0.2421
		Min.	–0.00005	–0.00028	–0.00033	–0.0105	–0.0462	–0.0567
Central and West Europe	0	Aver.	–0.00001	0.00003	0.00002	–0.0053	0.1229	0.1175
		Agg.	0.00000	0.00001	0.00001	–0.0059	0.0953	0.0894
		Median	0.00000	0.00003	0.00002	–0.0044	0.0992	0.0862
		Max.	0.00000	0.00018	0.00017	0.0033	0.3533	0.3567
		Min.	–0.00005	–0.00008	–0.00012	–0.0191	–0.0063	–0.0253
PRC	0	Agg.	–0.0020	0.0221	0.0200	–0.0219	0.2522	0.2306

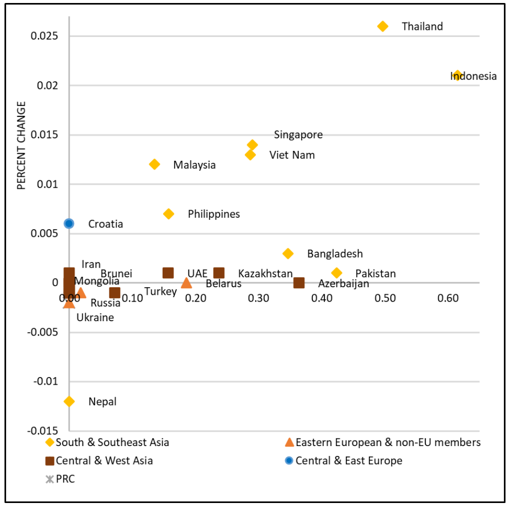
Source: Authors' summary.

able impact from the BRI transportation infrastructure investment. Conversely, Singapore, Nepal, and Thailand received less benefit from the inter-regional trade cost reduction, as shown in Figures 4.2(b) and (e).

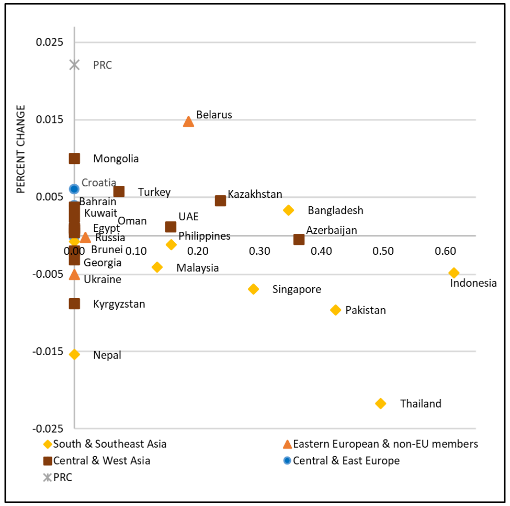
The total impact of the trade cost reduction resulting from transportation infrastructure investment in BRI projects is summarized in the combined impact scenario. In general, the investment in transportation infrastructure generates an aggregate positive impact in BRI countries. However, the influence is found again uneven among different regions.

As shown in Figure 4.2(c), 25 countries were found to have benefited from the trade cost reduction in the short run, given that the percent changes in real GDP are positive. For instance, the total economic impact in South and Southeast Asia is more substantial than in other regions due to the change in trade costs caused by transportation infrastructure investment in the long run. More precisely, in the short run and long run, the real GDP impacts were increased by 0.173% and 0.04% on average, respectively, compared with the case without such an investment. In particular, Lao PDR and Cambodia have experienced the highest growth in real GDP due to transportation infrastructure investment through BRI projects. Viet Nam and Thailand experienced the most extensive loss in real GDP of −0.022% and −0.031%.

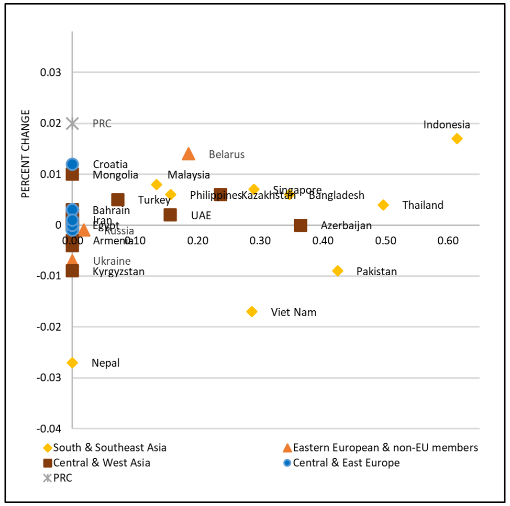
Considering the long-run influence, we found that 32 countries benefit from the growth in real GDP, as demonstrated by Figure 4.2(f). However, compared with the short-run impact, the influence is relatively smaller. Such a difference may attribute to the different assumptions of the closure rule. South and Southeast Asian countries are influenced significantly, with an average growth rate of 0.04% in real GDP. Meanwhile, we can observe the average increasing rates in real GDP are lower in Central and West Asia (0.00032%) and Non-EU countries in East Europe (00017%). The results also show that the economic impact of transportation infrastructure investment is minor in Central and East European countries. Specifically, the short- and long-run average real GDP growth are 0.0017% and 0.0002%, respectively. Such a relatively lower impact is not surprising, given that the regions did not experience growth in infrastructure investment from China during 2014 – 2020.



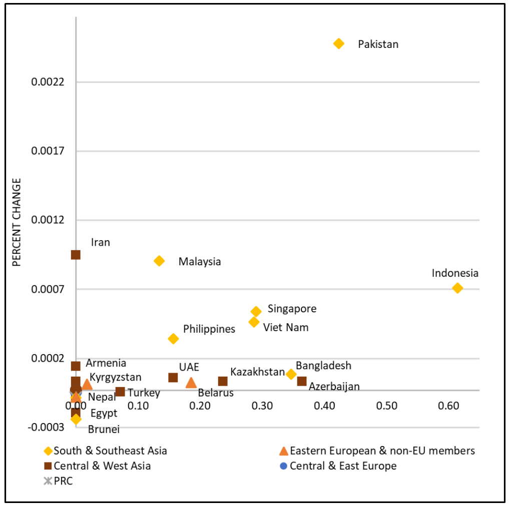
(a) Short-run intra-regional impact



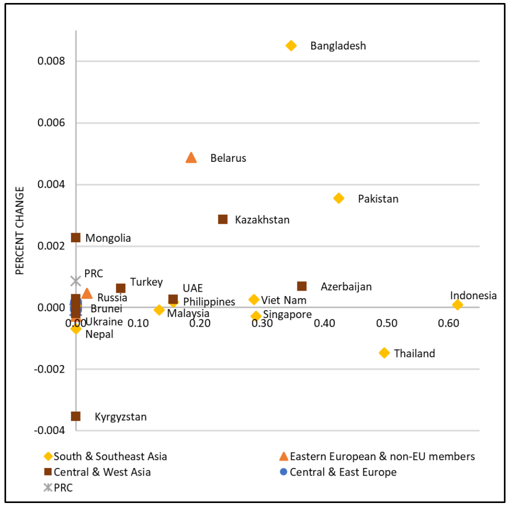
(b) Short-run inter-regional impact



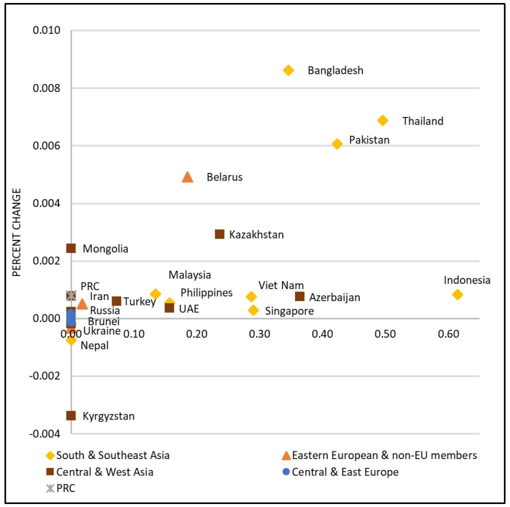
(c) Short-run combined impact



(d) long-run intra-regional impact



(e) Long-run inter-regional impact



(f) Long-run combined impact

Figure 4.2: GDP impact of transportation infrastructure investment from China

Note: The horizontal axis represents the investment growth rate of transportation infrastructure in BRI.

In conclusion, our result suggests that China's BRI infrastructure investment plays a more dominant role in promoting regional economic growth, especially among South and Southeast Asia countries. The result also suggests that the BRI investment in transportation infrastructure enables Central and West Asian countries to be more involved in the international trade markets with China, Western Europe, and South Asia.

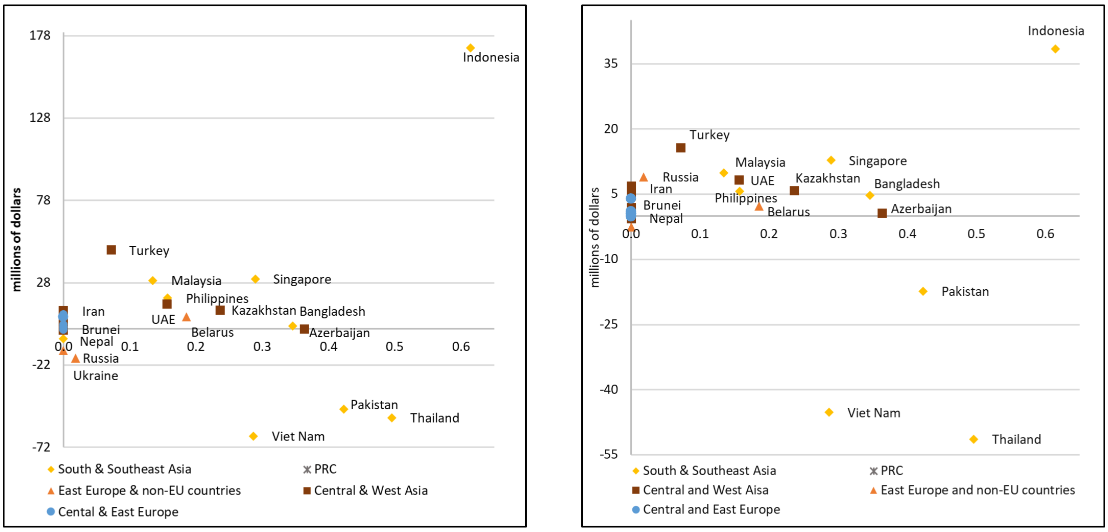
The welfare impact as a result of BRI infrastructure investment in transport is also evaluated. Detailed results of welfare changes are summarized in Appendix C. Similar to the impact of real GDP, the impact of intra-regional trade cost reduction is relatively small.

The combined impacts on welfare due to a trade cost reduction resulting from BRI transportation infrastructure investment also differ substantially among different regions. In general, the research finding reveals that around 29 countries experienced an increase in welfare in the short run due to a trade cost reduction and the development of BRI projects. As shown in Figure 4.3(a), among all the BRI countries, the effect of the transportation infrastructure investment is found more substantial in Central and West Asia than the rest of the Belt and Road countries. Most countries (11 of 15) gain a positive welfare change in the short-run scenario. Countries such as Lao PDR, Cambodia, and Singapore, received the most significant gain in economic welfare among all the BRI participant countries.

The result demonstrates that 32 countries benefit from an increase in welfare in the long run. In addition, countries such as China, Lao PDR, Indonesia, and Turkey benefited the most in terms of economic welfare in the long-run scenario (as shown in Figure4.3(b)). Conversely, other countries, such as Thailand, Viet Nam, and Pakistan, experienced a more considerable decrease in economic welfare per capita, which is likely caused by the negative spillover effects of trade competition. Furthermore, the welfare effect is inconsistent with the long-run impact on GDP in some countries. For instance, countries such as Croatia, Saudi Arabia, Estonia, and Czech experienced a negative GDP growth rate, whereas a positive welfare impact was observed. Given that the labor market is assumed full employment in the long-run scenario, the domestic consumption market could be impacted by globalization with a wage increase, hence, may lead to lower welfare.

In addition, some countries, such as Thailand, Viet Nam, and Brunei Darussalam, have experienced a negative impact on both real GDP and economic welfare. According to the data from AEI, the growth of transportation infrastructure investment resulting from BRI projects is exceptionally high in Lao PDR and Cambodia, with 38.93% and 17.94%, respectively. The negative impact on GDP growth may be caused by the negative spillover effect from other countries, given the improved regional transportation connectivity may enhance their regional trade competitiveness.

Overall, the assessment reveals that most Central and West Asia countries appear to benefit from the positive change in welfare with the BRI transportation infrastructure investment, whereas the effect is uneven among South and Southeast Asian countries. Moreover, the trade cost reduction effect was found to be much smaller among European countries related to BRI projects.



(a) Short-run Combined Impact

(b) Long-Run Combined Impact

Figure 4.3: Welfare Comparison based on the Scenario of Combined Impact

Note: The horizontal axis is the investment growth rate of transportation infrastructure in BRI.

4.6 Conclusion

Through the integration of econometric analysis with CGE modeling, our findings reveal that BRI transportation infrastructure investment has an overall positive effect among the Belt and Road countries, which is consistent with previous studies, such as Itakura (2014) and Zhai (2018). However, the impacts were found to vary substantially among different countries and regions. Central and West Asian countries were found to receive the largest gain in terms of growths in GDP and welfare, whereas the impacts were found to be relatively small in Central and Western Europe. The variation of growth rate in GDP and economic welfare are also found to be quite substantial in South and Southeast Asian countries.

This study provides at least two important policy implications. First, our modeling system may provide decision-makers with a more reliable and clear understanding of the regional economic impact of infrastructure investment and therefore improve the effectiveness of future decision-making on investment. Second, given that the economic impact of BRI transportation infrastructure investment was found to be dissimilar among different regions, future infrastructure development and investment plans need to be implemented more cautiously.

Chapter 5

Concluding remarks

In Chapter 2, we incorporate frictional unemployment into a one-sector footloose capital model. This study finds a new mechanism for breaking the symmetry when the job-matching function is elastic with respect to job vacancies. Agglomeration affects firms in three ways: a negative competition effect, a positive wage effect through HME, and a positive labor efficiency effect. Firms can benefit from a larger market through the HME when bargaining power is large and trade cost is small. With a larger matching elasticity with respect to vacancies, the relative employment level is enlarged. The demerit of competition is offset by the labor efficiency effect when the elasticity equals one. When trade costs are high, markets in the two regions are separated. If the matches are fully determined by the number of vacancies, the economy takes on a core–periphery pattern when trade costs fall. However, if the labor matching is elastic, then the full agglomeration is replaced by a partial one. As trade freeness gradually increases, a re-dispersion process of the industry could emerge.

In conclusion, matching elasticity is crucial for determining the configuration of economic geography. Moreover, we show that the bargaining power of workers acts as an agglomeration force by amplifying the HME. The unemployment rate is lower and the expected wage is higher in the agglomerated region. Both unemployed workers and employed workers are better off in the more agglomerated region.

Chapter 3 shows that capital mobility and population sizes are crucial factors in determining technology selection and intra-country inequalities. More precisely, if the population differential is sufficiently large, the small country always has a stronger incentive to export since the large market is attractive. Then the skill selection threshold in the small country decreases rapidly, whereas the threshold value keeps constant in the large country with decreasing trade costs. On the contrary, when the population differential is small, there is a stage that in both countries, only the more productive technology is exportable. Capital mobility affects the skill selection only if the trade is in that stage. Since the skill selection cutoff directly determines the intra-country inequality, we conclude that capital mobility affects the intra-country income inequality for a small population differential.

Moreover, Chapter 3 also explores how real incomes from labor markets and capital markets change in international trade. We find that trade may lead to a lower real total income in different exporting statuses when capital is mobile across countries. When trade starts and capital is internationally mobile, the large country attracts a more-than-proportionate share of capital due to the HME. However, the HME diminishes gradually when low-tech firms in the small country start exporting. With capital inflow, real labor income increases, whereas real capital income decreases. Exploring by numerical simulations, we find that the workers in the small country bear a loss in trade when the fixed cost for exporting is sufficiently small. With a small barrier for fixed input in foreign markets, the home market effect is more substantial when trade starts. As a result, the welfare for workers in the small country could decrease with the opening of trade and capital mobility.

Chapter 4 contributes to the literature by developing a detailed evaluation framework to assess the economic impacts of investment in BRI transportation infrastructure projects from China. Unlike previous studies, we provide an ex-post assessment based on the actual investment data by capturing the effect of transportation infrastructure through the reduction in trade cost. One should note that our study has several limitations that need to be improved in future research endeavors. First, given that the elasticity of trade cost was estimated from the regression model based on the historical data, the accuracy could be affected by the quality of the statistical data. Therefore, future research could be expanded through conducting sensitivity analysis to further examine to what extent the research finding is consistent given the change in the base data. Second, the analysis can be improved if more specific data of infrastructure investment among different countries (particularly developing countries) can be collected and applied to calculate the magnitude of drivers of the economy. Third, due to the data limitation, our assessment does not differentiate the economic impact of infrastructure investment by different transportation modes (sea, rail and road, and air), which again deserves to be further investigated in future research so that the effectiveness of investment in various transportation modes can be analyzed. Last but not least, the existing CGE modeling framework was based on the standard GTAP model, which does not explicitly capture any spatial spillover effect of the transportation infrastructure investment. There may also exist some biases in the results of small countries. Therefore, it would be worthwhile incorporating more advanced methods, such as spatial econometric analysis, into CGE analysis so that the effect of intra-regional trade and spatial effects of infrastructure investment can be captured.

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Appendix A

Appendixes for Chapter 2

A.1 Calculation of marginal revenue

Equation (2.3) can be rewritten as

$$p_{ii} = d_{ii}^{-\frac{1}{\sigma}} Y_i^{\frac{1}{\sigma}} P_i^{\frac{\sigma-1}{\sigma}},\ p_{ij} = d_{ij}^{-\frac{1}{\sigma}} Y_j^{\frac{1}{\sigma}} P_j^{\frac{\sigma-1}{\sigma}},\ i \neq j.$$

The revenue from the local and foreign markets for firm i are expressed as

$$R_{ii} = p_{ii} d_{ii} = d_{ii}^{\frac{\sigma-1}{\sigma}} Y_i^{\frac{1}{\sigma}} P_i^{\frac{\sigma-1}{\sigma}} = (\varphi l_{ii})^{\frac{\sigma-1}{\sigma}} Y_i^{\frac{1}{\sigma}} P_i^{\frac{\sigma-1}{\sigma}},$$

$$R_{ij} = p_{ij} d_{ij} = d_{ij}^{\frac{\sigma-1}{\sigma}} Y_j^{\frac{1}{\sigma}} P_j^{\frac{\sigma-1}{\sigma}} = \left(\frac{\varphi l_{ij}}{\tau}\right)^{\frac{\sigma-1}{\sigma}} Y_j^{\frac{1}{\sigma}} P_j^{\frac{\sigma-1}{\sigma}}.$$

The marginal revenues of the two markets are calculated as

$$\frac{\partial R_{ii}}{\partial l_{ii}} = \frac{\sigma-1}{\sigma} \varphi^{\frac{\sigma-1}{\sigma}} Y_i^{\frac{1}{\sigma}} P_i^{\frac{\sigma-1}{\sigma}} l_{ii}^{-\frac{1}{\sigma}},\ \frac{\partial R_{ij}}{\partial l_{ij}} = \frac{\sigma-1}{\sigma} \left(\frac{\varphi}{\tau}\right)^{\frac{\sigma-1}{\sigma}} Y_j^{\frac{1}{\sigma}} P_j^{\frac{\sigma-1}{\sigma}} l_{ij}^{-\frac{1}{\sigma}}.$$

A.2 Proof of (2.5)

Following (2.4), we can derive that

$$
\begin{aligned}
R_i =& R_{ii} + R_{ij} \\
=& (\varphi l_i)^{\frac{\sigma-1}{\sigma}} Y_i^{\frac{1}{\sigma}} P_i^{\frac{\sigma-1}{\sigma}} \left(\frac{P_i^{\sigma-1} Y_i}{P_i^{\sigma-1} Y_i + \phi P_j^{\sigma-1} Y_j} \right)^{\frac{\sigma-1}{\sigma}} \\
& + \left(\frac{\varphi l_i}{\tau} \right)^{\frac{\sigma-1}{\sigma}} Y_j^{\frac{1}{\sigma}} P_j^{\frac{\sigma-1}{\sigma}} \left(\frac{\phi P_j^{\sigma-1} Y_j}{P_i^{\sigma-1} Y_i + \phi P_j^{\sigma-1} Y_j} \right)^{\frac{\sigma-1}{\sigma}} \\
=& \left[\frac{P_i^{\sigma-1} Y_i}{\left(P_i^{\sigma-1} Y_i + \phi P_j^{\sigma-1} Y_j \right)^{\frac{\sigma-1}{\sigma}}} + \frac{P_j^{\sigma-1} Y_j \phi}{\left(P_i^{\sigma-1} Y_i + \phi P_j^{\sigma-1} Y_j \right)^{\frac{\sigma-1}{\sigma}}} \right] (\varphi l_i)^{\frac{\sigma-1}{\sigma}} \\
=& \left(P_i^{\sigma-1} Y_i + \phi P_j^{\sigma-1} Y_j \right)^{\frac{1}{\sigma}} (\varphi l_i)^{\frac{\sigma-1}{\sigma}} .
\end{aligned}
$$

A.3 Proof of Lemma 1

Let $\tilde{k} \equiv k/(1-k)$. For simplicity, we keep the function notations $\mathcal{F}^L(\cdot)$ and $\mathcal{B}_i(\cdot)$ $(i = 0, 1, 2)$ even when their variables are $\tilde{k}$ rather than k. Differentiating $\mathcal{F}^L(\tilde{k})$ with respect to $\tilde{k}$ in (2.29), we obtain

$$
\begin{aligned}
f_0 \equiv& \frac{\partial \mathcal{B}_0(\tilde{k})}{\partial \tilde{k}} + \frac{\partial [\mathcal{B}_2(\tilde{k})\phi^2]}{\partial \tilde{k}} = \phi^2[\beta(\sigma-2)+\sigma] + \sigma(1-\beta) > 0, \\
f_1 \equiv& \frac{\partial [\mathcal{B}_1(\tilde{k})\phi]}{\partial \tilde{k}} \\
=& 2\phi(\sigma-\beta)\tilde{k}^{(\mu-1)(\sigma+1)-1} \Big\{ [(1-\mu)(\sigma-1)-1]\tilde{k}^{3-2\mu} + (1-\mu)(\sigma-1)\tilde{k}^{2\sigma(1-\mu)} \Big\}.
\end{aligned}
$$

When $(1-\mu)(\sigma-1)-1 > 0$, we have $f_1 > 0$. $\mathcal{F}^L(\tilde{k})$ is an increasing function of $\tilde{k}$. The long-run equation (2.29) only has one solution, $\tilde{k} = 1$.

When $(1-\mu)(\sigma-1) < 1$, we have

$$
\frac{\partial f_1}{\partial \tilde{k}} = 2(1-\mu)(\sigma-1)(\sigma-\beta)[(1-\mu)(\sigma-1)-1]\tilde{k}^{-2} \left(\tilde{k}^{(1-\mu)(\sigma-1)} - \tilde{k}^{1-(1-\mu)(\sigma-1)} \right) \phi.
$$

Since $\mathcal{B}_0 + \mathcal{B}_2(\tilde{k})\phi^2 < 0$ for $\tilde{k} < 1$, $\mathcal{B}_1(\tilde{k})\phi = -\mathcal{B}_0 - \mathcal{B}_2(\tilde{k})\phi^2 > 0$ holds in the long-run equilibrium. Accordingly, $\tilde{k}^{(1-\mu)(\sigma-1)} - \tilde{k}^{1-(1-\mu)(\sigma-1)} > 0$ is true in equilibrium.

Therefore, we have

$$\frac{\partial^2 \mathcal{F}^L(\tilde{k})}{\partial \tilde{k}^2}\Big|_{\mathcal{F}^L(\tilde{k})=0} = \frac{\partial f_1}{\partial \tilde{k}}\Big|_{\mathcal{F}^L(\tilde{k})=0} > 0, \text{ for } (1-\mu)(\sigma-1) < 1,$$

where $\mathcal{F}^L(\tilde{k}) = 0$ has one solution at most in $(0,1)$. Since the two regions are symmetric, $\mathcal{F}^L(\tilde{k}) = 0$ has three solutions at most for $k \in (0,1)$.

A.4 A general form of hiring costs

In this appendix, we show that our results are robust even if the hiring cost is paid by both capital and labor. In real life, there is a human resource department. Now we assume that a firm needs to pay $c\eta$ units of labor working as human resource sector and $c(1-\eta)$ units of capital with $\eta \in [0,1)$ to post one vacancy. The total employment level (l_i^t) of a firm located in region i satisfies

$$l_i^t = l_i + \frac{c\eta}{m}\alpha_i^{1-\mu} l_i^t,$$

where l_i is the number of workers working for production. Let $A_i \equiv 1-(c\eta/m)\,\alpha_i^{1-\mu}$ denote the share of workers in the production department. Then we have $l_i^t = l_i/A_i$. The profit of a firm in region i is

$$\pi(l_i^t) = R(l_i^t) \underbrace{- w_i l_i - c\eta \frac{\alpha_i^{1-\mu}}{m} l_i^t w_i}_{labor} \underbrace{- c(1-\eta)\frac{\alpha^{1-\mu}}{m} l_i^t r_i - r_i}_{capital}$$

Similar to Section 2.4, the wage rate in the Nash bargaining is

$$w_i = \text{argmax } w_i^{\beta} \cdot \left[\frac{\partial R(l_i^t) - w_i l_i^t}{\partial l_i^t}\right].$$

The solution of the equation above is

$$w_i = \frac{\beta(1-\sigma)}{\sigma-\beta}\frac{R_i}{l_i^t}.$$

Maximizing the profit with respect to l_i^t, we have

$$\frac{c(1-\eta)}{m}\alpha^{1-\mu} r_i = \frac{(1-\beta)(\sigma-1)}{\sigma-\beta}\frac{R_i}{l_i^t}.$$

The total capital employed by a firm is σ. The labor market tightness in region i is solved as

$$\alpha_i = \frac{2(\sigma-1)}{c\sigma(1-\eta)}k_i.$$

The optimal price is solved as $p_{ii} = w_i/A_i$, $p_{ij} = \tau w_i/A_i$, for $i, j = 1, 2$, $i \neq j$. Then we get the price indices in the two regions,

$$P_i = \left\{\left[k_i\left(\frac{w_i}{A_i}\right)^{1-\sigma} + \phi k_j\left(\frac{w_j}{A_j}\right)^{1-\sigma}\right]\frac{K}{\sigma}\right\}^{\frac{1}{1-\sigma}}.$$

The labor market clearing condition is given as

$$(1-u_1)w_1 L_1 A_1 = k\frac{K}{\sigma\varphi}(d_{11} + \tau d_{12}).$$

Following the process in our basic framework, the stability condition at the symmetric equilibrium is written as

$$\left.\frac{\mathrm{d}\Delta r}{\mathrm{d}k}\right|_{k=\frac{1}{2}} = \frac{16\phi(\sigma-\beta)\sigma\left\{\eta(\sigma-1)-(1-\eta)c^2m\left[\mu(\sigma-1)+1\right]\left[\frac{\sigma-1}{(1-\eta)}\right]^{\mu}\right\}}{\left\{\phi^2\left[\beta(\sigma-2)+\sigma\right]+2(2\sigma-1)\phi(\sigma-\beta)+\sigma(1-\beta)\right\}}\times$$
$$\frac{1}{\eta(\sigma-1)+(\eta-1)c^2m\sigma\left[\frac{\sigma-1}{(1-\eta)\sigma}\right]^{\mu}} - 4 < 0,$$

The locus of $(\mathrm{d}\Delta r/\mathrm{d}k)\big|_{k=1/2}$ is an inverted-U shape with respect to ϕ. The symmetric equilibrium becomes unstable if $(\mathrm{d}\Delta r/\mathrm{d}k)\big|_{k=1/2} > 0$.

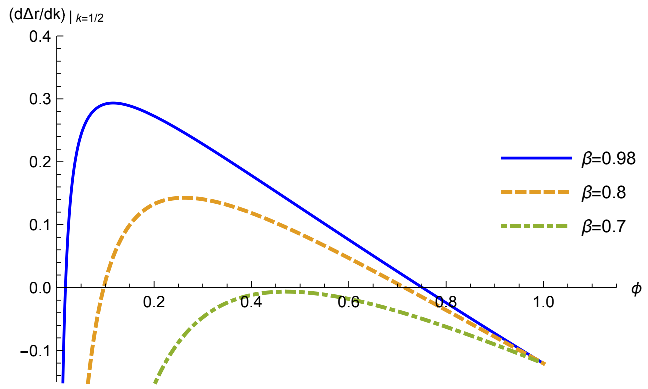

Figure A.1: Loci of $(\mathrm{d}\Delta r/\mathrm{d}k)\big|_{k=1/2}$ with different β

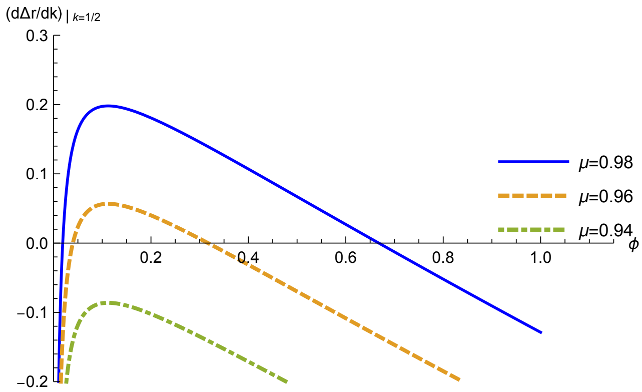

Figure A.2: Loci of $(\mathrm{d}\Delta r/\mathrm{d}k)\,\big|_{k=1/2}$ with different μ

Figure A.1 ($\sigma = 4$, $\mu = 0.95$, $eta = 0.4$, $c^2 m = 0.8$) shows that the locus of $(\mathrm{d}\Delta r/\mathrm{d}k)\,\big|_{k=1/2}$ crosses the horizontal axis twice for a large β. That is, the symmetry breaks when the bargaining power is large and trade costs are intermediate. In Figure A.2 ($\sigma = 5$, $\beta = 0.98$, $\eta = 0.4$, $c^2 m = 0.8$), we observe that the symmetric equilibrium becomes unstable when μ is sufficiently large. We can calculate that $(\mathrm{d}\Delta r/\mathrm{d}k)\,\big|_{k=1/2,\phi=1} = 0$ when $\mu = 1$. Hence, for $\mu = 1$, the dispersion pattern moves from symmetry to asymmetric agglomeration when trade costs are small and re-dispersion does not occur.

Simulations show that (i) the symmetry breaks for a large bargaining power and/or a large matching elasticity and (ii) re-dispersion emerges for $\mu < 1$ and disappears for $\mu = 1$. In conclusion, our main results are robust when vacancy costs are paid in a general form.

A.5 Proof of the properties for real incomes

(i) According to (2.30), the wage rate is not affected by trade costs in the symmetric equilibrium. According to (2.20), the price indices increase with trade costs in the symmetric equilibrium path. Both employed workers and unemployed workers are better off in the symmetric equilibrium with small trade costs.

(ii) According to Corollary 1, $(1 - \mu)(1 - \sigma) + 1 > 0$ is a necessary condition for the symmetry to break. Plugging (2.30) into (2.20), the price index in region

i is rewritten as

$$P_i = \frac{2^{1-\mu} c^{\mu} (\sigma - 1)^{1-\mu} \beta}{m(1-\beta)\sigma^{1-\mu}} \Big\{ [k_i^{(1-\mu)(1-\sigma)+1} + \phi(1-k_i)^{(1-\mu)(1-\sigma)+1}] \frac{K}{\sigma} \Big\}^{\frac{1}{1-\sigma}}.$$

If $(1-\mu)(1-\sigma)+1 > 0$, we have

$$\begin{aligned} \frac{\partial}{\partial k} \mathrm{Log}\Big(\frac{P_1}{P_2}\Big) &= - \frac{(1-\phi^2)[(1-\mu)(1-\sigma)+1](1-k)^{-2}}{(\sigma-1)\Big[\big(\frac{k}{1-k}\big)^{\mu-1} + \phi\big(\frac{k}{1-k}\big)^{\mu\sigma}\Big]\Big[\phi\big(\frac{k}{1-k}\big)^{\mu-1} + \big(\frac{k}{1-k}\big)^{1-(1-\mu)\sigma}\Big]} \\ &< 0. \end{aligned}$$

In the long-run equilibrium, the more agglomerated region always has a lower price index. In Proposition 1, we have shown that the nominal wage is always higher in the more agglomerated region for $\mu < 1$ and the relative nominal wage equals 1 for $\mu = 1$. Hence, real incomes are always higher in the agglomerated region for both employed and unemployed workers.

Appendix B

Appendixes for Chapter 3

B.1 Proof of Lemma 2

From(3.29), $(C_1^L)^A$ can be rewritten as

$$(C_1^L)^A = \frac{(1-\theta){Z_2}^{\sigma-2}\left(F{Z_2}^{1-\sigma}-1\right)(1-{Z_2}^2)}{\theta {Z_1}^{\sigma-2}\left(F{Z_1}^{1-\sigma}-1\right)(1-{Z_1}^2)}. \tag{B.1}$$

From (3.23) and (3.20), we can solve that

$$\phi[(C_1^L)^A]^{-\sigma}\frac{(1+{Z_2}^2)Z_1}{(1+{Z_1}^1)Z_2} = F{Z_2}^{1-\sigma}-1, \quad \phi[(C_1^L)^A]^{\sigma}\frac{(1+{Z_1}^2)Z_2}{(1+{Z_2}^2)Z_1} = F{Z_1}^{1-\sigma}-1$$
$$\Rightarrow \left[(C_1^L)^A\right]^{2\sigma} = \frac{(1+{Z_2}^2)^2{Z_1}^2(F{Z_1}^{1-\sigma}-1)}{(1+{Z_1}^2)^2{Z_2}^2(F{Z_2}^{1-\sigma}-1)}.$$

Combining the above equation with (B.1), we can rewrite $(C_1^L)^A$ as

$$(C_1^L)^A = \left[\frac{(1-\theta)\left(1+{Z_1}^2\right)^2\left(1-{Z_2}^2\right)}{\theta\left(1-{Z_1}^2\right)\left(1+{Z_2}^2\right)^2{Z_1}^{\sigma}{Z_2}^{-\sigma}}\right]^{\frac{1}{2\sigma-1}}$$

In Stage III, we can eliminate C_1^{L*} to get the following equation,

$$\mathcal{F}_1(Z_1,Z_2) \equiv \log\left[\frac{(1-\theta)\left(1+{Z_1}^2\right)^2\left(1-{Z_2}^2\right)}{\theta\left(1-{Z_1}^2\right)\left(1+{Z_2}^2\right)^2{Z_1}^{\sigma}{Z_2}^{-\sigma}}\right]$$
$$-\frac{2\sigma-1}{2\sigma}\log\left[\frac{\left({Z_1}^2+1\right)^2 Z_2^2\left(F{Z_1}^{1-\sigma}-1\right)}{{Z_1}^2\left({Z_2}^2+1\right)^2\left(F{Z_2}^{1-\sigma}-1\right)}\right] = 0. \tag{B.2}$$

If $Z_1^* = Z_2^*$, it is easy to verify that (B.2) does not hold for $\theta > 1/2$. From (3.20), we have another equation

$$\mathcal{F}_2(Z_1, Z_2) \equiv \log\left[\left(F{Z_1}^{1-\sigma} - 1\right)\left(F{Z_2}^{1-\sigma} - 1\right)\right] - \log\left(\phi^2\right) = 0. \tag{B.3}$$

Therefore, we can solve the equilibrium of the case with immobile capital by solving $\{{Z_1}^*, {Z_2}^*\}$ from (B.2) and (B.3).

$$\left.\frac{\partial Z_j}{\partial Z_i}\right|_{\mathcal{F}_1(\cdot)=0} = -\frac{\partial \mathcal{F}_1/\partial Z_i}{\partial \mathcal{F}_1/\partial Z_j} = \frac{\mathcal{A}(Z_i)}{\mathcal{A}(Z_j)}$$

where

$$\begin{aligned}\mathcal{A}(Z_i) \equiv &\frac{(\sigma-1)\left[\left(F - {Z_i}^{\sigma-1}\right)\left(1+3{Z_i}^4\right) + (2\sigma-1){Z_i}^{\sigma-1}\left(1-{Z_i}^4\right)\right]}{Z_i\left(1-{Z_i}^4\right)\left(F-{Z_i}^{\sigma-1}\right)} \\ &+ \frac{4(\sigma+1)(F-{Z_i}^{\sigma-1}){Z_i}^2}{Z_i\left(1-{Z_i}^4\right)\left(F-{Z_i}^{\sigma-1}\right)}.\end{aligned}$$

Furthermore, we can derive that

$$\begin{aligned}\left.\frac{\partial Z_i}{\partial \phi}\right|_{\mathcal{F}_2(\cdot)=0} &= -\frac{\partial \mathcal{F}_2/\partial \phi}{\partial \mathcal{F}_2/\partial Z_i + (\partial \mathcal{F}_2/\partial Z_j)(\partial Z_j/\partial Z_i)} \\ &= -\frac{2Z_iZ_j\left(F-{Z_i}^{\sigma-1}\right)\left(F-{Z_j}^{\sigma-1}\right)}{F(\sigma-1)\phi\left[(\partial Z_j/\partial Z_i)\left(F-{Z_i}^{\sigma-1}\right)Z_i + F - {Z_j}^{\sigma-1}\right]}.\end{aligned}$$

From (3.20), it can observed that $F{Z_i^*}^{1-\sigma} > 1$ holds in the equilibrium when $Z_i^* < 1$. Then, we can derive that $\partial Z_i^*/\partial\phi > 0$ for $Z_i^* < 1$.

We can verify that $\{Z_1^* = F^{1/(\sigma-1)}$, $Z_2^* = F^{1/(\sigma-1)}$, $(C_1^L)^A = [\theta/(1-\theta)]^{1/(2\sigma-1)}\}$ is the solution when $\phi \to 0$. Then we have

$$\left.\frac{\partial Z_1^*}{\partial \phi}\right|_{\phi\to 0} = -\frac{F^{\frac{1}{\sigma-1}}\left((C_1^L)^A\right)^{-\sigma}}{(\sigma-1)} < 0, \quad \left.\frac{\partial Z_2^*}{\partial \phi}\right|_{\phi\to 0} = -\frac{F^{\frac{1}{\sigma-1}}\left((C_1^L)^A\right)^{\sigma}}{(\sigma-1)} < 0 \tag{B.4}$$

Since $Z_1^* \neq Z_2^*$ for $\theta > 1/2$, we conclude that $Z_1^* > Z_2^*$ for $\phi \in (0, 1)$.

Following (i) in this lemma and (3.20), (ii) can be also proved.

B.2 Proof of Lemma 3

Using (3.24), (3.20), and (3.30), $(C_1^L)^B$ can we rewritten in the following two forms,

$$(C_1^L)^B = \frac{\sigma(1-\theta){Z_2}^{\sigma-2}\left(F{Z_2}^{1-\sigma}-1\right)(1-{Z_2}^2) - F\theta(1-\theta)\frac{1+{Z_2}^2}{Z_2}}{\sigma\theta{Z_1}^{\sigma-2}\left(F{Z_1}^{1-\sigma}-1\right)(1-{Z_1}^2) - F\theta(1-\theta)\frac{1+{Z_1}^2}{Z_1}}, \tag{B.5}$$

$$(C_1^L)^B = \left(\frac{F-{Z_1}^{\sigma-1}}{F-{Z_2}^{\sigma-1}}\right)^{\frac{1}{2\sigma-2}}. \tag{B.6}$$

Similar to the proof in Lemma 2, we can get the following equation to solve $({Z_1}^\sharp, {Z_2}^\sharp)$,

$$\begin{aligned}\mathcal{F}_3(Z_1, Z_2) \equiv{}& \frac{1}{2\sigma-2}\log\left(\frac{F{Z_1}^{1-\sigma}-1}{F{Z_2}^{1-\sigma}-1}\right) + \log(\theta) - \log(1-\theta)\\ &- \log\left[\frac{\sigma{Z_2}^{\sigma-2}\left(F{Z_2}^{1-\sigma}-1\right)(1-{Z_2}^2) - F\theta\frac{1+{Z_2}^2}{Z_2}}{\sigma{Z_1}^{\sigma-2}\left(F{Z_1}^{1-\sigma}-1\right)(1-{Z_1}^2) - F(1-\theta)\frac{1+{Z_1}^2}{Z_1}}\right] = 0.\end{aligned} \tag{B.7}$$

We can solve $\{{Z_1}^\sharp, {Z_2}^\sharp\}$ from (B.7) and (3.21).

$$\left.\frac{\partial Z_2}{\partial Z_1}\right|_{\mathcal{F}_3(\cdot)=0} = -\frac{\partial\mathcal{F}_3/\partial Z_1}{\partial\mathcal{F}_3/\partial Z_2} = -\frac{\mathcal{B}_1(Z_1)Z_1^{\sigma+1}}{\mathcal{B}_2(Z_2)Z_2^{\sigma+1}}\mathcal{C}(Z_1, Z_2)$$

where

$$\begin{aligned}\mathcal{B}_1(Z_1 \equiv)&\sigma\left(3{Z_1}^2+1\right){Z_1}^{1-\sigma}\left(F-{Z_1}^{\sigma-1}\right)^2 + (2\sigma-3)\sigma\left(1-{Z_1}^2\right)\left(F-{Z_1}^{\sigma-1}\right)\\ &+ F(1-\theta)\left(2-F{Z_1}^{1-\sigma}\right) + F(1-\theta){Z_1}^2\left(3F{Z_1}^{1-\sigma}-2\right),\\ \mathcal{B}_2(Z_2) \equiv&\sigma\left(3{Z_2}^2+1\right){Z_2}^{1-\sigma}\left(F-{Z_2}^{\sigma-1}\right)^2 + (2\sigma-3)\sigma\left(1-{Z_2}^2\right)\left(F-{Z_2}^{\sigma-1}\right)\\ &+ F\theta\left(2-F{Z_2}^{1-\sigma}\right) + F\theta{Z_2}^2\left(3F{Z_2}^{1-\sigma}-2\right),\end{aligned}$$

and

$$\mathcal{C}(\cdot) \equiv -\frac{FZ_2\left[\theta\left(1+{Z_2}^2\right) - \sigma\left(1-{Z_2}^2\right)\right] + \sigma\left(1-{Z_2}^2\right){Z_2}^\sigma}{FZ_1\left[(1-\theta)(1+{Z_1}^2) + \sigma(1-{Z_1}^2)\right] + \sigma\left(1-{Z_1}^2\right){Z_1}^\sigma}$$

According to (B.1), $\mathcal{C}(\cdot) \propto -(C_1^L)^B < 0$.

$$\begin{aligned}\frac{\partial Z_1}{\partial\phi} &= -\frac{\partial\mathcal{F}_2/\partial\phi}{\partial\mathcal{F}_2/\partial Z_1 + (\partial\mathcal{F}_2/\partial Z_2)(\partial Z_2/\partial Z_1)}\\ &= -\frac{2Z_1Z_2\left(F-{Z_1}^{\sigma-1}\right)\left(F-{Z_2}^{\sigma-1}\right)}{F(\sigma-1)\phi\left[(\partial Z_2/\partial Z_1)\left(F-{Z_1}^{\sigma-1}\right)Z_1 + Z_2(F-{Z_2}^{\sigma-1})\right]}\end{aligned}$$

We can observe that $F > {Z_i^\sharp}^{\sigma-1}$ holds in the equilibrium. Then, we can derive that $\partial Z_2/(\partial Z_1)|_{\mathcal{F}_3(\cdot)=0} > 0$ using $\sigma > 3/2$. Hence, $\partial Z_i^\sharp/\partial\phi < 0$ for $\sigma > 3/2$.

If $Z_1 = Z_2 \in (0,1)$, ${C_1^L}^\sharp \neq 1$ for any $\theta > 1/2$ from (B.5). This is contradict to (B.6). Hence, we conclude that ${C_1^L}^\sharp \neq 1$ and $Z_1^\sharp \neq Z_2^\sharp$.

We can easily verify that $\{Z_1^\sharp = 1, Z_2^\sharp = 1, {C_1^L}^\sharp = 1\}$ is the solution at $\phi = 0$ for $F < 1$. Then we have

$$\frac{\partial {C_1^L}^\sharp}{\partial\phi}\Big|_{\phi=0} = \frac{(2\theta-1)\sigma F^{\frac{3\sigma+2}{\sigma-1}}\left(1 - F^{\frac{4}{\sigma-1}}\right)}{(1-\theta)\theta\left(F^{\frac{2\sigma+2}{\sigma-1}} + F^{\frac{2\sigma}{\sigma-1}}\right)^2} > 0 \tag{B.8}$$

$$\frac{\partial Z_1^\sharp}{\partial\phi}\Big|_{\phi=0} = \frac{\partial Z_2^\sharp}{\partial\phi}\Big|_{\phi=0} = \frac{F^{\frac{1}{\sigma-1}}}{\sigma-1}.$$

Equation (B.8) implies $(C_1^L)^B > 1$ for $\phi > 0$. Combining this result with (B.6), we can conclude that $Z_1^\sharp > Z_2^\sharp$ for $\phi > 0$ and $F < 1$. Then (ii) can also be proved.

B.3 Proof of Corollary 2

We prove that $Z_i^* \neq Z_i^\sharp$ by contradiction. Assume there exist a $\phi \in (0,1)$ makes $Z_i^* = Z_i^\sharp$. Then, according to (3.22), the following equation must be true at that point,

$$[(C_1^L)^A]^{-\sigma}\frac{\left(1+{Z_2}^2\right)Z_1}{\left(1+{Z_1}^2\right)Z_2} = [(C_1^L)^B]^{1-\sigma}.$$

Combining the above equation with (B.5) and (B.1) leads to

$$\frac{\left(1+{Z_2}^2\right)Z_1}{\left(1+{Z_1}^2\right)Z_2} = \frac{(1-\theta){Z_2}^{\sigma-2}\left(F{Z_2}^{1-\sigma}-1\right)\left(1-{Z_2}^2\right)}{\theta{Z_1}^{\sigma-2}\left(F{Z_1}^{1-\sigma}-1\right)\left(1-{Z_1}^2\right)} = (C_1^L)^A$$
$$\Rightarrow \frac{\left(1+{Z_2}^2\right)Z_1}{(C_1^L)^A\left(1+{Z_1}^2\right)Z_2} = 1 \;\Rightarrow \frac{W_2}{W_1} = 1.$$

The last equation contradicts (ii) in Lemma 2, since the expected wage income is always higher in the large country. Hence, $Z_i^* = Z_i^\sharp$ is impossible, which means that the curves of Z_i^* and $Z_i^\sharp$ do not cross with each other for any $\phi > F - 1$.

According to the proofs of Lemmas 2 and 3, the following inequalities hold,

$$\frac{\partial Z_1^*}{\partial\phi}\Big|_{\phi=0} > \frac{\partial Z_1^\sharp}{\partial\phi}\Big|_{\phi=0} = \frac{\partial Z_2^\sharp}{\partial\phi}\Big|_{\phi=0} > \frac{\partial Z_2^*}{\partial\phi}\Big|_{\phi=0}.$$

Therefore, we can conclude that $Z_1^* > Z_1^\sharp$, $Z_2^* < Z_1^\sharp$ for $\sigma > 3/2$. $\square$

B.4 Proof of Proposition 5

Stage I $\to$ II

In section 3.3.1, we have shown that $\phi = F^X/F^H$ is the starting point for trade. In both countries, H firms have an incentive to export. Next, we show that at $\phi = F^X/F^H$, only a part of H firms in the large country start to export, whereas all H firms in the small country choose to export in the equilibrium (Stage II).

If H exporter and L non-exporter co-exist, the ratio of the expectable capital rents of t firms in country i with different exporting status can be rewritten as

$$\frac{(r_i^t)^X}{(r_i^t)^D} = \left(1 + \phi \frac{Y_j P_i^{1-\sigma}}{Y_i P_j^{1-\sigma}}\right) \frac{F^t}{F^t + F^X} \overset{(3.20)}{=} F Z_i^{1-\sigma} \frac{F^t}{F^t + F^X}. \tag{B.9}$$

Lemma 4 *Assume that $F^X < F^H$ and $\sigma > 3/2$. When trade cost falls, the trade pattern changes from Stage I to II at $\phi = F^X/F^H$.*

Proof We first suppose that the trade evolves Stage III at $\phi = F^X/F^H$. By using (ii) in Lemmas 2 and 3, we have $Z_2^* < \left(F^H/F^L\right)^{\frac{1}{\sigma-1}} \Psi < Z_1^*$ and $Z_2^\sharp < \left(F^H/F^L\right)^{\frac{1}{\sigma-1}} \Psi < Z_1^\sharp$ at $\phi = F^X/F^H$. Combining these inequalities with (B.9) gives

$$\left.\frac{(r_1^H)^X}{(r_1^H)^D}\right|_{\{Z_1^*, Z_2^*\}} < 1, \quad \left.\frac{(r_1^H)^X}{(r_1^H)^D}\right|_{\{Z_1^\sharp, Z_2^\sharp\}} < 1,$$
$$\left.\frac{(r_2^H)^X}{(r_2^H)^D}\right|_{\{Z_1^*, Z_2^*\}} > 1, \quad \left.\frac{(r_2^H)^X}{(r_2^H)^D}\right|_{\{Z_1^\sharp, Z_2^\sharp\}} > 1.$$

Accordingly, if all H firms in country 1 export $\phi = F^X/F^H$, they will find that it is profitable to stop serving the foreign market. Meanwhile, H firms in country 2 have no incentive to stop exporting. $\square$

Then we conclude that Stage II is appropriate when ϕ rises from F^X/F^H: only a part of H firms in the large country export whereas all H firms located in the small country export (Stage II).[1] At this stage, H firms in the large country pay the same capital rents no matter they are exporters or not.

Stage II → III

With decreasing trade costs, it is possible that all H firms exports in two countries. Next, we explore the condition for Stage III happens.

Suppose that the exporting fixed cost is not too large, such that $F^X < \sqrt{F^H F^L}$. Then we have

$$Z_2\big|_{\{(3.27),\phi=F^X/\sqrt{F^H F^L}\}} = \left(\frac{F^H + F^X}{F^L + F^X}\right)^{\frac{1}{\sigma-1}} \Psi,$$

which is the cutoff for both technologies are exportable. Hence, Stage II is only possible for $\phi \in (F^X/F^H, F^X/\sqrt{F^H F^L})$. In this range, if $n_1^H|_{(3.28)} < 1$, then the trade pattern takes the form of Stage II. Meanwhile, if the $n_1^H|_{(3.28)} \geqslant 1$, Stage II is impossible, implying that trade evolves into another stage.

We can derive the following lemmas.

Lemma 5 *Assume that $F^X < \sqrt{F^H F^L}$.*

$$\frac{\partial n_1^H}{\partial \theta}\Big|_{(3.28)} < 0 \quad \textit{for} \quad \phi \in \left(\frac{F^X}{F^H}, \frac{F^X}{\sqrt{F^H F^L}}\right).$$

Proof Substituting $n_2^L = 0$ into (3.25) and (3.26), Equation (3.28) can be rewritten as follows

$$\begin{aligned}
\mathcal{J}^A(n_1^H)\big|_{(3.27)} =& \frac{\theta\left(1 - {Z_1}^2\right)}{(1-\theta)Z_1}\left(1 - \frac{F^L {Z_1}^{\sigma-1}\Psi^{1-\sigma}}{F^H + F^X n_1^H}\right) \\
&- \left(1 - \frac{1}{F{Z_2}^{1-\sigma}}\right)\frac{1 - {Z_2}^2}{(C_1^L)^A Z_2}\Big|_{(3.27)} = 0, \\
\mathcal{J}^B(n_1^H)\big|_{(3.27)} \equiv& \left[\frac{1 + {Z_1}^2}{Z_1} + \sigma\left(\frac{F^L {Z_1}^{\sigma-1}\Psi^{1-\sigma}}{F^H + F^X n_1^H} - 1\right)\frac{1 - {Z_1}^2}{Z_1(1-\theta)}\right](C_1^L)^B \\
&- \frac{1 + {Z_2}^2}{Z_2} + \sigma\left(1 - \frac{{Z_2}^{\sigma-1}}{F}\right)\frac{1 - {Z_2}^2}{Z_2\theta}\Big|_{(3.27)} = 0
\end{aligned}$$

[1]Since L firms are not exportable at $\phi = F^X/F^H$, Stages IV and V are excluded

According to (3.20), $F{Z_2}^{1-\sigma} > 1$. Then we can show that

$$\left.\frac{\partial \mathcal{J}^A}{\partial n_1^H}\right|_{(3.27)} > 0, \quad \left.\frac{\partial \mathcal{J}^A}{\partial \theta}\right|_{(3.27)} > 0.$$

Since $Z_1|_{(3.27)} > Z_2|_{(3.27)}$ for $\phi > F^X/F^L$, we have $(C_1^L)^B > 1$ from (3.20) – (3.22) and (3.24). Then, we have

$$\left.\frac{1+{Z_1}^2}{Z_1}(C_1^L)^B - \frac{1+{Z_2}^2}{Z_2}\right|_{(3.27)} > 0.$$

According to $\mathcal{J}^B = 0$,

$$\left.\frac{F^L\Psi^{1-\sigma}{Z_1}^{\sigma-1}}{F^H + F^X n_1^H} - 1\right|_{(3.27)} < 0.$$

Then we can derive that

$$\left.\frac{\partial \mathcal{J}^B}{\partial n_1^H}\right|_{(3.27)} < 0, \quad \left.\frac{\partial \mathcal{J}^B}{\partial \theta}\right|_{(3.27)} < 0.$$

□

Lemma 5 implies that whether trade keeps in Stage II is related to the market size. With a larger θ, $n_1^H|_{(3.28)} < 1$ is more likely, which means that trade stays in Stage II. For a small θ, $n_1^H|_{(3.28)} \geqslant 1$ is more possible, implying that the trade pattern is changed to another stage.

Lemma 6 *Assume that* $\sigma > 3/2$, $F^X < \sqrt{F^H F^L}$ *and* $\phi \in (F^X/F^H, F^X/\sqrt{F^H F^L})$. $\tilde{\theta}^S$ *increases with* ϕ.

Proof If the solution $\underline{\phi}^A$ exists in Case A, we can solve that $Z_i|_{(3.27)} = Z_i^*$ at $\phi = \underline{\phi}^A$, since (3.28) and (3.29) take the same form for $n_1^H = 1$. According to (i) of Lemma 2, $Z_1^* < Z_1|_{(3.27)}$ for $\phi \in (\underline{\phi}^A, F^X/\sqrt{F^H F^L})$. Hence, if $\underline{\phi}^A$ exists, it is unique. Since $\underline{\phi}^A(\theta)$ is the inverse function of $\tilde{\theta}^A(\phi)$, $\tilde{\theta}^A(\phi)$ is monotonic. Since

$$\tilde{\theta}^A|_{\phi=F^X/F^H} = 1/2, \quad \tilde{\theta}^A|_{\phi=F^X/\sqrt{F^L F^H}} > 1/2,$$

$\tilde{\theta}^A(\phi)$ is an increasing function. Similarly, the result in Case B can be proved. □

Then we have the following conclusion that Stage III is more likely to appear when θ is small.

Lemma 7 *Assume that* $\sigma > 3/2$, $F^X < \sqrt{F^H F^L}$ *and* $\phi \in (F^X/F^H, F^X/\sqrt{F^H F^L})$. *(i) If* $\theta > \tilde{\theta}^S|_{\phi=F^X/\sqrt{F^H F^L}}$, *then trade stays in Stage II. (ii) If* $\theta < \tilde{\theta}^S|_{\phi=F^X/\sqrt{F^H F^L}}$, *trade is in Stage II for* $\phi < \underline{\phi}^S$ *and changes in Stage III for* $\phi > \underline{\phi}^S$.

Proof For $\phi < F^X/\sqrt{F^H F^L}$, we can derive that

$$Z_1|_{(3.27)} > Z_2|_{(3.27)} > \left(\frac{F^H + F^X}{F^L + F^X}\right)^{\frac{1}{\sigma-1}} \Psi \overset{(B.9)}{\Rightarrow} \frac{(r_i^L)^X}{(r_i^L)^D}\Big|_{(3.27),\ \phi<F^X/\sqrt{F^H F^L}} < 1.$$

This implies for $\theta > \tilde{\theta}^S|_{\phi=F^X/\sqrt{F^H F^L}}$, trade keeps in Stage II.

At $\phi = \underline{\phi}^S$, the trade change from Stage II to Stage III. According to (i) of Lemmas 2 and 3 , if Stage III happens, the following expressions hold

$$Z_1^* < \left(\frac{F^H}{F^L}\right)^{\frac{1}{\sigma-1}} \Psi \quad \text{for Case } A, \quad Z_1^\sharp < \left(\frac{F^H}{F^L}\right)^{\frac{1}{\sigma-1}} \Psi \quad \text{for Case } B$$

According to (ii) of Lemmas 2 and 3 and (3.21), we can solve that for $\phi \in (\underline{\phi}^S, F^X/\sqrt{F^H F^L})$,

$$Z_1^* > Z_2^* > \left(\frac{F^H + F^X}{F^L + F^X}\right)^{\frac{1}{\sigma-1}} \Psi, \quad \text{for Case } A$$
$$Z_1^\sharp > Z_2^\sharp > \left(\frac{F^H + F^X}{F^L + F^X}\right)^{\frac{1}{\sigma-1}} \Psi, \quad \text{for Case } B$$

Combining the above inequalities in (B.9) gives

$$\frac{(r_i^L)^X}{(r_i^L)^D}\Big|_{\{Z_1^*, Z_2^*\}} < 1 \quad \text{for } \phi \in (\underline{\phi}^A, F^X/\sqrt{F^H F^L}),$$
$$\frac{(r_i^L)^X}{(r_i^L)^D}\Big|_{\{Z_1^\sharp, Z_2^\sharp\}} < 1 \quad \text{for } \phi \in (\underline{\phi}^B, F^X/\sqrt{F^H F^L}).$$

Since L technology are not exportable in $(\underline{\phi}^S, F^X/\sqrt{F^H F^L})$, trade stays in Stage III in this range. □

Figure B.1 shows the condition for Stages II and III happens. If (ϕ, θ) locates below the curve of $\tilde{\theta}^S$, trade pattern evolves in Stage III. If $\theta > \tilde{\theta}^S|_{\phi=F^X/\sqrt{F^H F^L}}$, Stage III does not emerge for any $\phi < F^X/\sqrt{F^H F^L}$.

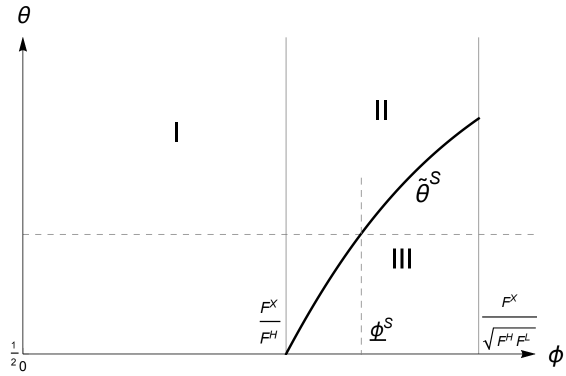

Figure B.1: Trade patterns with θ and ϕ ($\phi < F^X/\sqrt{F^H F^L}$)

Stage II → IV

Lemma 8 *Assume that* $F^X < \sqrt{F^H F^L}$ *and* $\theta > \tilde{\theta}^S|_{\phi=F^X/\sqrt{F^H F^L}}$. *With falling trade costs, the trade pattern changes from Stage II to Stage IV at* $\phi = F^X/\sqrt{F^H F^L}$.

Proof Suppose that trade is in Stage II at $\phi = F^X/\sqrt{F^H F^L}$. According to (3.27) and (B.9), the following inequalities hold at $\phi = F^X/\sqrt{F^H F^L}$,

$$\left.\frac{(r_1^H)^X}{(r_1^H)^D}\right|_{\{(3.27),\phi=F^X/\sqrt{F^H F^L}\}} = 1, \quad \left.\frac{(r_2^H)^X}{(r_2^H)^D}\right|_{\{(3.27),\phi=F^X/\sqrt{F^H F^L}\}} > 1.$$

$$\left.\frac{(r_1^L)^X}{(r_1^L)^D}\right|_{\{(3.27),\phi=F^X/\sqrt{F^H F^L}\}} < 1, \quad \left.\frac{(r_2^L)^X}{(r_2^L)^D}\right|_{\{(3.27),\phi=F^X/\sqrt{F^H F^L}\}} = 1.$$

It means that if an L firm in country 2 exports when ϕ becomes slightly larger than $F^X/\sqrt{F^H F^L}$, it earns a higher capital return if no other L firms export. Hence, if the trade is in Stage II at $\phi = F^X/\sqrt{F^H F^L}$, L firms in country 2 have incentive to export when trade freeness rises slightly. Meanwhile, L firms in country 1 are still not profitable to export. Then we conclude only Stage IV is appropriate at this point. □

Stage III → IV

In this section, we discuss when Stage III changes into another stage when trade costs fall. Suppose that $F^X < F^L$, we have the following intermediate result.

Lemma 9 *Assume $F^L < \phi F^X < F^H$. Stage IV is appropriate when ϕ are slightly smaller than F^X/F^L.*

Proof At $\phi = F^X/F^L$, by using (ii) in Lemmas 2 and 3, we have

$$Z_2^* < \left(\frac{F^H + F^X}{F^L + F^X}\right)^{\frac{1}{\sigma-1}} < Z_1^*, \quad Z_2^\sharp < \left(\frac{F^H + F^X}{F^L + F^X}\right)^{\frac{1}{\sigma-1}} < Z_1^\sharp.$$

We first suppose that the trade evolves Stage III at $\phi = F^X/F^L$. According to (B.9), we have

$$\left.\frac{(r_2^L)^X}{(r_2^L)^D}\right|_{\{Z_1^*, Z_2^*, \phi = F^X/F^H\}} > 1, \quad \left.\frac{(r_2^L)^X}{(r_2^L)^D}\right|_{\{Z_1^\sharp, Z_2^\sharp, \phi = F^X/F^H\}} > 1.$$

At $\phi = F^X/F^L$, L firms in country 2 are profitable to export, implying Stage III is impossible.

Assume that trade is in Stage IV at $\phi = F^X/F^L$.

$$\left.\frac{(r_1^L)^X}{(r_1^L)^D}\right|_{\{(3.31), \phi = F^X/F^L\}} = 1, \quad \left.\frac{(r_1^H)^X}{(r_1^H)^D}\right|_{\{(3.31), \phi = F^X/F^L\}} > 1,$$

$$\left.\frac{(r_2^L)^X}{(r_2^L)^D}\right|_{\{(3.31), \phi = F^X/F^L\}} = 1, \quad \left.\frac{(r_2^H)^X}{(r_2^H)^D}\right|_{\{(3.31), \phi = F^X/F^L\}} > 1.$$

Since

$$\left.\frac{\partial Z_1}{\partial \phi}\right|_{(3.31)} < 0, \quad \left.\frac{\partial Z_2}{\partial \phi}\right|_{(3.31)} = 0,$$

only L firms in country 2 are exportable when ϕ is slightly smaller than F^X/F^H. Hence, Stage IV is appropriate. □

For $\phi \in (F^X/\sqrt{F^H F^L}, F^X/F^L)$, only Stages III and IV are possible in this range. The trade pattern is determined as follows. If the solution satisfies $n_2^L|_{(3.32)} \leqslant 0$, trade stays in Stage III. If $n_2^L|_{(3.32)} > 0$, trade pattern takes the form of Stage IV. Then we can solve the specific condition for Stage III → IV.

Lemma 10 $\phi \in (F^X/\sqrt{F^H F^L}, F^X/F^L)$, $\partial n_2^L/(\partial\theta)|_{(3.28)} > 0$.

Proof I Stage IV, Equation (3.32) can be rewritten as follows,

$$\begin{aligned}\mathcal{J}^A(n_2^L)|_{(3.31)} =& \frac{\theta\left(1-{Z_1}^2\right)Z_2}{(1-\theta)\left(1-{Z_2}^2\right)Z_1}\left(1-\frac{{Z_1}^{\sigma-1}}{F}\right)(C_1^L)^A \\ & -\left(F{Z_2}^{1-\sigma}-1\right)\left[\frac{1}{F{Z_2}^{1-\sigma}}+\frac{2{Z_2}^2F^Ln_2^L}{\left(1-{Z_2}^2\right)(F^L+F^Xn_2^L)}\right]\Bigg|_{(3.31)} \\ \mathcal{J}^B(n_2^L)|_{(3.31)} =& \left[\frac{1+{Z_1}^2}{Z_1}+\sigma\left(\frac{{Z_1}^{\sigma-1}}{F}-1\right)\frac{1-{Z_1}^2}{Z_1(1-\theta)}\right](C_1^L)^B \\ & -\frac{1+{Z_2}^2}{Z_2}+\sigma\frac{F{Z_2}^{1-\sigma}-1}{\theta}\left(\frac{2F^Ln_2^LZ_2}{F^L+F^Xn_2^L}+\frac{1-{Z_2}^2}{F{Z_2}^{2-\sigma}}\right)\Bigg|_{(3.31)}\end{aligned}$$

According to (3.20), $F{Z_i}^{1-\sigma}>1$. Then we derive that

$$\begin{aligned}&\frac{\partial\mathcal{J}^A}{\partial n_2^L}\Big|_{(3.31)}<0, \quad \frac{\partial\mathcal{J}^A}{\partial\theta}\Big|_{(3.31)}>0. \\ &\frac{\partial\mathcal{J}^B}{\partial n_2^L}\Big|_{(3.31)}>0, \quad \frac{\partial\mathcal{J}^B}{\partial\theta}\Big|_{(3.31)}<0.\end{aligned}$$

□

Lemma 10 implies that whether trade keeps in Stage III is also related to the market size. With a larger θ, $n_2^L>0$ is more likely, which means that trade Stage IV is appropriate. For a small θ, $n_2^L\leqslant 0$ is more possible, implying that trade stays in Stage III.

Lemma 11 *Assume* $\sigma>3/2$, $F^X<F^L$, *and* $\phi\in(F^X/\sqrt{F^HF^L},F^X/F^L)$. $\hat{\theta}^S$ *decreases with* ϕ.

Proof In Case A, we can solve that $Z_i|_{(3.31)}=Z_i^*$ at $\underline{\phi}^S$, since (3.32) and (3.29) take the same form. According to (i) of Lemma 2, $Z_2^*>Z_2|_{(3.31)}$ for $\phi\in(F^X/\sqrt{F^HF^L},\overline{\phi}^S)$. $\overline{\phi}^A(\theta)$ is the inverse function of $\hat{\theta}^A(\phi)$, $\hat{\theta}^A(\phi)$ is monotonic. We can solve that

$$\hat{\theta}^A|_{\phi=F^X/F^L}=1/2, \quad \hat{\theta}^A|_{\phi=F^X/\sqrt{F^LF^H}}=\tilde{\theta}^A|_{\phi=F^X/\sqrt{F^LF^H}}>1/2,$$

$\hat{\theta}^A(\phi)$ is a decreasing function. Similarly, the result in Case B can be proved. Similarly, the result in Case B can be proved for $\sigma>3/2$. □

Lemma 12 *Assume* $F^X<F^L$ *and* $\theta<\hat{\theta}^S|_{\phi=F^X/\sqrt{F^HF^L}}$. *When trade costs fall, the trade pattern changes from Stage III to Stage IV at* $\phi=\overline{\phi}^S$.

Stage IV → V

From Lemma 9, we have the following result.

Lemma 13 *Assume $\phi F^X > F^L$. When trade costs fall, the trade pattern changes from Stage IV to Stage V at $\phi = F^X/F^L$.*

Using lemmas 4 – 13, we can conclude that only the five stages listed in Chapter 3.2.3 are possible. The boundaries of these stages are shown in Figure 3.1.

Appendix C

Appendixes for Chapter 4

Table C.1: Results of short-run economic impact

Region & Country	Transport Infra. Investment growth rate	Real GDP level change: Intraregion impact	Real GDP level change: Interregion impact	Real GDP level change: Combined impact	Real GDP percent change: Intraregion impact	Real GDP percent change: Interregion impact	Real GDP percent change: Combined impact	Economic Welfare level change: Intraregion impact	Economic Welfare level change: Interregion impact	Economic Welfare level change: Combined impact	Economic Welfare per capita level change: Intraregion impact	Economic Welfare per capita level change: Interregion impact	Economic Welfare per capita level change: Combined impact
PRC	0	–119.5	1617.5	1498.0	–0.002	0.022	0.02	–0.10	1.39	1.28	–0.10	1.39	1.28
South and Southeast Asia													
Bangladesh	0.35	2.9	3.7	6.6	0.003	0.003	0.006	0.02	–0.01	0.01	0.02	–0.01	0.01
Brunei	0	–0.1	–0.1	–0.2	0	–0.001	–0.001	–0.55	–0.25	–0.80	–0.55	–0.25	–0.80
Cambodia	17.94	50.1	71.0	121.0	0.39	0.553	0.943	0.90	–0.20	0.70	0.90	–0.20	0.70
Indonesia	0.61	180.7	–40.3	140.4	0.021	–0.005	0.017	4.84	1.92	6.77	4.84	1.92	6.77
Lao PDR	38.93	89.0	20.1	109.1	1.078	0.244	1.322	19.05	1.11	20.16	19.05	1.11	20.16
Malaysia	0.13	34.2	–11.8	22.4	0.012	–0.004	0.008	0.24	–0.96	–0.72	0.24	–0.96	–0.72
Nepal	0	–2.2	–2.9	–5.1	–0.012	–0.015	–0.027	1.61	–0.60	1.02	1.61	-0.60	1.02
Pakistan	0.42	2.3	–20.6	–18.3	0.001	–0.010	–0.009	–0.10	–0.13	–0.23	–0.10	–0.13	–0.23
Philippines	0.16	16.6	–2.7	13.9	0.007	–0.001	0.006	–0.01	–0.27	–0.28	–0.01	–0.27	–0.28
Singapore	0.29	37.5	–18.8	18.7	0.014	–0.007	0.007	0.23	–0.03	0.20	0.23	–0.03	0.20
Sri Lanka	1.52	5.3	–11.8	–6.5	0.009	–0.020	–0.011	10.86	–5.07	5.80	10.86	–5.07	5.80
Thailand	0.50	88.2	–75.1	13.2	0.026	–0.022	0.004	1.16	–1.97	–0.81	1.16	–1.97	–0.81
Viet Nam	0.29	18.3	–41.6	–23.3	0.013	–0.031	–0.017	0.07	–0.81	–0.74	0.07	–0.81	–0.74
Non-EU countries in East Europe													
Belarus	0.19	–0.2	8.8	8.6	0	0.015	0.014	–0.02	0.79	0.77	–0.02	0.79	0.77
Russia	0.02	–13.1	–4.6	–17.8	–0.001	0.000	–0.001	–0.10	–0.02	–0.12	–0.10	–0.02	–0.12
Ukraine	0	–2.9	–8.1	–11.0	–0.002	–0.005	–0.007	–0.07	–0.21	–0.29	–0.07	–0.21	–0.29
Central and West Asia													
Armenia	0	–0.1	–0.2	–0.3	–0.001	–0.002	–0.003	–0.05	–0.08	–0.13	–0.05	–0.08	–0.13
Azerbaijan	0.36	0.1	–0.4	–0.3	0	–0.001	0	0.03	–0.04	–0.01	0.03	–0.04	–0.01
Bahrain	0	–0.2	1.1	0.9	–0.001	0.004	0.003	–0.24	1.68	1.44	–0.24	1.68	1.44
Egypt	0	–1.9	2.4	0.5	–0.001	0.001	0	–0.03	0.04	0.01	–0.03	0.04	0.01
Georgia	0	–0.2	–0.4	–0.6	–0.001	–0.003	–0.004	–0.04	–0.12	–0.16	–0.04	–0.12	–0.16
Iran	0	3.9	3.8	7.6	0.001	0.001	0.001	0.04	0.10	0.14	0.04	0.10	0.14
Kazakhstan	0.24	2.1	8.5	10.7	0.001	0.005	0.006	0.16	0.51	0.68	0.16	0.51	0.68
Kuwait	0	–0.4	3.8	3.4	0	0.002	0.002	0.01	–0.17	–0.17	0.01	–0.17	–0.17
Kyrgyzstan	0	0.0	–0.5	–0.5	0	–0.009	–0.009	–0.26	3.11	2.85	–0.26	3.11	2.85
Mongolia	0	0.0	0.9	0.9	0	0.010	0.01	0.00	0.44	0.44	0.00	0.44	0.44
Oman	0	–0.5	0.6	0.1	–0.001	0.001	0	–0.35	0.62	0.27	–0.35	0.62	0.27
Qatar	0	–0.5	1.4	0.9	0	0.001	0.001	–0.31	1.75	1.44	–0.31	1.75	1.44
Saudi Arabia	0	–3.2	2.9	–0.2	0	0.000	0	–0.16	0.33	0.17	–0.16	0.33	0.17
Turkey	0.07	–6.1	44.1	37.9	–0.001	0.006	0.005	–0.10	0.75	0.65	–0.10	0.75	0.65
UAE	0.16	4.4	3.9	8.3	0.001	0.001	0.002	1.03	0.65	1.68	1.03	0.65	1.68
Central and East Europe													
Bulgaria	0	–0.3	0.7	0.4	–0.001	0.001	0.001	–0.04	0.17	0.12	–0.04	0.17	0.12
Croatia	0	3.8	3.7	7.4	0.006	0.006	0.012	1.00	1.00	2.00	1.00	1.00	2.00
Czech	0	–1.2	–0.5	–1.6	–0.001	0.000	–0.001	–0.11	0.04	–0.07	–0.11	0.04	–0.07
Estonia	0	–0.2	0.2	0.0	–0.001	0.001	0	–0.12	0.24	0.12	–0.12	0.24	0.12
Hungary	0	–0.8	–0.1	–0.9	–0.001	0.000	–0.001	–0.07	0.04	–0.03	–0.07	0.04	–0.03
Latvia	0	–0.2	1.1	0.9	–0.001	0.004	0.003	–0.09	0.70	0.61	–0.09	0.70	0.61
Lithuania	0	–0.2	1.7	1.4	–0.001	0.004	0.003	–0.06	0.85	0.78	–0.06	0.85	0.78
Poland	0	–3.9	7.4	3.5	–0.001	0.001	0.001	–0.11	0.30	0.19	–0.11	0.30	0.19
Romania	0	–1.6	2.1	0.5	–0.001	0.001	0	–0.08	0.15	0.07	–0.08	0.15	0.07
Slovakia	0	–0.5	0.3	–0.2	–0.001	0.000	0	–0.09	0.18	0.09	–0.09	0.18	0.09
Slovenia	0	–0.5	0.9	0.5	–0.001	0.002	0.001	–0.23	0.62	0.39	–0.23	0.62	0.39

Source: Authors' summary.

Table C.2: Results of long-run economic impact

Region & Country	Transport Infra. Investment growth rate	Real GDP: level change: Intraregion impact	Real GDP: level change: Interregion impact	Real GDP: level change: Combined impact	Real GDP: percent change: Intraregion impact	Real GDP: percent change: Interregion impact	Real GDP: percent change: Combined impact	Economic Welfare: level change: Intraregion impact	Economic Welfare: level change: Interregion impact	Economic Welfare: level change: Combined impact	Economic Welfare: percent change: Intraregion impact	Economic Welfare: percent change: Interregion impact	Economic Welfare: percent change: Combined impact
PRC	0	1.56	62.5	58.5	0.0006	0.0009	0.0008	–29.5	339	310	–0.022	0.252	0.231
South and Southeast Asia													
Bangladesh	0.35	0.13	9.53	9.66	0.0001	0.0085	0.0086	0.55	4.18	4.72	0.004	0.027	0.031
Brunei	0	–0.04	0.01	–0.03	–0.0002	0.0001	–0.0002	–0.2	0.05	–0.15	–0.503	0.133	–0.37
Cambodia	17.94	7.36	21.48	28.85	0.0574	0.1674	0.2248	32	–16.6	15.4	0.187	–0.03	0.158
Indonesia	0.61	6.25	0.81	7.06	0.0007	0.0001	0.0008	45.7	–7.23	38.4	2.192	–1.137	1.055
Lao PDR	38.93	9.29	16.33	25.62	0.1125	0.1979	0.3104	45.5	3.52	49.1	7	0.542	7.554
Malaysia	0.13	2.72	–0.22	2.5	0.0009	–0.0001	0.0009	16.3	–6.45	9.89	0.082	–0.403	–0.321
Nepal	0	–0.01	–0.13	–0.14	–0.0001	–0.0007	–0.0007	–0.13	–0.34	–0.47	0.566	–0.224	0.343
Pakistan	0.42	5.36	7.58	12.94	0.0025	0.0035	0.0061	0.95	–18.3	–17.3	–0.005	–0.012	–0.017
Philippines	0.16	0.83	0.39	1.23	0.0004	0.0002	0.0005	6.08	–0.44	5.65	0.005	–0.104	–0.098
Singapore	0.29	1.56	–0.78	0.78	0.0006	–0.0003	0.0003	23.5	–10.7	12.8	0.064	–0.005	0.059
Sri Lanka	1.52	2.05	–0.07	1.98	0.0035	–0.0001	0.0033	1.71	–8.42	–6.71	4.519	–2.058	2.462
Thailand	0.5	28.84	–5.09	23.75	0.0083	–0.0015	0.0069	16.6	–68	–51.4	0.249	–1.021	–0.772
Viet Nam	0.29	0.67	0.36	1.02	0.0005	0.0003	0.0008	–12.7	–32.5	–45.2	–0.145	–0.37	–0.515
Eastern European non-EU countries													
Belarus	0.19	0.03	2.91	2.94	0.0001	0.0049	0.0049	0.1	2.2	2.3	0.01	0.22	0.23
Russia	0.02	0.88	8.75	9.63	0	0.0005	0.0005	–0.26	9.26	9	0	0.04	0.04
Ukraine	0	–0.08	–0.45	–0.55	–0.0001	–0.0003	–0.0003	–0.48	–2.11	–2.59	–0.01	–0.03	–0.03
Central and West Asia													
Armenia	0	0.01	–0.01	–0.01	0.0001	–0.0001	–0.0001	–0.03	–0.05	–0.08	0.546	0.376	0.922
Azerbaijan	0.36	0.04	0.46	0.5	0.0001	0.0007	0.0008	0.17	0.42	0.59	–0.009	–0.017	–0.026
Bahrain	0	–0.01	0.08	0.07	0	0.0003	0.0003	–0.14	1.23	1.09	0.018	0.046	0.064
Egypt	0	–0.38	0.42	0.05	–0.0002	0.0002	0	–0.74	1.23	0.49	–0.106	0.946	0.838
Georgia	0	0	–0.02	–0.02	0	–0.0001	–0.0002	–0.02	–0.14	–0.16	–0.009	0.015	0.006
Iran	0	5.19	–0.94	4.19	0.001	–0.0002	0.0008	4.43	2.42	6.85	–0.004	–0.031	–0.036
Kazakhstan	0.24	0.13	5.38	5.5	0.0001	0.0029	0.0029	0.8	5.03	5.83	0.059	0.032	0.091
Kuwait	0	–0.02	0.19	0.17	0	0.0001	0.0001	–0.49	6.2	5.71	0.048	0.303	0.351
Kyrgyzstan	0	0.01	–0.22	–0.21	0.0002	–0.0035	–0.0034	0.04	–0.73	–0.69	0.008	–0.133	–0.125
Mongolia	0	0.02	0.2	0.21	0.0002	0.0023	0.0024	0.04	0.39	0.43	–0.156	2	1.842
Oman	0	–0.03	0.09	0.05	0	0.0001	0.0001	–0.66	1.22	0.56	0.015	0.14	0.154
Qatar	0	0	0.05	0.05	0	0	0	–0.21	2.1	1.89	–0.219	0.407	0.188
Saudi Arabia	0	–0.06	0.06	0	0	0	0	–1.58	6.22	4.63	–0.111	1.105	0.995
Turkey	0.07	–0.13	4.81	4.75	0	0.0006	0.0006	–1.27	16.9	15.7	–0.057	0.224	0.167
UAE	0.16	0.31	0.94	1.28	0.0001	0.0003	0.0004	4.86	3.35	8.21	–0.017	0.231	0.215
Central and East Europe													
Bulgaria	0	0	0.04	0.04	0	0.0001	0.0001	–0.03	0.6	0.57	–0.004	0.082	0.078
Croatia	0	–0.03	–0.05	–0.07	0	–0.0001	–0.0001	–0.08	–0.03	–0.11	0.001	0.063	0.064
Czech	0	0	–0.13	–0.11	0	–0.0001	–0.0001	0.01	0.67	0.68	–0.013	0.099	0.086
Estonia	0	0	–0.01	–0.01	0	0	0	–0.02	0.13	0.11	–0.019	–0.006	–0.025
Hungary	0	0	–0.05	–0.05	0	0	0	0.02	0.44	0.47	0.002	0.044	0.047
Latvia	0	0	0.05	0.05	0	0.0002	0.0002	–0.01	0.49	0.48	0.003	0.353	0.357
Lithuania	0	0	0.06	0.06	0	0.0001	0.0001	0.01	1.06	1.07	–0.005	0.234	0.229
Poland	0	–0.03	0.16	0.09	0	0	0	–0.44	4.44	4	–0.011	0.115	0.104
Romania	0	0	0.08	0.08	0	0	0	–0.06	1.14	1.08	–0.003	0.057	0.054
Slovakia	0	0	0	0	0	0	0	0	0.62	0.62	–0.001	0.115	0.115
Slovenia	0	0	0.02	0.02	0	0	0	–0.02	0.41	0.39	–0.009	0.194	0.185

Source: Authors' summary.