CSIS Discussion Paper No. 151

International migration, linguistic friction, and industrial agglomeration*

Mariko Nakagawa †

February 2, 2018

Abstract

In this paper, we analyze how the frictional costs of migration, captured by lower productivity at the destination due to difficulty in the transference of skill, affect the spatial equilibrium configuration of industrial agglomeration. For symmetric migration costs, when international migration friction is severe, migration cannot occur. In contrast, if the migration cost is low, the industrial core country can attract the entire high-skilled workers. For asymmetric migration costs, the less frictional country is more likely to attract high-skilled workers and to be industrially agglomerated. These results coincide with the findings in the empirical literature: potential migrants are more likely to choose destinations where their skills are more transferable in terms of language use and communication, and English-speaking countries can attract more international migrants because such countries present fewer language barriers.

JEL code: F22, R13, F66

Key words: International migration, frictional cost, language difference, skill transfer, industrial agglomeration

*I would like to thank participants at Asian Seminar in Regional Science at National Taiwan University and NARSC in Vancouver for valuable comments and suggestions. All remaining errors are the author's responsibility. This study is supported by Research Activity Start-up (Research project number: 16H06703) provided by the Japan Society for the Promotion of Science (JSPS).

†Center for Spatial Information Science, University of Tokyo. E-mail: mnakagawa@csis.u-tokyo.ac.jp. Address: 5-1-5 Kashiwanoha, Kashiwa-shi, Chiba, 277-8568, Japan

1 Introduction

In the context of international migration, migrants are more likely to choose a destination country where their mother tongue is widely perceived or dominantly used. Adsera and Pytlikova (2015) argue that this is possibly because such destinations present less friction for migrants when supplying and using their skills because of easier communication with indigenous people. Since migration can be considered a process of transferring workers' origin-accumulated skills, the existence of frictional costs in skill transfer would affect migrants' choice of destination, impacting the realized configuration of skills or industrial distribution across countries.

Sharing a common language, which imposes less friction in international migration, is empirically shown to accelerate international migration. Clark et al. (2007) consider a relationship between immigrants' language backgrounds and the choice of an initial destination in the case of migration to the United States. The authors find that English-speaking source countries tend to exhibit a higher migration rate, implying that the migration cost to the United States is lower if the origin country's dominant language is English. The positive effect on international migration from sharing a common language is, of course, not limited to the United States but can be extended to migration in OECD countries. Pedersen et al. (2008) argue that common languages between origin and destination countries play important roles for immigrants in OECD countries. Belot and Ederveen (2012) also empirically show that sharing common languages and shorter linguistic distances between the origin and destination promote international migration among OECD countries.[1]

The fact that language proximity promotes international migration is related to international migrants' difficulties in transferring skills. Belot and Hatton (2012) empirically argue that if the language barrier that migrants face is less severe, then the transferability of their human capital to a destination is greater. Additionally, a higher proficiency of language in the destination country increases immigrants' earnings in Germany (Dustmann and Van Soest, 2001, 2002). These findings support the idea that less earnings due to language barriers are interpreted as a cost for immigrants. As Chiswick and Miller (2014) note, a set of skills useful in origin countries does not necessarily coincide with useful skills in a destination country, which induces difficulty in skill transference for migrants. Geographic differences in technology, customs, occupational licenses, and language differences are considered ex-

[1]The authors capture linguistic distance as an expression of cultural barriers. Linguistic distance also can be considered a proxy for the severity of the language barrier for immigrants by following the discussions in Beenstock et al. (2001) and Chiswick and Miller (2005), in which linguistic distance expresses the extent to which difficulty in acquiring languages other than the mother tongue leads to proficiency in the predominant language in destination countries.

amples of the source of difficulties in skill transference. A mismatch in language induces disadvantages for immigrants, which leads to lower productivity. Through this channel of lower productivity at the destination, immigrants are affected by differences in language when choosing their destination, and immigrants seek countries where they can earn more. In this sense, their choice of destination is based on income maximization, which matches Roy's (1951) model; a simple but pioneering model of international migration.

Similar discussions on language difference and international skill transfer have been conducted in realms other than international migration, such as task trading (Grossman and Rossi-Hansberg, 2008) and offshoring (Ottaviano et al., 2013), shedding light on the aspects of frictional costs associated with labor supply, that is, skills or labor endowments cannot be fully utilized due to differences in culture, operation, and languages.

In this paper, we model the tendency of potential migrants to prefer destination countries with less friction, where their productivity or earnings do not suffer due to mismatch in language use by employing a standard new economic geography (NEG) model. The primary aim of this research is to see how the equilibrium configuration of industrial (high-skilled worker) distribution is affected by introducing frictional costs related to international skill transfer to a spatial economics model proposed by Forslid and Ottaviano (2003). The reason for the assumption of perfect mobility of high-skilled workers, which is normally imposed in the context of the NEG, is that migration is typically considered at the regional scale within a country.[2] In the field of international migration, however, it should be natural to consider the imperfect mobility of high-skilled workers. Thus, we introduce the costs of international skill transfer caused by lower productivity at the destination.

One concern with applying an NEG model to the context of international migration arises from whether the skill level of migrants observed in the empirical literature matches the assumption imposed in the model. The model assumes that high-skilled workers are mobile across countries, while low-skilled workers are immobile. In practice, on the other hand, low-skilled migration may also occur along with the migration of high-skilled workers. The findings in the empirical literature, however, may ease this concern. Supporting evidence for imposing the assumption on mobility of high- and

[2]Ludema and Wooton (1999) consider the imperfect mobility of manufacturing workers by modeling a relative real wage difference affected by living and working preferences and targeting non-pecuniary elements. Although the authors' model can be listed in a category of models of imperfect migration, it should also be grouped in the same series of Tabuchi and Thisse (2002), in which heterogeneous tastes for locational choice are considered, because Ludema and Wooton (1999) fundamentally model location preference differences rather than costs in migration. Unlike Ludema and Wooton (1999), this paper explicitly introduces migration costs in terms of lower productivity at the destination starting from skill transfer difficulties in migration.

low-skilled workers can be asserted from the host and source country sides.[3]

The evidence from the source country side is related to migrants' self-selection. Grogger and Hanson (2011) find that high-skilled workers select themselves to migrate in contrast to low-skilled workers when migrating to OECD destinations. In addition, the findings in Chiquiar and Hanson (2005) suggest that Mexican immigrants in the United States are more educated than non-immigrants remaining in Mexico, implying that high-skilled people are more likely to be migrants from Mexico to the United States. Because of this skilled workers' relative tendency and higher likelihood of being migrants compared to unskilled workers, the high-skilled mobility/low-skilled immobility assumption is not unnatural.

From the destination side, the immigration policies adopted by host countries support the assumption of high-skilled mobility/low-skilled immobility. Some countries adopt a point-based immigration policy, in which only potential migrants with appropriate economic, educational, and cultural attributes can be applicants. Indeed, the strictness of immigration policy in destination countries affects international migration flows (Mayda, 2010). The fact that application for migrants is limited to sufficiently educated and skilled workers may be one rationale for the assumption of high-skilled mobility/low-skilled immobility in the model from the host country side. Our theoretical analysis finds that a country can be the industrial core by attracting high-skilled migrants under less severe frictional migration costs. In contrast, if the migration cost is severe, international migration cannot occur.

Moreover, we investigate the impacts of asymmetric frictional costs, where the extent of friction when migrating from one country to another is not identical to migration in the opposite direction. Put differently, we consider the situation in which some countries are less frictional for migrants than other countries because of higher skill transference and less severe language barriers. For instance, migrating to English-speaking destination may induce less friction when transferring skills even for immigrants whose mother tongue is not English, because there is a large population of English speakers as an acquired language, and hence, migration to English-speaking countries is less friction-inducing than migration to non-English-speaking destinations. Indeed, English-speaking countries may attract more migrants than non-English-speaking countries as discussed in Adsera and Pytlikova (2015) and Grogger

[3]In the model part, the assumption that high-skilled workers are mobile by incurring some migration costs while low-skilled workers are immobile can be interpreted as follows: For low-skilled workers, migrating to other countries with language barriers is prohibitively costly so that they cannot have this option to migrate instead of being remained in their origin as stayers. By contrast, migration costs are not prohibitively high for high-skilled workers so that they have an option to be migrants.

and Hanson (2011). To express this in the analysis, we extend the base model with symmetric frictional migration costs to the model with asymmetric frictional costs. In the analysis based on asymmetric migration costs, we obtain the result that the less frictional country in transferring skills (i.e., English-speaking countries) can attract high-skilled workers and become the industrially agglomerated core country.

The remainder of this paper is organized as follows. Section 2 presents the model. Section 3 analyzes the stable equilibria in the case of symmetric migration costs. In Section 4, the model is extended to a modified version of asymmetric migration costs, and discusses some possibility of policies to attract international migrants. In addition, comments on the extension to multi-country models are noted. Section 5 concludes the paper.

2 Model

The economy consists of two countries, A and B, both of which are characterized by an official domestic language, that is, the official language in country A (country B, respectively) is language A (language B, respectively). There are two sectors; manufacturing (Q), producing a horizontally differentiated good transportable with iceberg trade costs, and agriculture (Z), producing a homogeneous good freely traded, which is chosen as the numeraire.

There are two types of workers with respect to their skill level, high- and low-skilled workers, the former of which is mobile across countries in the long run by incurring frictional migration costs, as we will explain, while the latter is immobile and dependent on the country of origin.[4] Workers are assumed to be intersectionally mobile. Each worker is endowed with one unit of labor corresponding to her skill level. In addition to skill level, she is attached to a language type $l \in \{A, B\}$, which corresponds to the country of origin, so that a worker who originates from country A (country B, respectively) is attached by her language type $l = A$ ($l = B$, respectively). In other words, the mother tongue of each worker is the official (dominantly used) language of her country of birth. The language assigned to each worker is the essence of migration costs for high-skilled workers. If a worker migrates to the other country whose official language is different from her mother tongue, then a mismatch in terms of language in the destination may occur, causing, for instance, a drop in productivity that would not have been experienced in the origin. To express this aspect, we introduce frictional migration costs

[4] This assumption of low-skilled immobility may be interpreted in a way that migration costs (or lost productivity at destination) are prohibitively high for low-skilled workers so that they cannot have an option to be immigrants and are forced to be stayers in the origin country.

captured by lower productivity in the destination following Grossman and Rossi-Hansberg (2008) and Ottaviano et al. (2013).[5] A high-skilled worker of language type l endowed with one unit of labor that can be supplied fully in the country of origin, can provide only $\delta_i^l \in (0,1)$ fraction of her labor endowment in destination i, and $1-\delta_i^l$ fraction of it disappears, so that δ_i^l captures the inverse cost of migration. In other words, larger δ_i^l implies less frictional migration, and friction in migration is less severe if δ_i^l is larger and closer to one. Specifically, the earnings of a high-skilled worker with language type l and residing in country i is

$$y_i^{lH} = \delta_i^l w_i^H, \tag{1}$$

where w_i^H is a high-skilled wage in country i determined in equilibrium, and the indicator expressing migration frictional costs is

$$\delta_i^l = \begin{cases} 1 & \text{if } i = l \\ \delta \in (0,1) & \text{otherwise.} \end{cases} \tag{2}$$

By this specification, for the moment, the frictional costs of migration are identical for both the direction of migration (from country A to B, and B to A) for both language types A and B, and we conduct an analysis of the spatial equilibrium under the symmetric frictional cost associated with migration in Section 3. In Section 4, an analysis based on the asymmetric migration cost (i.e., δ can differ for the choice of origin/destination and language types of migrants) is conducted.

The total endowment of high-skilled workers with language type l, H^l, is H for languages A and B, so that the total population of high-skilled workers in the economy is $2H$. Since high-skilled workers are (imperfectly) mobile across countries, the high-skilled population with language type l, H^l, can be split into two countries. H_i^l is defined as the population of high-skilled workers residing in country i whose language type is l, which satisfies $\sum_{i\in\{A,B\}} H_i^l = H^l = H$ for $l \in \{A,B\}$. The endowment of low-skilled workers for country $i \in \{A,B\}$ is $L_i = L$, and thus, there are $2L$ low-skilled workers, who are immobile across countries, in the economy. Hereafter, let λ_i^l be a fraction of high-skilled workers of language type l residing in country i, so that the total population in country i is $\sum_{l\in\{A,B\}} \lambda_i^l H + L$.

For the demand side, consumption of a horizontally differentiated good (manufactured good) and a homogeneous good (agricultural good) defines the utility function of the representative consumer in

[5] We simply employ the expression of lower productivity at destination used in Grossman and Rossi-Hansberg (2008) and Ottaviano et al. (2013), that is, the specification of lower productivity that does not take into consideration the aspects of task ordering is employed in the present model.

country i,

$$U_i = \mu^{-\mu}(1-\mu)^{-(1-\mu)} Q_i^{\mu} Z_i^{1-\mu}, \tag{3}$$

where Q_i is the consumption of the manufactured good, which is the composite of horizontally differentiated good consumed in country i characterized by a constant elasticity of substitution (CES) over a continuum of varieties of manufactured good,

$$Q_i = \left[\sum_{j \in \{A,B\}} \int_0^{n_j} q_{ji}(\nu)^{\frac{\sigma-1}{\sigma}} \mathrm{d}\nu \right]^{\frac{\sigma}{\sigma-1}}, \tag{4}$$

$\mu \in (0,1)$ is a constant expressing the expenditure share of manufactured good, Z_i is the consumption of an agricultural good, $q_{ji}(\nu)$ is the consumption of variety ν of manufactured good produced in country j and consumed in country i, and $\sigma > 1$ is the elasticity of substitution between any two varieties. n_i is the mass of varieties produced in country i, and N is the total mass of varieties such that $\sum_{i \in \{A,B\}} n_i = N$. The representative consumer in country i maximizes utility function (3) subject to the budget constraint

$$\sum_{j \in \{A,B\}} \int_0^{n_j} p_{ji}(\nu) q_{ji}(\nu) \mathrm{d}\nu + p_i^Z Z_i = Y_i, \tag{5}$$

where $p_{ji}(\nu)$ is the consumer price of a variety produced in country j and sold in country i, and p_i^Z is the price of agricultural good. Y_i is the total income in country i

$$Y_i = \sum_{l \in \{A,B\}} y_i^{lH} \lambda_i^l H + w_i^L L, \tag{6}$$

and w_i^L is a low-skilled wage in country i. By utility maximization, the CES demand function of residents in country i consuming variety ν produced in country j is derived as

$$d_{ji}(\nu) = \frac{p_{ji}(\nu)^{-\sigma}}{P_i^{1-\sigma}} \mu Y_i, \qquad i, j \in \{A, B\}, \tag{7}$$

where P_i is the price index in country i defined as

$$P_i \equiv \left[\sum_{j \in \{A,B\}} \int_0^{n_j} p_{ji}(\nu)^{1-\sigma} \mathrm{d}\nu \right]^{\frac{1}{1-\sigma}}. \tag{8}$$

Combining the above, the indirect utility function of a high-skilled worker of language type l residing in country i is obtained as

$$V_i^l = \delta_i^l w_i^H P_i^{-\mu} \tag{9}$$

On the supply side, a homogeneous good in the agricultural sector is produced under perfect competition and constant returns to scale with low-skilled labor as the sole input. For an output of one unit of the agricultural good, one unit of low-skilled labor is required. Perfect competition ensures marginal cost pricing, so that $p_i^Z = w_i^L$. International equalization of the agricultural good price due to free transportability, and by the choice of the agricultural good as the numeraire, $w_A^L = w_B^L = 1$. In the manufacturing sector, firms employ high-skilled labor as the fixed requirement and low-skilled labor as a variable requirement under monopolistic competition and increasing returns to scale. Product differentiation ensures that each firm produces a single differentiated good. Specifically, by following Forslid and Ottaviano's (2003) footloose entrepreneur model instead of Krugman's (1991) model for analytical tractability to produce x units of a variety, one unit of high-skilled labor as fixed inputs and cx units of low-skilled labor as variable inputs are required. Then, the total cost of producing x units of a variety is $TC_i = w_i^H + cx_i$ by using $w_A^L = w_B^L = 1$. Differentiated good transportation for the other country is inhabited by iceberg transportation costs $\tau > 1$, that is, for one unit of the differentiated good to reach the other country, τ units of it must be shipped. A profit function for a typical firm in country i is

$$\Pi_i = [p_{ii} - c]x_{ii} + [p_{ij} - \tau c]x_{ij} - w_i^H. \tag{10}$$

Maximizing (10) with respect to prices yields

$$p_{ii} = \frac{\sigma c}{\sigma - 1}, \qquad p_{ij} = \frac{\tau \sigma c}{\sigma - 1}, \qquad j \neq i. \tag{11}$$

By substituting (11) to the price index (8), we obtain

$$P_i = \frac{\sigma c}{\sigma - 1}(n_i + \phi n_j)^{\frac{1}{1-\sigma}}, \tag{12}$$

where freeness of trade ϕ is defined as $\phi \equiv \tau^{1-\sigma} \in (0, 1)$. By market clearing of the high-skilled labor, the number of firms for country i is

$$n_i = \sum_{l \in \{A,B\}} \delta_i^l \lambda_i^l H. \tag{13}$$

By the zero-profit condition implied by assuming free entry and exit, $\Pi_i = 0$, (7), (10), (11), and (12), two equations for the high-skilled wage rate in country i are obtained as

$$w_i^H = \frac{\mu}{\sigma}\left(\frac{Y_i}{n_i + \phi n_j} + \frac{\phi Y_j}{n_j + \phi n_i}\right). \tag{14}$$

Combining (1), (2), (6), (14), and $w_i^L = 1$ yields the instantaneous equilibrium high-skilled wage rate

$$w_i^H = \frac{\frac{\mu}{\sigma}L}{1-\frac{\mu}{\sigma}} \frac{2\phi n_i + [1 - \frac{\mu}{\sigma} + (1+\frac{\mu}{\sigma})\phi^2]n_j}{\phi(n_i^2 + n_j^2) + [1 - \frac{\mu}{\sigma} + (1+\frac{\mu}{\sigma})\phi^2]n_i n_j} \tag{15}$$

for $i \in \{A, B\}$.[6]

3 Long-run equilibrium

In this section, we conduct an analysis of the long-run spatial equilibrium under symmetric frictional costs of migration. In the long run, high-skilled workers are mobile across countries and move to the country where she can enjoy a higher indirect utility. We denote the indirect utility that a high-skilled worker with language type l enjoys when residing in country i as V_i^l. A spatial equilibrium $\boldsymbol{\lambda}^*$ in the long run arises when high-skilled workers with the same language type l must reach the same utility level $\bar{V}^l$. Formally, for $l \in \{A, B\}$,

$$\begin{aligned} V_i^l &= \bar{V}^l \quad \text{if} \quad \lambda_i^{l*} > 0, \\ V_i^l &\leq \bar{V}^l \quad \text{if} \quad \lambda_i^{l*} = 0. \end{aligned}$$

Because V_i^l is continuous with respect to λ_i^l, a spatial equilibrium exists for all sets of parameters (Ginsburgh et al., 1985). Hereafter, we denote λ^l is a fraction of high-skilled workers of language type l residing in country A, so that $\lambda_A^l \equiv \lambda^l$ and $\lambda_B^l \equiv 1 - \lambda^l$.

For the stability of the equilibrium, we adopt a standard dynamic system, replicator dynamics, often used by following Fujita et al. (1999), to express the international migration flow of high-skilled workers, to obtain two dynamic equations

$$\dot{\lambda}^l \equiv \frac{\mathrm{d}\lambda^l}{\mathrm{d}t} = \lambda^l \Delta V^l(\boldsymbol{\lambda})(1 - \lambda^l) \qquad (l \in \{A, B\}), \tag{16}$$

[6] By using the instantaneous equilibrium wage (15), we obtain the non-full-specialization (NFS) condition to guarantee that both sectors, manufacturing and agriculture, are active, as $\mu < \sigma/(2\sigma - 1)$.

where $\Delta V^l(\boldsymbol{\lambda}) \equiv V_A^l(\boldsymbol{\lambda}) - V_B^l(\boldsymbol{\lambda})$ and $\boldsymbol{\lambda} \equiv (\lambda^A, \lambda^B)$. Under this dynamic system, all spatial equilibria $\boldsymbol{\lambda}^*$ are steady states of (16).

By combining (2), (9), (12), (13), and (15), the indirect utility differential for $l \in \{A, B\}$ is

$$\Delta V^l(\boldsymbol{\lambda}) = \frac{\Phi_1}{\Phi_2(\boldsymbol{\lambda})} \Delta v^l(\boldsymbol{\lambda}), \tag{17}$$

where

$$\begin{aligned}
\Phi_1 &\equiv \left(\frac{\sigma c}{\sigma - 1}\right)^{-\mu} \left(\frac{\frac{\mu}{\sigma} L}{1 - \frac{\mu}{\sigma}}\right) H^{\frac{\mu}{\sigma-1}-1}, \\
\Phi_2(\boldsymbol{\lambda}) &\equiv \phi[(\lambda^A + \delta\lambda^B)^2 + (\delta(1-\lambda^A) + (1-\lambda^B))^2] \\
&\quad + \left[1 - \frac{\mu}{\sigma} + \left(1 + \frac{\mu}{\sigma}\right)\phi^2\right](\lambda^A + \delta\lambda^B)(\delta(1-\lambda^A) + (1-\lambda^B)), \\
\Delta v^A(\boldsymbol{\lambda}) &\equiv v_1(\boldsymbol{\lambda}) - \delta v_2(\boldsymbol{\lambda}), \qquad (18)\\
\Delta v^B(\boldsymbol{\lambda}) &\equiv \delta v_1(\boldsymbol{\lambda}) - v_2(\boldsymbol{\lambda}), \qquad (19)\\
v_1(\boldsymbol{\lambda}) &\equiv [(\lambda^A + \delta\lambda^B) + \phi(\delta(1-\lambda^A) + (1-\lambda^B))]^{\frac{\mu}{\sigma-1}} \\
&\quad \times \left[2\phi(\lambda^A + \delta\lambda^B) + \left[1 - \frac{\mu}{\sigma} + \left(1 + \frac{\mu}{\sigma}\right)\phi^2\right](\delta(1-\lambda^A) + (1-\lambda^B))\right] \\
v_2(\boldsymbol{\lambda}) &\equiv \left[(\delta(1-\lambda^A) + (1-\lambda^B)) + \phi(\lambda^A + \delta\lambda^B)\right]^{\frac{\mu}{\sigma-1}} \\
&\quad \times \left[2\phi(\delta(1-\lambda^A) + (1-\lambda^B)) + \left[1 - \frac{\mu}{\sigma} + \left(1 + \frac{\mu}{\sigma}\right)\phi^2\right](\lambda^A + \delta\lambda^B)\right].
\end{aligned} \tag{20}$$

Because $\Phi_1 > 0$ and $\Phi_2(\boldsymbol{\lambda}) > 0$, the sign of $\Delta V^l(\boldsymbol{\lambda})$ is determined by that of $\Delta v^l(\boldsymbol{\lambda})$. Determination of the equilibrium depends thoroughly on $\Delta v^l(\boldsymbol{\lambda})$. In what follows, we analyze the equilibria and their stability under symmetric frictional migration costs. The full agglomeration of industry in country A (country B, respectively) is expressed by $(\lambda^A, \lambda^B) = (1, 1)$ ($(\lambda^A, \lambda^B) = (0, 0)$, respectively) for the fully agglomerated core country A (country B, respectively). Additionally, $(\lambda^A, \lambda^B) = (1, 0)$ represents the industrial dispersed configuration for the total distribution of industry as a whole economy because when $(\lambda^A, \lambda^B) = (1, 0)$, high-skilled workers are evenly distributed across countries.[7]

First, we consider the dispersed equilibrium, $(\lambda^A, \lambda^B) = (1, 0)$. Because $\Delta v^A(\boldsymbol{\lambda})|_{\boldsymbol{\lambda}=(1,0)} > 0$ and $\Delta v^B(\boldsymbol{\lambda})|_{\boldsymbol{\lambda}=(1,0)} < 0$ when (inverse) migration cost δ exists, the stability condition for the dispersed equilibrium is satisfied for both language types, A and B throughout ϕ.

[7]The last part of this section considers evenly distributed equillibria with numerical simulations. At this point, our analysis of the dispersed equilibrium is limited to an inspection of $(\lambda^A, \lambda^B) = (1, 0)$ because it is analytically tractable.

Next, we turn to the agglomerated configuration. The fully agglomerated configurations, $(\lambda^A, \lambda^B, \lambda) = (1,1,1), (0,0,0)$, are stable equilibria if and only if

$$\min\{\Delta v^A(\boldsymbol{\lambda})|_{\boldsymbol{\lambda}=(1,1)}, \Delta v^B(\boldsymbol{\lambda})|_{\boldsymbol{\lambda}=(1,1)}\} > 0 \tag{21}$$

for the case of country A as the core, or

$$\max\{\Delta v^A(\boldsymbol{\lambda})|_{\boldsymbol{\lambda}=(0,0)}, \Delta v^B(\boldsymbol{\lambda})|_{\boldsymbol{\lambda}=(0,0)}\} < 0$$

for the case of country B as the core. Hereafter, our analysis focuses on the case of country A as the core. The discussion for the case of country B as the core is the same. Because

$$\begin{aligned}
\Delta v^A(\boldsymbol{\lambda})|_{\boldsymbol{\lambda}=(1,1)} &= \Xi(\phi,\delta) f(\phi,\delta), \\
\Delta v^B(\boldsymbol{\lambda})|_{\boldsymbol{\lambda}=(1,1)} &= \Xi(\phi,\delta) g(\phi,\delta),
\end{aligned}$$

where

$$\begin{aligned}
\Xi(\delta,\phi) &\equiv (1+\delta)^{\frac{\mu}{\sigma-1}+1}\phi > 0, \\
f(\delta,\phi) &\equiv 2 - \delta\phi^{\frac{\mu}{\sigma-1}-1}\left[\left(1-\frac{\mu}{\sigma}\right) + \left(1+\frac{\mu}{\sigma}\right)\phi^2\right], \\
g(\delta,\phi) &\equiv 2\delta - \phi^{\frac{\mu}{\sigma-1}-1}\left[\left(1-\frac{\mu}{\sigma}\right) + \left(1+\frac{\mu}{\sigma}\right)\phi^2\right],
\end{aligned} \tag{22}$$

the sustain condition for country A to be the core (21) is equivalent to

$$\min\{f(\delta,\phi), g(\delta,\phi)\} > 0. \tag{23}$$

Moreover, because it can be easily verified that $f(\delta,\phi) > g(\delta,\phi)$, (23) reduces to the following simple form of the sustain condition (the condition that country A attracts all high-skilled workers in the economy):

$$g(\delta,\phi) > 0. \tag{24}$$

It is natural that we have $f(\delta,\phi) > g(\delta,\phi)$, which is originated in $\Delta v^A(\boldsymbol{\lambda})|_{\boldsymbol{\lambda}=(1,1)} > \Delta v^B(\boldsymbol{\lambda})|_{\boldsymbol{\lambda}=(1,1)}$, since high-skilled workers of language type A enjoy the benefits of agglomeration without incurring frictional costs of skill transfer under international migration, while high-skilled workers with language type B suffer from $1-\delta$ fraction of lost productivity when residing in country A to enjoy the benefits of the core country due to the mismatch in language use.

By inspecting the shape of $g(\delta,\phi)$, the sustain condition, $g(\delta,\phi)>0$, under which the fully agglomerated equilibrium is stable, is analyzed to see if the fully agglomerated distribution can be a stable equilibrium. Specifically, we investigate how $g(\delta,\phi)$ changes with ϕ. The first derivative of $g(\delta,\phi)$ with respect to ϕ is

$$\frac{\partial g(\delta,\phi)}{\partial\phi}=-\phi^{\frac{\mu}{\sigma-1}-2}\left[\left(\frac{\mu}{\sigma-1}-1\right)\left(1-\frac{\mu}{\sigma}\right)+\left(\frac{\mu}{\sigma-1}+1\right)\left(1+\frac{\mu}{\sigma}\right)\phi^2\right]. \tag{25}$$

The shape of the function $g(\delta,\phi)$ is characterized according to the following two cases: (i) $\mu<\sigma-1$ and (ii) $\mu\geq\sigma-1$.

In the case of $\mu<\sigma-1$, $\partial g(\delta,\phi)/\partial\phi$ can be positive or negative because the first term in the brackets is negative while the second term is positive, so that $g(\delta,\phi)$ is not monotone with ϕ. However, it can be checked that when $\mu<\sigma-1$, $\lim_{\phi\to1}g(\delta,\phi)=-2(1-\delta)<0$, $\lim_{\phi\to1}\partial g(\delta,\phi)/\partial\phi=-2\mu[1/(\sigma-1)+1/\sigma]<0$, $\lim_{\phi\to0}g(\delta,\phi)=-\infty$, and $\lim_{\phi\to0}\partial g(\delta,\phi)/\partial\phi=-\infty$. Moreover, $\partial g(\delta,\phi)/\partial\phi|_{\phi=\hat{\phi}}=0$, where $\hat{\phi}\equiv\sqrt{\frac{(\sigma-1-\mu)(\sigma-\mu)}{(\sigma-1+\mu)(\sigma+\mu)}}$, and $\partial^2 g(\delta,\phi)/\partial\phi^2<0$. Then, for $\phi\in(0,1)$, $g(\delta,\phi)$ has a unique maximum,

$$\begin{aligned}g_{\max}(\delta)&\equiv g(\delta,\phi)|_{\phi=\hat{\phi}}\\&=2\delta-\left[\left(\frac{\sigma-\mu}{\sigma}\right)\left(\frac{(\sigma-1-\mu)(\sigma-\mu)}{(\sigma-1+\mu)(\sigma+\mu)}\right)^{\frac{\mu-\sigma+1}{2(\sigma-1)}}+\left(\frac{\sigma+\mu}{\sigma}\right)\left(\frac{(\sigma-1-\mu)(\sigma-\mu)}{(\sigma-1+\mu)(\sigma+\mu)}\right)^{\frac{\mu+\sigma-1}{2(\sigma-1)}}\right].\end{aligned} \tag{26}$$

If $g_{\max}(\delta)\leq0$ (i.e., $\boldsymbol{\lambda}=(1,1)$ is unstable), then $g(\delta,\phi)\leq0$ for $\phi\in(0,1)$. By contrast, if $g_{\max}(\delta)>0$ (i.e., $\boldsymbol{\lambda}=(1,1)$ is stable), then there exists an interval $(\underline{\phi},\bar{\phi})$ such that $g(\delta,\phi)>0$ for $\phi\in(\underline{\phi},\bar{\phi})$ and $g(\delta,\phi)\leq0$ (i.e., $\boldsymbol{\lambda}=(1,1)$ is unstable) for $\phi\notin(\underline{\phi},\bar{\phi})$, where $\underline{\phi}$ and $\bar{\phi}$ are the roots of $g(\delta,\phi)=0$. By (26), $g_{\max}(\delta)\leq0$ ($g_{\max}(\delta)>0$, respectively) can be rewritten as $\delta\leq\bar{\delta}$ ($\delta>\bar{\delta}$, respectively), where

$$\bar{\delta}\equiv\frac{1}{2}\left[\left(\frac{\sigma-\mu}{\sigma}\right)\left(\frac{(\sigma-1-\mu)(\sigma-\mu)}{(\sigma-1+\mu)(\sigma+\mu)}\right)^{\frac{\mu-\sigma+1}{2(\sigma-1)}}+\left(\frac{\sigma+\mu}{\sigma}\right)\left(\frac{(\sigma-1-\mu)(\sigma-\mu)}{(\sigma-1+\mu)(\sigma+\mu)}\right)^{\frac{\mu+\sigma-1}{2(\sigma-1)}}\right], \tag{27}$$

which yields the following proposition by combining the results obtained by inspecting the stability of the dispersed equilibrium:[8]

[8]The qualitative results induced by the sustain condition remain the same as in Proposition 3.1 if we employ the quasi-linear upper-tier utility function, $U_i=\mu\ln Q_i+Z_i$, following Pflüger (2004).

Proposition 3.1. *When agglomeration force is less intense ($\mu < \sigma - 1$),*

(i) if international skill transfer is highly frictional ($\delta \leq \bar{\delta}$), then the fully agglomerated equilibrium cannot be stable, while the completely dispersed configuration can be the stable equilibrium ($(\lambda^{A*}, \lambda^{B*}) = (1, 0)$), implying that each country can attract only domestic high-skilled workers.

(ii) if international skill transfer is less frictional ($\delta > \bar{\delta}$), then

(ii-a) for very high or low freeness of trade ($\phi \notin (\underline{\phi}, \bar{\phi})$), the fully agglomerated equilibrium cannot be stable, while the completely dispersed configuration can be the stable equilibrium ($(\lambda^{A*}, \lambda^{B*}) = (1, 0)$), implying that each country can attract only domestic high-skilled workers.

(ii-b) for intermediate freeness of trade ($\phi \in (\underline{\phi}, \bar{\phi})$), the fully agglomerated configuration as well as the dispersed configuration can be the stable equilibria ($(\lambda^{A*}, \lambda^{B*}) = (1, 1), (0, 0), (1, 0)$), implying that the core country can attract high-skilled workers of both language types.

Industrial distribution in the stable equilibrium is affected by two dispersion factors: τ (or inverse ϕ) and inverse δ. In Proposition 3.1, when the extent of friction associated with international migration is severe ($\delta \leq \bar{\delta}$), industrially dispersed configuration can consist of the stable equilibrium, while the full agglomeration cannot be a stable equilibrium, since providing labor endowment in a country where there is a mismatch in language use is too costly, and thus, a high-skilled worker chooses to remain in the country of origin. In this dispersed configuration as the stable equilibrium, each worker is a domestic worker and no international migration occurs.

In contrast, under less frictional skill transfer ($\delta > \bar{\delta}$), the economic integration process wears a flavor of "dispersion→agglomeration→redispersion" as ϕ goes from 0 to 1 in that only for the intermediate ϕ, the full agglomeration is stable while the dispersed configuration keeps being the stable equilibrium throughout ϕ. Although there are two dispersion phases, one for low freeness of trade ($\phi \leq \underline{\phi}$) and the other for high freeness of trade ($\phi \geq \bar{\phi}$), these emerge for different reasons. The first transition of industrial configuration around $\phi = \underline{\phi}$ is due to a decline in trade costs. When $\phi \leq \underline{\phi}$, the manufacturing sector is dispersed because of severe export losses stemming from large τ. When ϕ reaches $\underline{\phi}$, and shipping is not too costly, this leads to stability of the international industrial agglomeration in one country. However, once ϕ exceeds $\bar{\phi}$, the fully agglomerated configuration again becomes unstable while dispersed equilibrium retains its stability. Frictional skill transfer associated with international migration gives rise to this second transition in the economic integration process. Without $\delta < 1$ (i.e., $\delta = 1$), under completely free trade ($\phi = 1$), location choice is indifferent for high-skilled workers of language type B (language type A, respectively) in the core-periphery structure, that is, $\Delta v^B(\boldsymbol{\lambda})|_{\boldsymbol{\lambda}=(1,1)} = 0$ ($\Delta v^A(\boldsymbol{\lambda})|_{\boldsymbol{\lambda}=(0,0)} = 0$, respectively). However, in this model, the skill transferring cost δ still exists even when completely free trade is accomplished. Since δ works as a dispersion force from the viewpoint of factors determining international distribution of the manufacturing sector, dispersed configuration is the stable equilibrium even at the high level of ϕ ($\phi > \bar{\phi}$). This result of the dispersed configuration in stable equilibrium under highly free trade coordinates with $\boldsymbol{\lambda}^* = (1,0)$ under extremely free trade ($\phi \to 1$) because $\lim_{\phi\to 1} \Delta v^A(\boldsymbol{\lambda}) > 0$ and $\lim_{\phi\to 1} \Delta v^B(\boldsymbol{\lambda}) < 0$.[9]

Turning to the case of $\mu \geq \sigma - 1$, $g(\delta, \phi)$ is monotonically decreasing with ϕ since $\partial g(\delta,\phi)/\partial\phi < 0$ regardless of ϕ. In addition, $\lim_{\phi\to 0} g(\delta,\phi) = 2\delta > 0$ and $\lim_{\phi\to 1} g(\delta,\phi) = -2(1-\delta) < 0$. Combining these, there exists $\tilde{\phi} \in (0,1)$, the unique root of $g(\delta,\phi) = 0$, such that $g(\delta,\phi) > 0$ (i.e., $\boldsymbol{\lambda} = (1,1)$ or $0,0$ are stable equilibria) for $\phi < \tilde{\phi}$ and $g(\delta,\phi) \leq 0$ for $\phi \geq \tilde{\phi}$ (i.e., $\boldsymbol{\lambda} = (1,1)$ or $0,0$ are unstable equilibria). Then, we obtain the following proposition:

Proposition 3.2. *When agglomeration force is strong ($\mu \geq \sigma - 1$),*
(i) if freeness of trade is sufficiently high ($\phi \geq \tilde{\phi}$), then the fully agglomerated configuration cannot be a stable equilibrium, while the completely dispersed configuration can be the stable equilibrium ($(\lambda^{A*}, \lambda^{B*}) = (1,0)$), implying that each country can attract only domestic high-skilled workers.
(ii) if freeness of trade is sufficiently low ($\phi < \tilde{\phi}$), then the fully agglomerated configuration as well as the dispersed configuration can be the stable equilibria ($(\lambda^{A*}, \lambda^{B*}) = (1,1),(0,0),(1,0)$), implying that the core country can attract high-skilled workers of both language types.

From Proposition 3.2, we observe another interesting result. Proposition 3.2 suggests that even when the agglomeration force is too strong ($\mu \geq \sigma - 1$), the manufacturing sector can disperse in sufficiently free trade circumstances ($\phi \geq \tilde{\phi}$), and industrial agglomeration can be in stable equilibrium for a sufficiently low value of ϕ ($\phi < \tilde{\phi}$). At first glance, the finding that free trade induces industrial dispersion seems unreasonable. This, however, is not curious when compared to the finding in Proposition 3.1. In Proposition 3.1, there are two transitions for a change in ϕ. The transition for a smaller ϕ, $\underline{\phi}$, is brought by a decline in τ while the transition for a larger ϕ, $\bar{\phi}$, stems from the effect of δ. For the present case with $\mu \geq \sigma - 1$, the latter impact given by δ is the essential factor.

To extend the discussion, consider what $\mu \geq \sigma - 1$ captures in the original model proposed by Forslid and Ottaviano (2003). The condition $\mu \geq \sigma - 1$ is originally known as the black hole

[9] $\lim_{\phi\to 1} \Delta v^A(\boldsymbol{\lambda}) = 2(1-\delta)[(1-\delta)(\lambda^A - \lambda^B) + 1 + \delta]^{\frac{\mu}{\sigma-1}+1} > 0$ because $(1-\delta)(\lambda^A - \lambda^B) + 1 + \delta \in [2\delta, 2]$. Similarly, $\lim_{\phi\to 1} \Delta v^B(\boldsymbol{\lambda}) = -2(1-\delta)[(1-\delta)(\lambda^A - \lambda^B) + 1 + \delta]^{\frac{\mu}{\sigma-1}+1} < 0$.

condition in the normal context of the NEG, in which the frictional cost of international migration is beyond consideration (i.e., $\delta = 1$). The black hole condition captures the situation in which the agglomeration force is so strong that for any value of the trade cost τ (and hence ϕ), industrial agglomeration in the core remains in stable equilibrium. This implies that when $\mu \geq \sigma - 1$, industrial agglomeration configuration is determined regardless of the value of ϕ so that ϕ cannot strongly operate the equilibrium configuration.

If we apply this discussion to the present model, we can assert that what operates the distinction of equilibrium configuration is the force of δ, not ϕ. A change in δ drastically affects which patterns, agglomeration or dispersion, can emerge in stable equilibrium. By setting $\delta = 0$, $g(\delta, \phi) < 0$ for every $\phi \in (0, 1)$ when $\mu \geq \sigma - 1$, implying that the fully agglomerated equilibrium cannot be stable, while the dispersed configuration is the stable equilibrium. In contrast, setting $\delta = 1$ yields $g(\delta, \phi) > 0$ for every $\phi \in (0, 1)$, which can lead to the agglomerated configuration as the stable equilibrium as well as the dispersed equilibrium. From these exercises, we can certify how strongly δ determines equilibrium configurations when $\mu \geq \sigma - 1$. Thus, we conclude that in our model with costly international migration, the core country cannot attract the entire manufacturing sector even when agglomeration force is severely strong.

Before finishing this section, we note observations on the equilibria in which at least one of λ^l is interior. For expositional convenience, we denote $\lambda^{l,int}$ as an interior λ^l. Appendix A shows that there is no possibility that $(\lambda^{A,int}, \lambda^{B,int})$ is in equilibrium whether it is unstable or stable. In addition, only partial agglomeration can be in equilibrium in which at least one of the language types is completely dependent on the country of origin, that is, $\boldsymbol{\lambda} = (1, \lambda^{B,int})$ or $(\lambda^{A,int}, 0)$ can be in equilibrium. Unfortunately, the full description of the stability analysis of $\boldsymbol{\lambda} = (1, \lambda^{B,int})$ and $(\lambda^{A,int}, 0)$ is not possible analytically. However, it can be asserted that in circumstances of extremely free migration ($\delta \to 1$), there is no possibility for $\boldsymbol{\lambda} = (1, \lambda^{B,int})$ or $(\lambda^{A,int}, 0)$ to be the stable equilibrium (see Appendix B). This non-existence of partial agglomeration configurations (because $\boldsymbol{\lambda} = (1, \lambda^{B,int})$ ($\boldsymbol{\lambda} = (\lambda^{A,int}, 0)$, respectively) implies $\lambda > 1/2$ ($\lambda < 1/2$, respectively), which captures partial agglomeration) as the stable equilibria for the extremely free migration comes from the choice of the Cobb-Douglas upper-tier utility function. If, instead, a quasi-linear form is employed as the upper-tier utility function following Pflüger (2004), for instance, it is possible that partial agglomeration of the manufacturing sector is a stable equilibrium.[10] We also consider another extreme case, $\delta \to 0$ (international migration

[10]This difference of stability of partial agglomeration configurations stems from the difference between bifurcation diagrams under the choice of the Cobb-Douglas and the quasi-linear upper-tier utility functions. More specifically, the

is prohibitively costly, or origin skills are completely useless in the destination). When $\delta \to 0$, it is shown that $\lambda^{l,int} \notin [0,1]$, implying that there is no possibility for $\boldsymbol{\lambda} = (1, \lambda^{B,int})$ or $(\lambda^{A,int}, 0)$ to be in equilibrium when the international migration cost is prohibitively high (see Appendix B).

Furthermore, in order not to limit our analysis to the extreme cases of migration freeness, we run numerical simulations with various sets of values of δ and ϕ by setting $(\mu, \sigma) = (0.5, 1.2)$ for the case of $\mu \geq \sigma - 1$ and $(\mu, \sigma) = (0.5, 2.0)$ for the case of $\mu < \sigma - 1$ in Appendix B.[11] The simulations show that in both cases of $\mu \geq \sigma - 1$ and $\mu < \sigma - 1$, $\boldsymbol{\lambda} = (1, \lambda^{B,int})$ and $(\lambda^{A,int}, 0)$ cannot consist of stable equilibria because the (asymptotic) stability condition is not satisfied for the whole range of δ and ϕ. By this numerical result, our analytical propositions obtained above may not be so restrictive even though they come from inspection of only the sustain condition.

4 Asymmetric frictional migration costs

We extend the model to an analysis based on the asymmetric frictional migration cost rather than the symmetric frictional migration cost already analyzed in Sections 2 and 3. As noted in Section 1, English-speaking countries may be more likely to be chosen as the destination and attract more migrants because of less friction in skill transfer through smoother communication via a world-widely used language, English, as empirically argued in Adsera and Pytlikova (2015) and Grogger and Hanson (2011). To express this aspect, we extend the model to one with asymmetric frictional costs. In doing so, we let δ differ for the choice of destination. If the destination is an English-speaking country, immigrants may suffer less from difficulty in skill transfer. In contrast, if the destination is a non-English-speaking country, immigrants may experience more frictional costs in skill transfer.

Departing from the specification of the frictional cost (2), we characterize asymmetry in terms of

Cobb-Douglas upper-tier utility function, following Forslid and Ottaviano (2003), brings about a tomahawk bifurcation diagram while the quasi-linear upper-tier utility function, following Pflüger (2004), induces a pitchfork bifurcation diagram.

[11] Both sets of parameters satisfy the NFS condition.

being less productive at the destination:[12]

$$\delta_i^l = \begin{cases} 1 & \text{if } i = l \\ \delta_i \in (0,1) & \text{otherwise.} \end{cases} \tag{29}$$

If, for instance, $\delta_A > \delta_B$, then migration to country A is less frictional than migration to country B. In the context related to international migration and the corresponding impacts of English communication, country A is considered an English-speaking country, while country B is considered a non-English-speaking country, so that country A does not bear severe frictional costs when transferring skills, compared to country B. Hereafter, we continue to assume $\delta_A > \delta_B$.

Following the same procedure in Sections 2 and 3, we obtain the indirect utility differential for each language type $l \in \{A, B\}$ as below:

$$\Delta V^{l,asym}(\boldsymbol{\lambda}) = \frac{\Phi_1^{asym}}{\Phi_2^{asym}(\boldsymbol{\lambda})} \Delta v^{l,asym}(\boldsymbol{\lambda}), \tag{30}$$

where $\Phi_1^{asym} > 0$, and $\Phi_2^{asym}(\boldsymbol{\lambda}) > 0$. Complete expressions for Φ_1^{asym}, $\Phi_2^{asym}(\boldsymbol{\lambda})$, and $\Delta v^{l,asym}(\boldsymbol{\lambda})$ appear in Appendix C. By inspecting (30) in the same fashion as in Section 3, we obtain the sustain condition for country i to be the core country attracting the whole industrial sector in the case of asymmetric frictional costs:[13]

$$g_i(\delta_i, \phi) \equiv 2\delta_i - \phi^{\frac{\mu}{\sigma-1}-1} \left[\left(1 - \frac{\mu}{\sigma}\right) + \left(1 + \frac{\mu}{\sigma}\right) \phi^2 \right] > 0 \tag{31}$$

for $i \in \{A, B\}$.[14]

Investigation of $g_i(\delta_i, \phi)$ is again conducted separately in the case of (i) $\mu < \sigma - 1$ and (ii) $\mu \geq \sigma - 1$.

[12]There is another possibility in introducing asymmetry of frictional costs in migration:

$$\delta_i^l = \begin{cases} 1 & \text{if } i = l \\ \delta^l \in (0,1) & \text{otherwise.} \end{cases} \tag{28}$$

This expression features asymmetry originated in a migrant characteristic, that is, their mother tongue. In contrast, the expression in (29) features asymmetry originated in a country characteristic, that is, official languages. In our settings with two countries and two languages, each of which is attached to a country-specific status, the analysis is effectively the same using either (28) or (29). Since our motivation comes from a country-specific feature whereby countries that speak a worldwide language may attract more migrants, we adopt (29), and accordingly, the results obtained are interpreted in this direction.

[13]The sustain condition for country i should originally depend not only on δ_i and ϕ but also δ_j $(i \neq j)$, that is, $g_i(\delta_i, \delta_j, \phi)$. However, calculating g_i reveal that g_i does not depend on δ_j as in (31), so that the expression of $g_i(\delta_i, \delta_j, \phi)$ reduces to $g_i(\delta_i, \phi)$.

[14]Sustain conditions are obtained from $\Delta v^{B,asym}(\boldsymbol{\lambda})|_{\boldsymbol{\lambda}=(1,1)} = -(1+\delta_A)^{\frac{\mu}{\sigma-1}+1} \phi g_A(\delta_A, \phi) < 0$ for the case of country A as the core and $\Delta v^{A,asym}(\boldsymbol{\lambda})|_{\boldsymbol{\lambda}=(0,0)} = (1+\delta_B)^{\frac{\mu}{\sigma-1}+1} \phi g_B(\delta_B, \phi) > 0$ for the case of country B as the core.

The functional form of $g_i(\delta_i, \phi)$ is the same as that of the symmetric frictional cost case, $g(\delta, \phi)$ given in (22), and thus, the shape of $g_i(\delta_i, \phi)$ is the same in its reaction to a change in ϕ, but the only difference is given by δ_i. Then, the analysis is mostly concerned with how a difference in δ_i impacts the stable equilibrium configuration.[15]

When $\mu < \sigma - 1$, there are three cases that arise according to the value of δ_i: (I) $\delta_A \leq \bar{\delta}$, (II) $\delta_B \leq \bar{\delta} < \delta_A$, and (III) $\bar{\delta} < \delta_B$, where $\bar{\delta}$ is given in (27). In the case with $(\delta_B <)\delta_A \leq \bar{\delta}$, $g_A(\delta_A, \phi) < 0$ and $g_B(\delta_B, \phi) < 0$ for every $\phi \in (0, 1)$, so that neither country can meet the sustain condition $g_i(\delta_i, \phi) > 0$ implying that complete agglomeration cannot occur in this economy. When $\delta_B \leq \bar{\delta} < \delta_A$, the sustain condition for country B remains unsatisfied, that is, $g_B(\delta_B, \phi) < 0$ for $\phi \in (0, 1)$. On the other hand, $g_A(\delta_A, \phi)$ can be positive in the range of ϕ, $\phi \in (\underline{\phi}_A, \bar{\phi}_A)$, where $\underline{\phi}_A$ and $\bar{\phi}_A$ are the roots of $g_A(\delta_A, \phi) = 0$. Outside this range, $\phi \notin (\underline{\phi}_A, \bar{\phi}_A)$, $g_A(\delta_A, \phi)$ is negative, so that the sustain condition for country A is satisfied only with the intermediate value of ϕ. Thus, when $\delta_B \leq \bar{\delta} < \delta_A$, only country A has a possibility of attracting the whole industry for an intermediate range of ϕ while country B does not have a chance of attracting the entire manufacturing sector. Lastly, if $\bar{\delta} < \delta_B (< \delta_A)$, then it is possible for each country to be the core accommodating all high-skilled workers existing in the economy because $g_A(\delta_A, \phi) > 0$ for $\phi \in (\underline{\phi}_A, \bar{\phi}_A)$, and $g_B(\delta_B, \phi) > 0$ for $\phi \in (\underline{\phi}_B, \bar{\phi}_B)$. However, there is a difference; country A is more likely to attract the entire manufacturing sector in its range of ϕ in which the sustain condition is satisfied, because it can be confirmed that $\underline{\phi}_A < \underline{\phi}_B < \bar{\phi}_B < \bar{\phi}_A$, and hence, $(\underline{\phi}_A, \bar{\phi}_A) \supset (\underline{\phi}_B, \bar{\phi}_B)$.[16]

To summarize, the above yields the following proposition:[17]

Proposition 4.1. *Assume country A is less frictional for migrants than country B ($\delta_A > \delta_B$). When*

[15] Following the similar procedures in Appendix A, we can show that only $\boldsymbol{\lambda} = (1, \lambda^{B,int})$ or $(\lambda^{A,int}, 0)$ can be in equilibrium other than the stable equilibria analyzed with the sustain condition, $\boldsymbol{\lambda} = (1, 1)$, $(1, 0)$, and $(0, 0)$. Additionally, by following the same discussions and numerical simulations in Appendix B, it is asserted that $\boldsymbol{\lambda} = (1, \lambda^{B,int})$ and $(\lambda^{A,int}, 0)$ are unlikely to be stable in the present settings. Details are provided upon request.

[16] Rigorously, we obtain $\underline{\phi}_A < \underline{\phi}_B < \bar{\phi}_B < \bar{\phi}_A$ by using the implicit function theorem. First, consider the case with $\phi < \hat{\phi}$ and the implicit function $g_i(\delta_i, \underline{\phi}_i) = 0$, where $\underline{\phi}_i$ is the root of $g_i(\delta_i, \phi) = 0$. Because $\partial g_i(\delta_i, \underline{\phi}_i)/\partial \phi > 0$ when $\underline{\phi}_i < \hat{\phi}$, by applying the implicit function theorem to $g_i(\delta_i, \underline{\phi}_i) = 0$, we obtain $\mathrm{d}\underline{\phi}_i/\mathrm{d}\delta_i < 0$. Since $\delta_B < \delta_A$, we obtain $\underline{\phi}_A < \underline{\phi}_B$. Similarly, in the case of $\phi > \hat{\phi}$, applying the implicit function theorem to $g_i(\delta_i, \bar{\phi}_i) = 0$ yields $\mathrm{d}\bar{\phi}_i/\mathrm{d}\delta_i > 0$ because $\partial g_i(\delta_i, \bar{\phi}_i)/\partial \phi < 0$ when $\bar{\phi} > \hat{\phi}$. Since $\delta_B < \delta_A$, we obtain $\bar{\phi}_A > \bar{\phi}_B$. Combining these yields $\underline{\phi}_A < \underline{\phi}_B < \bar{\phi}_B < \bar{\phi}_A$.

[17] The complete description of the stable equilibria is as follows:
Assume $\delta_A > \delta_B$. When $\mu < \sigma - 1$,
(i) if $(\delta_B <)\delta_A \leq \bar{\delta}$, then $(\lambda^{A*}, \lambda^{B*}) = (1, 0)$ can be the stable equilibrium.
(ii) if $\delta_B \leq \bar{\delta} < \delta_A$, then $(\lambda^{A*}, \lambda^{B*}) = (1, 1)$ or $(\lambda^{A*}, \lambda^{B*}) = (1, 0)$ can consist of the stable equilibria for $\phi \in (\underline{\phi}_A, \bar{\phi}_A)$, and $(\lambda^{A*}, \lambda^{B*}) = (1, 0)$ can consist of the stable equilibrium for $\phi \notin (\underline{\phi}_A, \bar{\phi}_A)$.
(iii) if $\bar{\delta} < \delta_B (< \delta_A)$, then $(\lambda^{A*}, \lambda^{B*}) = (1, 1)$, $(\lambda^{A*}, \lambda^{B*}) = (0, 0)$, or $(\lambda^{A*}, \lambda^{B*}) = (1, 0)$ can be the stable equilibria for $\phi \in (\underline{\phi}_B, \bar{\phi}_B)$, $(\lambda^{A*}, \lambda^{B*}) = (1, 1)$ or $(\lambda^{A*}, \lambda^{B*}) = (1, 0)$ can consist of the stable equilibria for $\phi \in (\underline{\phi}_A, \underline{\phi}_B] \cup [\bar{\phi}_B, \bar{\phi}_A)$, and $(\lambda^{A*}, \lambda^{B*}) = (1, 0)$ consists of the stable equilibrium for $\phi \notin (\underline{\phi}_A, \bar{\phi}_A)$.

the agglomeration force is less intense ($\mu < \sigma - 1$),

(i) if international skill transfer is severely frictional for both countries ($(\delta_B <)\delta_A \leq \bar{\delta}$), then neither country can be an industrial core, and both cannot attract the entire manufacturing sector.

(ii) if international skill transfer is highly frictional for a country, but not severely frictional for the other country ($\delta_B \leq \bar{\delta} < \delta_A$), then complete industrial agglomeration can occur in the less frictional country with the intermediate level of freeness of trade ($\phi \in (\underline{\phi}_A, \bar{\phi}_A)$) while the severely frictional country does not have a chance to be an industrial core.

(iii) if international skill transfer is not severely frictional for both countries ($\bar{\delta} < \delta_B(< \delta_A)$), then industrial agglomeration can occur in both countries at the intermediate level of freeness of trade ($\phi \in (\underline{\phi}_A, \bar{\phi}_A)$ for country A and $\phi \in (\underline{\phi}_B, \bar{\phi}_B)$ for country B), but the less frictional country is more likely to attract the entire manufacturing sector than the more frictional country ($(\underline{\phi}_A, \bar{\phi}_A) \supset (\underline{\phi}_B, \bar{\phi}_B)$).

What is new in Proposition 4.1 compared to Proposition 3.1 is that the possibility of being the industrial core attracting the entire manufacturing sector differs in accordance with the difference in frictional costs of in-migration: a less frictional country for immigrants is more likely to attract high-skilled workers than the more frictional country. This coordinates with the assertion in Adsera and Pytlikova (2015) that English-speaking countries can attract more migrants than non-English-speaking countries because skill transfer is smoother when English-speaking countries are chosen as the destination.

Related to this assertion that English speaking countries are more likely to attract international migrants than non-English speaking countries, a couple of immigration policies in terms of language education may be considered effective. The first policy option is from the viewpoint of language investment of arriving migrants. If countries with high linguistic barrier but want to promote immigration invest in language development for arriving migrants and support them in acquiring indigenous languages, such countries may be more likely to be chosen as the destination. The second option is to invest language development of indigenous people. If their English ability is high, this leads to smoother communication with immigrants, which would ease language barriers for arriving migrants. Then, potential migrants are more likely to choose such countries with less difficulty in communication.

As in Section 3, we quickly examine the stable equilibrium in the case of $\mu \geq \sigma - 1$. Using similar procedures in the case of $\mu < \sigma - 1$, we obtain the result that country A is more likely to experience complete industrial agglomeration than country B because $g_A(\delta_A, \phi) > 0$ can hold for $\phi \in (0, \tilde{\phi}_A)$ and $g_B(\delta_B, \phi) > 0$ can hold for $\phi \in (0, \tilde{\phi}_B)$, but $\tilde{\phi}_A > \tilde{\phi}_B$. Obviously, $(0, \tilde{\phi}_A) \supset (0, \tilde{\phi}_B)$ holds so that the range of ϕ for country A to be the core is larger than that of country B. Then, we obtain the following proposition:[18]

Proposition 4.2. *Assume country A is less frictional for migrants than country B ($\delta_A > \delta_B$). When the agglomeration force is strong ($\mu \geq \sigma - 1$), both countries can be an industrial core, but the possibility of attracting the whole industrial sector is higher for the less frictional country than the more frictional country ($(0, \tilde{\phi}_A) \supset (0, \tilde{\phi}_B)$).*

Again, in the case with stronger agglomeration forces, the less frictional country is more likely to be the core, and hence, international migrants prefer to choose destinations where they can transfer their skills smoothly to avoid inefficiency stemming from migration costs partly caused by difficulty in communication via common languages or differences in culture.

Finally, a quick comment on the extension to a multi-country model (such as a three-country model) should be noted, in which migrating to a less (least) frictional country (country A) is less costly compared to migrating to more frictional countries (country B or C). Namely, a high-skilled worker who migrates to country A suffers from only $1 - \bar{\delta}$ fraction of lost productivity while a high-skilled worker who migrates to country B or C suffers from $1 - \underline{\delta}$ fraction of lost productivity, where $\bar{\delta} > \underline{\delta}$. Expanding the discussion shown in the two-country model to a multi-country model is straightforward if the discussion is limited to industrial distributions of complete dispersion and agglomeration.

For the dispersed configuration, it is always in stable equilibrium following the same discussion in Section 3, since under existence of the migration cost ($\delta < 1$), $V_l^l|_{disp}$ is always higher than $V_{-l}^l|_{disp}$, where $V_l^l|_{disp}$ indicates a high-skilled distribution in which all high-skilled workers reside in their origin countries so that there are no migrants and high-skilled workers are evenly distributed across countries. In words, the indirect utility obtained in the origin country under dispersed configuration is higher than that in the destination country because staying in the origin does not bear migration costs.

Turning to the agglomerated configuration, first consider the case in which country A is the core attracting all high-skilled workers. In this case, the sustain condition for agglomeration in country is to satisfy both A is $V_A^B|_{aggA} > V_B^B|_{aggA}$ and $V_A^C|_{aggA} > V_C^C|_{aggA}$, where the subscript $aggA$ indicates that all high-skilled workers are in country A. The sustain condition comes from an observation that, for high-skilled workers of language type B (language type C, respectively), residing in country

[18] The complete description of the stable equilibria is as follows:
Assume $\delta_A > \delta_B$. When $\mu \geq \sigma - 1$,
(i) if $\phi \in (0, \tilde{\phi}_B)$, then $(\lambda^{A*}, \lambda^{B*}) = (1, 1)$, $(\lambda^{A*}, \lambda^{B*}) = (0, 0)$, or $(\lambda^{A*}, \lambda^{B*}) = (1, 0)$ can be the stable equilibria.
(ii) if $\phi \in [\tilde{\phi}_B, \tilde{\phi}_A)$, then $(\lambda^{A*}, \lambda^{B*}) = (1, 1)$ or $(\lambda^{A*}, \lambda^{B*}) = (1, 0)$ can consist of the stable equilibria.
(iii) if $\phi \in [\tilde{\phi}_A, 1)$, then $(\lambda^{A*}, \lambda^{B*}) = (1, 0)$ is the stable equilibrium.

A always bears higher indirect utilities than residing in country C (country B, respectively) due to industrial agglomeration in country A, so that the final comparison for the sustain condition of agglomeration in country A is between residing in country A and residing in country of her origin (i.e., country B (country C, respectively) for high-skilled workers with language type B (language type C, respectively)).

Next, consider the case in which country B is the industrial core attracting all high-skilled workers. In this case, the sustain condition for agglomeration in country B is $V_B^A|_{aggB} > V_A^A|_{aggB}$ and $V_B^C|_{aggB} > V_C^C|_{aggB}$. This sustain condition comes from an observation that high-skilled workers of language type A (language type C, respectively) always enjoy higher indirect utilities when residing in country A (country C, respectively) than residing in country C (country A, respectively) due to the existence of migration costs, so that the final comparison is between residing in country A (country C, respectively) and in country B. The situation is the same for the case of country C as the industrial core, so that the sustain condition for country C to be the core is $V_C^A|_{aggC} > V_A^A|_{aggC}$ and $V_C^B|_{aggC} > V_B^B|_{aggC}$.

Now we can compare the sustain condition for country A to be the core and that for country B (country C, respectively) to be the core. Because migration to country A is less costly than migration to country B or C (because $\bar{\delta} > \underline{\delta}$), satisfying the sustain condition for country A to be the core is less strict than satisfying the sustain condition for country B or C to be the core. (Notice that the sustain condition for country A to be the core comes from the migration decision of high-skilled workers with language type B and C, which implies that the migration cost they have to incur in order to migrate to country A is $1-\bar{\delta}$. On the other hand, the sustain condition for country B (country C, respectively) to be the core comes from the migration decision of high-skilled workers with language type A and C (language type A and B, respectively), which implies that the migration cost to country B (country C, respectively) is $1 - \underline{\delta}$, which exhibits a severer migration cost compared to the case of migrating to country A as the core.) These observations imply that the sustain condition for country A to be the core is less severe to be satisfied than the sustain condition for country B or C to be the core. From this rough discussion, we can assert that in a multi-country setting, the obtained result that the least frictional country to be the industrial core attracting all high-skilled mobile workers remains unchanged.

5 Conclusion

In this paper, we analyzed how frictional migration costs affect spatial equilibrium configuration of industrial agglomeration. Our specification of frictional costs captures the difficulty in skill transference in terms of lower productivity at destination countries. When international migration occurs, differences in language use, culture, and production processes may induce a drop in productivity for immigrant workers. Unlike in the traditional NEG context, in which mobile workers are assumed to move across regions freely, it is inappropriate to assume costless migration in our model that addresses international migration associated with linguistic or cultural barriers. Then, we conduct a theoretical analysis based on Forslid and Ottaviano's (2003) footloose entrepreneur model and introduce frictional migration costs in terms of lower productivity at destinations with a specification that follows Grossman and Rossi-Hansberg (2008) and Ottaviano et al. (2013).

The essence of the obtained results is as follows. For the case of symmetric migration costs, when international migration is severely frictional, migration cannot occur. In contrast, if migration is less frictional, high-skilled workers can be attracted to one country, which becomes an industrial core. For the case of asymmetric migration costs, a less frictional country is more likely to attract high-skilled workers, and can experience industrial agglomeration. These results coincide with the findings from real world migration: potential migrants are more likely to migrate to destinations with less frictional migration costs (caused by language difference), and English-speaking countries can attract more international migrants because such countries offer less severe language barriers and difficulty in communication.

References

Adsera, A. and M. Pytlikova (2015): "The Role of Language in Shaping International Migration," *The Economic Journal*, 125, F49–F81.

Beenstock, M., B. R. Chiswick, and G. L. Repetto (2001): "The Effect of Linguistic Distance and Country of Origin on Immigrant Language Skills: Application to Israel," *International Migration*, 39, 33–60.

Belot, M. and S. Ederveen (2012): "Cultural Barriers in Migration between OECD Countries," *Journal of Population Economics*, 25, 1077–1105.

BELOT, M. V. AND T. J. HATTON (2012): "Immigrant Selection in the OECD," *The Scandinavian Journal of Economics*, 114, 1105–1128.

CHIQUIAR, D. AND G. H. HANSON (2005): "International Migration, Self-selection, and the Distribution of Wages: Evidence from Mexico and the United States," *Journal of Political Economy*, 113, 239–281.

CHISWICK, B. R. AND P. W. MILLER (2005): "Linguistic Distance: A Quantitative Measure of the Distance between English and Other Languages," *Journal of Multilingual and Multicultural Development*, 26, 1–11.

——— (2014): "International Migration and the Economics of Language," *Handbook of the Economics of Immigration*, 211–269.

CLARK, X., T. J. HATTON, AND J. G. WILLIAMSON (2007): "Explaining US Immigration, 1971–1998," *The Review of Economics and Statistics*, 89, 359–373.

DUSTMANN, C. AND A. VAN SOEST (2001): "Language Fluency and Earnings: Estimation with Misclassified Language Indicators," *Review of Economics and Statistics*, 83, 663–674.

——— (2002): "Language and the Earnings of Immigrants," *Industrial and Labor Relations Review*, 55, 473–492.

FORSLID, R. AND G. I. OTTAVIANO (2003): "An Analytically Solvable Core-periphery Model," *Journal of Economic Geography*, 3, 229–240.

FUJITA, M., P. KRUGMAN, AND A. J. VENABLES (1999): *The Spatial Economy: Cities, Regions, and International Trade*, Cambridge, MA: MIT Press.

GINSBURGH, V., Y. PAPAGEORGIOU, AND J.-F. THISSE (1985): "On Existence and Stability of Ppatial Equilibria and Steady-states," *Regional Science and Urban economics*, 15, 149–158.

GROGGER, J. AND G. H. HANSON (2011): "Income Mmaximization and the Selection and Sorting of International Migrants," *Journal of Development Economics*, 95, 42–57.

GROSSMAN, G. M. AND E. ROSSI-HANSBERG (2008): "Trading Tasks: A Simple Theory of Offshoring," *American Economic Review*, 98, 1978–1997.

KRUGMAN, P. (1991): "Increasing Returns and Economic Geography," *Journal of Political Economy*, 99, 483–499.

LUDEMA, R. D. AND I. WOOTON (1999): "Regional Integration, Trade and Migration: Are Demand Linkages Relevant in Europe?" *Migration: The Controversies and the Evidence*, 51–68.

MAYDA, A. M. (2010): "International Migration: A Panel Data Analysis of the Determinants of Bilateral Flows," *Journal of Population Economics*, 23, 1249–1274.

OTTAVIANO, G. I., G. PERI, AND G. C. WRIGHT (2013): "Immigration, Offshoring, and American jobs," *American Economic Review*, 103, 1925–1959.

PEDERSEN, P. J., M. PYTLIKOVA, AND N. SMITH (2008): "Selection and Network Effects—Migration Flows into OECD Countries 1990–2000," *European Economic Review*, 52, 1160–1186.

PFLÜGER, M. (2004): "A Simple, Analytically Solvable, Chamberlinian Agglomeration Model," *Regional Science and Urban Economics*, 34, 565–573.

ROY, A. D. (1951): "Some Thoughts on the Distribution of Earnings," *Oxford Economic Papers*, 3, 135–146.

TABUCHI, T. AND J.-F. THISSE (2002): "Taste Heterogeneity, Labor Mobility and Economic Geography," *Journal of Development Economics*, 69, 155–177.

Appendix A Inspection of ΔV^l and the possible interior equilibrium

To find which pairs of λ^ls can be in equilibrium, first we consider nine cases whose classification is based on the signs of $\Delta v^l(\boldsymbol{\lambda})$:

(i) $(\Delta v^A(\boldsymbol{\lambda}), \Delta v^B(\boldsymbol{\lambda})) = (+,+)$, (ii) $(\Delta v^A(\boldsymbol{\lambda}), \Delta v^B(\boldsymbol{\lambda})) = (+,-)$, (iii) $(\Delta v^A(\boldsymbol{\lambda}), \Delta v^B(\boldsymbol{\lambda})) = (+,0)$,

(iv) $(\Delta v^A(\boldsymbol{\lambda}), \Delta v^B(\boldsymbol{\lambda})) = (-,+)$, (v) $(\Delta v^A(\boldsymbol{\lambda}), \Delta v^B(\boldsymbol{\lambda})) = (-,-)$, (vi) $(\Delta v^A(\boldsymbol{\lambda}), \Delta v^B(\boldsymbol{\lambda})) = (-,0)$,

(vii) $(\Delta v^A(\boldsymbol{\lambda}), \Delta v^B(\boldsymbol{\lambda})) = (0,+)$, (viii) $(\Delta v^A(\boldsymbol{\lambda}), \Delta v^B(\boldsymbol{\lambda})) = (0,-)$, (ix) $(\Delta v^A(\boldsymbol{\lambda}), \Delta v^B(\boldsymbol{\lambda})) = (0,0)$,

where a notation $(\Delta v^A(\boldsymbol{\lambda}), \Delta v^B(\boldsymbol{\lambda})) = (+,+)$ means $\Delta v^A(\boldsymbol{\lambda}) > 0$ and $\Delta v^B(\boldsymbol{\lambda}) > 0$, $(\Delta v^A(\boldsymbol{\lambda}), \Delta v^B(\boldsymbol{\lambda})) = (-,0)$ means $\Delta v^A(\boldsymbol{\lambda}) < 0$ and $\Delta v^B(\boldsymbol{\lambda}) = 0$, and so on. Below we show that only cases (i), (ii), (iii), (v), and (viii) can hold without contradiction, but cases (iv), (vi), (vii), and (ix) never hold in the present settings. An analysis is conducted based on the classification of $\Delta v^B(\boldsymbol{\lambda})$: (I) $\Delta v^B(\boldsymbol{\lambda}) > 0$, (II) $\Delta v^B(\boldsymbol{\lambda}) = 0$, and (III) $\Delta v^B(\boldsymbol{\lambda}) < 0$.[19]

(I) $\Delta v^B(\boldsymbol{\lambda}) > 0$

When $\Delta v^B(\boldsymbol{\lambda}) > 0$,[20] by using (19),

$$\begin{aligned}
&\delta\left[\left(\lambda^A+\delta\lambda^B\right)+\phi\left(\delta\left(1-\lambda^A\right)+\left(1-\lambda^B\right)\right)\right]^{\frac{\mu}{\sigma-1}} \\
&\quad\times\left[2\phi\left(\lambda^A+\delta\lambda^B\right)+\left[1-\frac{\mu}{\sigma}+\left(1+\frac{\mu}{\sigma}\right)\phi^2\right]\left(\delta\left(1-\lambda^A\right)+\left(1-\lambda^B\right)\right)\right] \\
&>\left[\left(\delta\left(1-\lambda^A\right)+\left(1-\lambda^B\right)\right)+\phi\left(\lambda^A+\delta\lambda^B\right)\right]^{\frac{\mu}{\sigma-1}} \\
&\qquad\times\left[2\phi\left(\delta\left(1-\lambda^A\right)+\left(1-\lambda^B\right)\right)+\left[1-\frac{\mu}{\sigma}+\left(1+\frac{\mu}{\sigma}\right)\phi^2\right]\left(\lambda^A+\delta\lambda^B\right)\right]. \qquad (32)
\end{aligned}$$

[19] The results are the same when the classification is based on $\Delta v^A(\boldsymbol{\lambda})$ instead of $\Delta v^B(\boldsymbol{\lambda})$.

[20] At this point for case (I), we assume $\Delta v^B(\boldsymbol{\lambda}) > 0$. Effectively, the condition on which $\Delta v^B(\boldsymbol{\lambda}) > 0$ holds is the sustain condition $g(\delta, \phi) > 0$ proposed in Section 3.

By substituting the inequality in (32) into (18),

$$
\begin{aligned}
\Delta v^A(\boldsymbol{\lambda}) = & \left[\left(\lambda^A+\delta\lambda^B\right)+\phi\left(\delta\left(1-\lambda^A\right)+\left(1-\lambda^B\right)\right)\right]^{\frac{\mu}{\sigma-1}} \\
& \quad \times\left[2\phi\left(\lambda^A+\delta\lambda^B\right)+\left[1-\frac{\mu}{\sigma}+\left(1+\frac{\mu}{\sigma}\right)\phi^2\right]\left(\delta\left(1-\lambda^A\right)+\left(1-\lambda^B\right)\right)\right] \\
& -\delta\left[\left(\delta\left(1-\lambda^A\right)+\left(1-\lambda^B\right)\right)+\phi\left(\lambda^A+\delta\lambda^B\right)\right]^{\frac{\mu}{\sigma-1}} \\
& \quad \times\left[2\phi\left(\delta\left(1-\lambda^A\right)+\left(1-\lambda^B\right)\right)+\left[1-\frac{\mu}{\sigma}+\left(1+\frac{\mu}{\sigma}\right)\phi^2\right]\left(\lambda^A+\delta\lambda^B\right)\right] \\
> & \left[\left(\lambda^A+\delta\lambda^B\right)+\phi\left(\delta\left(1-\lambda^A\right)+\left(1-\lambda^B\right)\right)\right]^{\frac{\mu}{\sigma-1}} \\
& \quad \times\left[2\phi\left(\lambda^A+\delta\lambda^B\right)+\left[1-\frac{\mu}{\sigma}+\left(1+\frac{\mu}{\sigma}\right)\phi^2\right]\left(\delta\left(1-\lambda^A\right)+\left(1-\lambda^B\right)\right)\right] \\
& -\delta^2\left[\left(\lambda^A+\delta\lambda^B\right)+\phi\left(\delta\left(1-\lambda^A\right)+\left(1-\lambda^B\right)\right)\right]^{\frac{\mu}{\sigma-1}} \\
& \quad \times\left[2\phi\left(\lambda^A+\delta\lambda^B\right)+\left[1-\frac{\mu}{\sigma}+\left(1+\frac{\mu}{\sigma}\right)\phi^2\right]\left(\delta\left(1-\lambda^A\right)+\left(1-\lambda^B\right)\right)\right] \\
= & (1+\delta)(1-\delta)\left[\left(\lambda^A+\delta\lambda^B\right)+\phi\left(\delta\left(1-\lambda^A\right)+\left(1-\lambda^B\right)\right)\right]^{\frac{\mu}{\sigma-1}} \\
& \quad \times\left[2\phi\left(\lambda^A+\delta\lambda^B\right)+\left[1-\frac{\mu}{\sigma}+\left(1+\frac{\mu}{\sigma}\right)\phi^2\right]\left(\delta\left(1-\lambda^A\right)+\left(1-\lambda^B\right)\right)\right] \\
> & \, 0.
\end{aligned}
$$

Thus, when $\Delta v^B(\boldsymbol{\lambda}) > 0$, (i) can hold without contradiction, while (iv) and (vii) never hold.

(II) $\Delta v^B(\boldsymbol{\lambda}) = 0$

When $\Delta v^B(\boldsymbol{\lambda}) = 0$, by using (19),

$$
\begin{aligned}
& \delta\left[\left(\lambda^A+\delta\lambda^B\right)+\phi\left(\delta\left(1-\lambda^A\right)+\left(1-\lambda^B\right)\right)\right]^{\frac{\mu}{\sigma-1}} \\
& \quad \times\left[2\phi\left(\lambda^A+\delta\lambda^B\right)+\left[1-\frac{\mu}{\sigma}+\left(1+\frac{\mu}{\sigma}\right)\phi^2\right]\left(\delta\left(1-\lambda^A\right)+\left(1-\lambda^B\right)\right)\right] \\
& =\left[\left(\delta\left(1-\lambda^A\right)+\left(1-\lambda^B\right)\right)+\phi\left(\lambda^A+\delta\lambda^B\right)\right]^{\frac{\mu}{\sigma-1}} \\
& \quad \times\left[2\phi\left(\delta\left(1-\lambda^A\right)+\left(1-\lambda^B\right)\right)+\left[1-\frac{\mu}{\sigma}+\left(1+\frac{\mu}{\sigma}\right)\phi^2\right]\left(\lambda^A+\delta\lambda^B\right)\right].
\end{aligned}
\tag{33}
$$

By substituting (33) into (18),

$$\begin{aligned}
\Delta v^A(\boldsymbol{\lambda}) &= \left[\left(\lambda^A+\delta\lambda^B\right)+\phi\left(\delta\left(1-\lambda^A\right)+\left(1-\lambda^B\right)\right)\right]^{\frac{\mu}{\sigma-1}} \\
&\qquad \times\left[2\phi\left(\lambda^A+\delta\lambda^B\right)+\left[1-\frac{\mu}{\sigma}+\left(1+\frac{\mu}{\sigma}\right)\phi^2\right]\left(\delta\left(1-\lambda^A\right)+\left(1-\lambda^B\right)\right)\right] \\
&\quad -\delta\left[\left(\delta\left(1-\lambda^A\right)+\left(1-\lambda^B\right)\right)+\phi\left(\lambda^A+\delta\lambda^B\right)\right]^{\frac{\mu}{\sigma-1}} \\
&\qquad \times\left[2\phi\left(\delta\left(1-\lambda^A\right)+\left(1-\lambda^B\right)\right)+\left[1-\frac{\mu}{\sigma}+\left(1+\frac{\mu}{\sigma}\right)\phi^2\right]\left(\lambda^A+\delta\lambda^B\right)\right] \\
&= \left[\left(\lambda^A+\delta\lambda^B\right)+\phi\left(\delta\left(1-\lambda^A\right)+\left(1-\lambda^B\right)\right)\right]^{\frac{\mu}{\sigma-1}} \\
&\qquad \times\left[2\phi\left(\lambda^A+\delta\lambda^B\right)+\left[1-\frac{\mu}{\sigma}+\left(1+\frac{\mu}{\sigma}\right)\phi^2\right]\left(\delta\left(1-\lambda^A\right)+\left(1-\lambda^B\right)\right)\right] \\
&\quad -\delta^2\left[\left(\lambda^A+\delta\lambda^B\right)+\phi\left(\delta\left(1-\lambda^A\right)+\left(1-\lambda^B\right)\right)\right]^{\frac{\mu}{\sigma-1}} \\
&\qquad \times\left[2\phi\left(\lambda^A+\delta\lambda^B\right)+\left[1-\frac{\mu}{\sigma}+\left(1+\frac{\mu}{\sigma}\right)\phi^2\right]\left(\delta\left(1-\lambda^A\right)+\left(1-\lambda^B\right)\right)\right] \\
&= (1+\delta)(1-\delta)\left[\left(\lambda^A+\delta\lambda^B\right)+\phi\left(\delta\left(1-\lambda^A\right)+\left(1-\lambda^B\right)\right)\right]^{\frac{\mu}{\sigma-1}} \\
&\qquad \times\left[2\phi\left(\lambda^A+\delta\lambda^B\right)+\left[1-\frac{\mu}{\sigma}+\left(1+\frac{\mu}{\sigma}\right)\phi^2\right]\left(\delta\left(1-\lambda^A\right)+\left(1-\lambda^B\right)\right)\right] \\
&> 0.
\end{aligned}$$

Thus, when $\Delta v^B(\boldsymbol{\lambda})=0$, (iii) can hold without contradiction, while (vi) and (ix) never hold.

(III) $\Delta v^B(\boldsymbol{\lambda})<0$

When $\Delta v^B(\boldsymbol{\lambda})<0$, $\Delta v^A(\boldsymbol{\lambda})$ can be positive or negative. Thus, (ii), (v), and (viii) can hold without contradiction.

Summing the above, only (i), (ii), (iii), (v), and (viii) survive as candidates of equilibrium. Especially, because (ix) $(\Delta v^A(\boldsymbol{\lambda}),\Delta v^B(\boldsymbol{\lambda}))=(0,0)$ can never hold, this implies $(\lambda^{A,int},\lambda^{B,int})$ cannot be in equilibrium in our model. Turning to the survivors, (i), (ii), and (v) are already considered in Section 3. The remnants, (iii) and (viii) imply that $\boldsymbol{\lambda}=(1,\lambda^{B,int})$ or $(\lambda^{A,int},0)$ can be in equilibrium. In (iii) (in (viii), respectively), $\boldsymbol{\lambda}=(1,\lambda^{B,int})$ ($\boldsymbol{\lambda}=(\lambda^{A,int},0)$, respectively) consists of an equilibrium, expressing partial agglomeration in country A (country B, respectively), and the core country accommodates all native high-skilled workers (whose country of origin is the core) plus some fraction of immigrant high-skilled workers.

Appendix B Inspection of the (in)stability of the other equilibria

We discuss the (in)stability of $\boldsymbol{\lambda} = (1, \lambda^{B,int})$ and $(\lambda^{A,int}, 0)$ as follows: (I) we derive the stability condition that $\boldsymbol{\lambda} = (1, \lambda^{B,int})$ and $(\lambda^{A,int}, 0)$ have to satisfy, and (II) we discuss analytically whether it is impossible for $\boldsymbol{\lambda} = (1, \lambda^{B,int})$ or $(\lambda^{A,int}, 0)$ to be stable in the present settings by restricting the analysis to the extreme cases of freeness of migration, and additionally, (III) we run numerical simulations with various values of δ and ϕ to check the robustness of the (in)stability of the equilibria. (II) and (III) reveal that the stability condition is unlikely to be satisfied in the present settings. We focus on the industrial distribution in which country A attracts more high-skilled workers (i.e., $\boldsymbol{\lambda} = (1, \lambda^{B,int})$). The same discussion applies to the case of $\boldsymbol{\lambda} = (\lambda^{A,int}, 0)$.

(I) Stability condition for the equilibrium $\boldsymbol{\lambda} = (1, \lambda^{B,int})$

By (19) and $\lambda^A = 1$, $\Delta v^B(\boldsymbol{\lambda})|_{\lambda^A=1} = 0$ is rewritten as

$$\begin{aligned}
&\delta[(1+\delta\lambda^B) + \phi(1-\lambda^B)]^{\frac{\mu}{\sigma-1}} \left[2\phi\left(1+\delta\lambda^B\right) + \left[1 - \frac{\mu}{\sigma} + \left(1+\frac{\mu}{\sigma}\right)\phi^2\right]\left(1-\lambda^B\right)\right] \\
&= [(1-\lambda^B) + \phi(1+\delta\lambda^B)]^{\frac{\mu}{\sigma-1}} \left[2\phi\left(1-\lambda^B\right) + \left[1 - \frac{\mu}{\sigma} + \left(1+\frac{\mu}{\sigma}\right)\phi^2\right]\left(1+\delta\lambda^B\right)\right]. \qquad (34)
\end{aligned}$$

A candidate of $\lambda^{B,int}$ satisfies (34) as well as $\lambda^{B,int} \in [0, 1]$. The stability of the equilibrium $\boldsymbol{\lambda} = (1, \lambda^{B,int})$ is analyzed by inspecting the Jacobian of the dynamic system (16),

$$\boldsymbol{J} \equiv \left.\begin{pmatrix} \frac{\partial J^A(\boldsymbol{\lambda})}{\partial \lambda^A} & \frac{\partial J^A(\boldsymbol{\lambda})}{\partial \lambda^B} \\ \frac{\partial J^B(\boldsymbol{\lambda})}{\partial \lambda^A} & \frac{\partial J^B(\boldsymbol{\lambda})}{\partial \lambda^B} \end{pmatrix}\right|_{\boldsymbol{\lambda}=(1,\lambda^{B,int})}, \qquad (35)$$

where $J^l(\boldsymbol{\lambda}) \equiv \mathrm{d}\lambda^l/\mathrm{d}t$ given in (16). Since $\boldsymbol{J}$ is a 2×2 matrix, the (asymptotic) stability condition for $\boldsymbol{\lambda} = (1, \lambda^{B,int})$ is $\det\boldsymbol{J} > 0$ and $\mathrm{Tr}\boldsymbol{J} < 0$.

(II) Instability of $\boldsymbol{\lambda} = (1, \lambda^{B,int})$ for the extreme cases of migration costs

It is not possible to induce completely analytical inference on the stability of the equilibrium, $\boldsymbol{\lambda} = (1, \lambda^{B,int})$, but special cases are tractable. We first consider whether $\boldsymbol{\lambda} = (1, \lambda^{B,int})$ can be a stable equilibrium when high-skilled workers are extremely freely mobile. In other words, we discuss whether a partially agglomerated equilibrium ($\lambda > 1/2$) can be stable when $\delta \to 1$. Below we confirm that a partial agglomeration cannot be a stable equilibrium.

When $\delta \to 1$, our model reduces to the original model proposed in Forslid and Ottaviano (2003) except for the total population size, which does not affect the equilibrium pattern. In Forslid and Ottaviano's (2003) model, however, partial agglomerated equilibria are shown to be unstable for every ϕ.[21] Hence, it can be asserted that partially agglomerated equilibrium, $\lambda > 1/2$, or $\boldsymbol{\lambda} = (1, \lambda^{B,int})$, cannot be a stable equilibrium under extremely freely international migration.

The second extreme case is the one under prohibitively high migration costs, that is, $\delta \to 0$. When $\delta \to 0$, (34) reduces to $(1 + \phi - \lambda^{B,int})^{\mu/(\sigma-1)} = 0$. However, $\lambda^{B,int}$ satisfying this equality cannot lie between 0 and 1 ($\lambda^{B,int} \notin [0,1]$). Thus, when migration costs are extremely high ($\delta \to 0$), $\boldsymbol{\lambda} = (1, \lambda^{B,int})$ cannot be in equilibrium.

(III) Numerical simulation for the (in)stability of $\boldsymbol{\lambda} = (1, \lambda^{B,int})$

To relax the restriction on δ imposed in (II), we rely on numerical exercises and see the reaction of the value of $\lambda^{B,int}$ and its (in)stability accompanied by the changes in δ and ϕ. For the case of $\mu \geq \sigma - 1$, we set $(\mu, \sigma) = (0.5, 1.2)$, while for the case of $\mu < \sigma - 1$, we set $(\mu, \sigma) = (0.5, 2.0)$.[22] Tables 1-3 show the returned values of $\lambda^{B,int}$ satisfying (34), the determinant and trace of the Jacobian (35) evaluated at $\boldsymbol{\lambda} = (1, \lambda^{B,int})$ for the case of $(\mu, \sigma) = (0.5, 1.2)$. Tables 4-6 display those for the case of $(\mu, \sigma) = (0.5, 2.0)$. The listed values satisfy $\lambda^{B,int} \in [0,1]$ and the entries indicated by "." mean $\lambda^{B,int} \notin [0,1]$. For both cases of $(\mu, \sigma) = (0.5, 1.2)$ and $(0.5, 2.0)$, returned values of the determinant of the Jacobian are negative throughout the ranges of δ and ϕ, implying that $\boldsymbol{\lambda} = (1, \lambda^{B,int})$ is unstable.[23]

[21]For rigorous discussions, see Section 3 in Forslid and Ottaviano (2003).

[22]Both sets of parameters satisfy the NFS condition.

[23]The numerical simulation for $\boldsymbol{\lambda} = (\lambda^{A,int}, 0)$ returns the same results as that of $\boldsymbol{\lambda} = (1, \lambda^{B,int})$. Details are provided upon request.

Table 1: $\lambda^{B,int}$ when country A is the core under high agglomeration force ($\mu \geq \sigma - 1$): $\boldsymbol{\lambda} = (1, \lambda^{B,int})$, $\mu = 0.5$, $\sigma = 1.2$

$\phi \backslash \delta$	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95
0.05	0.856	0.760	0.678	0.604	0.537	0.475	0.418	0.365	0.317	0.273	0.233	0.196	0.162	0.132	0.104	0.079	0.056	0.036	0.017
0.1	0.876	0.773	0.688	0.612	0.542	0.479	0.421	0.368	0.319	0.275	0.234	0.197	0.163	0.132	0.105	0.079	0.057	0.036	0.017
0.15	0.904	0.797	0.708	0.630	0.558	0.493	0.433	0.378	0.328	0.282	0.241	0.203	0.168	0.136	0.108	0.082	0.058	0.037	0.017
0.2	0.939	0.828	0.736	0.655	0.581	0.514	0.452	0.395	0.343	0.295	0.252	0.212	0.176	0.143	0.113	0.086	0.061	0.039	0.018
0.25	0.978	0.865	0.771	0.687	0.611	0.541	0.476	0.417	0.362	0.312	0.266	0.224	0.186	0.151	0.119	0.091	0.065	0.041	0.019
0.3	.	0.907	0.811	0.725	0.646	0.573	0.506	0.444	0.386	0.333	0.285	0.240	0.199	0.162	0.128	0.097	0.069	0.044	0.021
0.35	.	0.953	0.856	0.769	0.687	0.612	0.541	0.476	0.415	0.359	0.307	0.259	0.215	0.175	0.139	0.105	0.075	0.047	0.023
0.4	.	.	0.908	0.818	0.735	0.657	0.583	0.514	0.449	0.389	0.333	0.282	0.234	0.191	0.151	0.115	0.082	0.052	0.025
0.45	.	.	0.965	0.875	0.790	0.709	0.632	0.559	0.490	0.425	0.365	0.309	0.258	0.210	0.167	0.127	0.090	0.057	0.027
0.5	.	.	.	0.939	0.852	0.769	0.688	0.611	0.538	0.469	0.403	0.343	0.286	0.234	0.185	0.141	0.101	0.064	0.030
0.55	.	.	.	.	0.924	0.839	0.755	0.674	0.596	0.521	0.450	0.383	0.320	0.262	0.208	0.159	0.113	0.072	0.034
0.6	.	.	.	.	.	0.920	0.834	0.749	0.665	0.585	0.507	0.433	0.363	0.298	0.237	0.181	0.130	0.082	0.039
0.65	.	.	.	.	.	.	0.929	0.840	0.751	0.664	0.578	0.496	0.418	0.344	0.274	0.210	0.150	0.095	0.045
0.7	.	.	.	.	.	.	.	0.952	0.858	0.764	0.670	0.578	0.489	0.404	0.324	0.248	0.178	0.113	0.054
0.75	.	.	.	.	.	.	.	.	0.996	0.895	0.792	0.689	0.587	0.487	0.392	0.301	0.217	0.138	0.066
0.8	.	.	.	.	.	.	.	.	.	.	0.961	0.845	0.726	0.608	0.492	0.380	0.274	0.175	0.084
0.85	.	.	.	.	.	.	.	.	.	.	.	.	0.943	0.799	0.653	0.509	0.370	0.237	0.114
0.9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.957	0.758	0.557	0.360	0.173
0.95	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.720	0.351

Each element in the table is the returned λ^B satisfying $\Delta v^B = 0$ when $\lambda^A = 1$, $\mu = 0.5$, $\sigma = 1.2$, δ and ϕ are given.
Entries are indicated by "." if the returned value of $\lambda^B \notin [0, 1]$.

Table 2: Determinant of the Jacobian when country A is the core under high agglomeration force ($\mu \geq \sigma - 1$): $\boldsymbol{\lambda} = (1, \lambda^{B,int})$, $\mu = 0.5$, $\sigma = 1.2$

$\phi \backslash \delta$	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95
0.05	-0.003	-0.011	-0.025	-0.043	-0.066	-0.088	-0.109	-0.125	-0.134	-0.136	-0.130	-0.118	-0.102	-0.082	-0.062	-0.042	-0.025	-0.011	-0.003
0.1	-0.005	-0.021	-0.046	-0.080	-0.119	-0.159	-0.193	-0.219	-0.234	-0.235	-0.225	-0.204	-0.175	-0.141	-0.105	-0.072	-0.042	-0.020	-0.005
0.15	-0.007	-0.031	-0.072	-0.127	-0.190	-0.255	-0.312	-0.355	-0.380	-0.383	-0.367	-0.333	-0.285	-0.230	-0.173	-0.118	-0.069	-0.032	-0.008
0.2	-0.006	-0.039	-0.098	-0.180	-0.278	-0.378	-0.470	-0.541	-0.584	-0.594	-0.571	-0.521	-0.449	-0.364	-0.274	-0.187	-0.111	-0.051	-0.013
0.25	-0.003	-0.043	-0.121	-0.235	-0.376	-0.527	-0.669	-0.783	-0.857	-0.882	-0.857	-0.788	-0.684	-0.558	-0.421	-0.289	-0.171	-0.079	-0.020
0.3	.	-0.039	-0.133	-0.282	-0.475	-0.691	-0.903	-1.082	-1.207	-1.262	-1.243	-1.155	-1.012	-0.830	-0.631	-0.435	-0.259	-0.120	-0.031
0.35	.	-0.024	-0.128	-0.308	-0.558	-0.853	-1.156	-1.428	-1.631	-1.740	-1.743	-1.642	-1.455	-1.205	-0.923	-0.640	-0.383	-0.179	-0.046
0.4	.	.	-0.099	-0.300	-0.603	-0.984	-1.400	-1.796	-2.115	-2.313	-2.364	-2.267	-2.037	-1.707	-1.320	-0.921	-0.555	-0.260	-0.068
0.45	.	.	-0.043	-0.244	-0.583	-1.046	-1.589	-2.139	-2.618	-2.954	-3.099	-3.035	-2.775	-2.360	-1.846	-1.301	-0.790	-0.372	-0.097
0.5	.	.	.	-0.134	-0.476	-0.997	-1.660	-2.386	-3.071	-3.607	-3.909	-3.931	-3.674	-3.181	-2.525	-1.800	-1.103	-0.524	-0.138
0.55	.	.	.	.	-0.269	-0.795	-1.543	-2.441	-3.365	-4.167	-4.711	-4.903	-4.712	-4.173	-3.374	-2.441	-1.513	-0.725	-0.192
0.6	.	.	.	.	.	-0.424	-1.175	-2.190	-3.350	-4.472	-5.355	-5.834	-5.817	-5.307	-4.394	-3.240	-2.038	-0.988	-0.263
0.65	.	.	.	.	.	.	-0.532	-1.540	-2.858	-4.299	-5.605	-6.514	-6.833	-6.489	-5.549	-4.196	-2.692	-1.324	-0.357
0.7	.	.	.	.	.	.	.	-0.472	-1.750	-3.393	-5.129	-6.600	-7.467	-7.517	-6.727	-5.270	-3.475	-1.745	-0.478
0.75	.	.	.	.	.	.	.	.	-0.043	-1.571	-3.552	-5.602	-7.228	-7.992	-7.671	-6.339	-4.352	-2.252	-0.630
0.8	.	.	.	.	.	.	.	.	.	.	-0.659	-2.971	-5.379	-7.197	-7.842	-7.094	-5.202	-2.823	-0.816
0.85	.	.	.	.	.	.	.	.	.	.	.	.	-1.132	-3.997	-6.168	-6.803	-5.679	-3.366	-1.033
0.9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.779	-3.735	-4.770	-3.543	-1.243
0.95	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-1.794	-1.228

Each element in the table is the returned value of the determinant of the Jacobian matrix corresponding the value of λ^B reported in Table 1 when $\lambda^A = 1$, $\mu = 0.5$, $\sigma = 1.2$, δ and ϕ are given.
Entries are indicated by "." if the returned value of $\lambda^B \notin [0, 1]$ in Table 1.
This table exhibits that $\boldsymbol{\lambda} = (1, \lambda^{B,int})$ is unstable at different values of δ and ϕ since the determinants reported in the table negative.

Table 3: Trace of the Jacobian when country A is the core under high agglomeration force ($\mu \geq \sigma - 1$): $\boldsymbol{\lambda} = (1, \lambda^{B,int})$, $\mu = 0.5$, $\sigma = 1.2$

$\phi \backslash \delta$	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95
0.05	-0.200	-0.268	-0.323	-0.365	-0.394	-0.412	-0.418	-0.414	-0.400	-0.379	-0.351	-0.319	-0.283	-0.244	-0.204	-0.162	-0.121	-0.080	-0.039
0.1	-0.308	-0.394	-0.461	-0.511	-0.544	-0.562	-0.565	-0.555	-0.534	-0.503	-0.465	-0.420	-0.372	-0.320	-0.267	-0.212	-0.158	-0.104	-0.051
0.15	-0.414	-0.523	-0.608	-0.670	-0.711	-0.732	-0.735	-0.720	-0.692	-0.651	-0.600	-0.542	-0.479	-0.412	-0.343	-0.273	-0.203	-0.134	-0.066
0.2	-0.515	-0.654	-0.762	-0.842	-0.896	-0.925	-0.929	-0.912	-0.876	-0.825	-0.761	-0.688	-0.608	-0.523	-0.435	-0.346	-0.257	-0.169	-0.083
0.25	-0.609	-0.783	-0.920	-1.025	-1.098	-1.139	-1.149	-1.132	-1.091	-1.029	-0.951	-0.861	-0.761	-0.654	-0.544	-0.433	-0.322	-0.212	-0.104
0.3	.	-0.904	-1.078	-1.215	-1.314	-1.373	-1.395	-1.382	-1.337	-1.266	-1.173	-1.063	-0.941	-0.810	-0.674	-0.536	-0.398	-0.262	-0.129
0.35	.	-1.012	-1.229	-1.405	-1.538	-1.625	-1.665	-1.661	-1.617	-1.538	-1.430	-1.300	-1.152	-0.993	-0.827	-0.657	-0.488	-0.320	-0.157
0.4	.	.	-1.364	-1.588	-1.764	-1.887	-1.954	-1.967	-1.929	-1.846	-1.725	-1.573	-1.398	-1.207	-1.006	-0.800	-0.593	-0.389	-0.191
0.45	.	.	-1.476	-1.754	-1.983	-2.153	-2.258	-2.298	-2.273	-2.191	-2.059	-1.886	-1.682	-1.455	-1.214	-0.965	-0.715	-0.469	-0.230
0.5	.	.	.	-1.890	-2.181	-2.410	-2.567	-2.645	-2.646	-2.573	-2.436	-2.243	-2.008	-1.742	-1.455	-1.158	-0.858	-0.561	-0.274
0.55	.	.	.	.	-2.342	-2.642	-2.865	-2.999	-3.039	-2.988	-2.854	-2.646	-2.381	-2.072	-1.735	-1.381	-1.022	-0.668	-0.326
0.6	.	.	.	.	.	-2.827	-3.132	-3.340	-3.440	-3.429	-3.310	-3.097	-2.805	-2.452	-2.058	-1.639	-1.213	-0.791	-0.384
0.65	.	.	.	.	.	.	-3.339	-3.643	-3.828	-3.880	-3.799	-3.594	-3.283	-2.887	-2.431	-1.940	-1.434	-0.933	-0.452
0.7	.	.	.	.	.	.	.	-3.867	-4.165	-4.314	-4.302	-4.131	-3.817	-3.385	-2.865	-2.291	-1.693	-1.099	-0.529
0.75	.	.	.	.	.	.	.	.	-4.395	-4.684	-4.787	-4.691	-4.405	-3.952	-3.371	-2.705	-1.999	-1.292	-0.618
0.8	.	.	.	.	.	.	.	.	.	.	-5.181	-5.229	-5.028	-4.595	-3.968	-3.205	-2.370	-1.525	-0.722
0.85	.	.	.	.	.	.	.	.	.	.	.	.	-5.629	-5.302	-4.680	-3.828	-2.841	-1.817	-0.847
0.9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-5.527	-4.659	-3.502	-2.227	-1.013
0.95	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-3.007	-1.303

Each element in the table is the returned value of the trace of the Jacobian matrix corresponding the value of λ^B reported in Table 1 when $\lambda^A = 1$, $\mu = 0.5$, $\sigma = 1.2$, δ and ϕ are given.
Entries are indicated by "." if the returned value of $\lambda^B \notin [0, 1]$ in Table 1.

Table 4: $\lambda^{B,int}$ when country A is the core under low agglomeration force ($\mu < \sigma - 1$): $\boldsymbol{\lambda} = (1, \lambda^{B,int})$, $\mu = 0.5$, $\sigma = 2.0$

$\phi \backslash \delta$	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95
0.05	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
0.15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
0.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.987	0.818
0.25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.936	0.741	0.440
0.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.962	0.782	0.555	0.285
0.35	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.876	0.681	0.460	0.228
0.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.826	0.627	0.415	0.203
0.45	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.992	0.806	0.605	0.397	0.193
0.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.811	0.605	0.396	0.192
0.55	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.839	0.625	0.408	0.197
0.6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.889	0.662	0.432	0.209
0.65	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.965	0.720	0.471	0.228
0.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.806	0.529	0.257
0.75	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.931	0.614	0.299
0.8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.746	0.365
0.85	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.966	0.477
0.9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.701
0.95	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Each element in the table is the returned λ^B satisfying $\Delta v^B = 0$ when $\lambda^A = 1$, $\mu = 0.5$, $\sigma = 2.0$, δ and ϕ are given.
Entries are indicated by "." if the returned value of $\lambda^B \notin [0, 1]$.

Table 5: Determinant of the Jacobian when country A is the core under low agglomeration force ($\mu < \sigma - 1$): $\boldsymbol{\lambda} = (1, \lambda^{B,int})$, $\mu = 0.5$, $\sigma = 2.0$

$\phi \backslash \delta$	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95
0.05	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
0.15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
0.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.001	-0.004
0.25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.009	-0.015	-0.007
0.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.009	-0.029	-0.026	-0.010
0.35	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.033	-0.049	-0.037	-0.013
0.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.054	-0.068	-0.049	-0.017
0.45	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.004	-0.072	-0.087	-0.061	-0.021
0.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.084	-0.105	-0.075	-0.026
0.55	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.085	-0.119	-0.088	-0.031
0.6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.069	-0.127	-0.100	-0.036
0.65	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.025	-0.124	-0.111	-0.042
0.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.100	-0.116	-0.048
0.75	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.041	-0.111	-0.053
0.8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.084	-0.056
0.85	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.013	-0.053
0.9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.035
0.95	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Each element in the table is the returned value of the determinant of the Jacobian matrix corresponding the value of λ^B reported in Table 4 when $\lambda^A = 1$, $\mu = 0.5$, $\sigma = 2.0$, δ and ϕ are given.
Entries are indicated by "." if the returned value of $\lambda^B \notin [0, 1]$ in Table 4.
This table exhibits that $\boldsymbol{\lambda} = (1, \lambda^{B,int})$ is unstable at different values of δ and ϕ since the determinants reported in the table negative.

Table 6: Trace of the Jacobian when country A is the core under low agglomeration force ($\mu < \sigma - 1$): $\boldsymbol{\lambda} = (1, \lambda^{B,int})$, $\mu = 0.5$, $\sigma = 2.0$

$\phi \backslash \delta$	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95
0.05	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
0.15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
0.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.194	-0.075
0.25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.331	-0.205	-0.094
0.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.509	-0.366	-0.229	-0.102
0.35	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.567	-0.406	-0.251	-0.112
0.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.631	-0.449	-0.276	-0.122
0.45	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.908	-0.703	-0.498	-0.304	-0.135
0.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.784	-0.553	-0.337	-0.149
0.55	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.877	-0.616	-0.373	-0.164
0.6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.984	-0.689	-0.416	-0.181
0.65	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-1.110	-0.776	-0.465	-0.201
0.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.880	-0.524	-0.223
0.75	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-1.011	-0.597	-0.250
0.8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.693	-0.283
0.85	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.832	-0.329
0.9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-0.405
0.95	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Each element in the table is the returned value of the trace of the Jacobian matrix corresponding the value of λ^B reported in Table 4 when $\lambda^A = 1$, $\mu = 0.5$, $\sigma = 2.0$, δ and ϕ are given.
Entries are indicated by "." if the returned value of $\lambda^B \notin [0, 1]$ in Table 4.

Appendix C Complete forms of indirect utility differentials under asymmetric frictional migration costs

The complete expressions for indirect utility differentials are given as follows:

$$\Delta V^{l,asym}(\boldsymbol{\lambda}) = \frac{\Phi_1^{asym}}{\Phi_2^{asym}(\boldsymbol{\lambda})} \Delta v^{l,asym}(\boldsymbol{\lambda}),$$

where

$$\begin{aligned}
\Phi_1^{asym} &\equiv \left(\frac{\sigma c}{\sigma - 1}\right)^{-\mu} \left(\frac{\frac{\mu}{\sigma} L}{1 - \frac{\mu}{\sigma}}\right) H^{\frac{\mu}{\sigma-1}-1}, \\
\Phi_2^{asym}(\boldsymbol{\lambda}) &\equiv \phi[(\lambda^A + \delta_A \lambda^B)^2 + (\delta_B(1-\lambda^A) + (1-\lambda^B))^2] \\
&\quad + \left[1 - \frac{\mu}{\sigma} + \left(1 + \frac{\mu}{\sigma}\right)\phi^2\right](\lambda^A + \delta_A\lambda^B)(\delta_B(1-\lambda^A) + (1-\lambda^B)), \\
\Delta v^{A,asym}(\boldsymbol{\lambda}) &\equiv v_1^{asym}(\boldsymbol{\lambda}) - \delta_B v_2^{asym}(\boldsymbol{\lambda}), \\
\Delta v^{B,asym}(\boldsymbol{\lambda}) &\equiv \delta_A v_1^{asym}(\boldsymbol{\lambda}) - v_2^{asym}(\boldsymbol{\lambda}), \\
v_1^{asym}(\boldsymbol{\lambda}) &\equiv [(\lambda^A + \delta_A\lambda^B) + \phi(\delta_B(1-\lambda^A) + (1-\lambda^B))]^{\frac{\mu}{\sigma-1}} \\
&\quad \times \left[2\phi(\lambda^A + \delta_A\lambda^B) + \left[1 - \frac{\mu}{\sigma} + \left(1 + \frac{\mu}{\sigma}\right)\phi^2\right](\delta_B(1-\lambda^A) + (1-\lambda^B))\right], \\
v_2^{asym}(\boldsymbol{\lambda}) &\equiv [(\delta_B(1-\lambda^A) + (1-\lambda^B)) + \phi(\lambda^A + \delta_A\lambda^B)]^{\frac{\mu}{\sigma-1}} \\
&\quad \times \left[2\phi(\delta_B(1-\lambda^A) + (1-\lambda^B)) + \left[1 - \frac{\mu}{\sigma} + \left(1 + \frac{\mu}{\sigma}\right)\phi^2\right](\lambda^A + \delta_A\lambda^B)\right].
\end{aligned}$$