Integration, Agglomeration, and Costly Adjustment of Labor

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Abstract

How large are the welfare effects of EU enlargement and to what extent are skilled workers affected differently than unskilled workers in each region? In this paper, imperfect labor mobility is modeled within an economic geography framework to examine the welfare implications of goods and factor market integration. While unskilled workers are immobile, forward-looking skilled workers have the option to relocate, which involves an adjustment cost with a common and an idiosyncratic component. Consequently, steady-state properties depend on the distribution of these costs. Furthermore, trade liberalization does not necessarily harm the periphery.

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1 Introduction

The Common Market Initiative of the European Union (EU) seeks to advance the "four freedoms", the most politically sensitive of which has been the free movement of persons. Fears of mass labor movement have repeatedly proven unfounded though. Indeed, since the enactment of the Single European Act in 1986, the share of EU citizens living in a member state different from where they were born has remained around 1.5% (Puga, 2002 and Brücker, 2002). These fears, nevertheless, do lead to questions about the impact of EU enlargement on the existing and new member countries: How large are the welfare effects of EU enlargement and to what extent are skilled workers affected differently than unskilled workers in each region?

This paper addresses these questions by developing a dynamic model based on an economic geography framework. The new economic geography (NEG) literature to date largely considers models in which migration is permanent and costless, and as a result the models exhibit features that are often incompatible with empirical facts.[1] Our model includes forward-looking migration and idiosyncratic adjustment costs into a single model. By doing so, the model can explain some important stylized facts about the migration process within the EU, which, in turn, has important implications for the steady-state and welfare results.

For one, while Germany may be one of the largest recipients of migrants, migration flows within the EU are often bi-directional. For example in 2002, 13,757 immigrants moved from Germany to Spain, and at the same time 15,426 moved from Spain to Germany. (Eurostat) The inclusion of idiosyncratic adjustment costs in our model allows for gross flows to be greater than net flows, as shown in the data. These costs capture the idea that psychological costs, such as separation from family, friends and the familiar environment, are important considerations in an individual's location decision. Survey results from the International Organization for Migration (IOM) show that even in countries with very high migration potential, family and community ties play a decisive role in constraining out migration. (IOM, 1998).

This idea of accounting for non-pecuniary barriers has been shown before in Ludema and Wooton (1999) and Tabuchi and Thisse (2002).[2] However, modeling idiosyncratic adjustment costs is not sufficient to explain another feature about the migration process within the EU – that these flows are not permanent, but often short-term (Dustmann, 1996 and Piracha and Vickerman, 2003). Adda et al. (2006) points out that much of the migrations from Southern to Western Europe between 1950 and 1970 were temporary.

[1] Dustmann (2003) makes a similar observation about the migration literature.

[2] The closely related study by Murata (2003) introduces taste heterogeneity in a model without the conventional immobile factor found in standard NEG models. The paper finds that taste heterogeneity acts as a "probabilistic immobile factor" that weakens self-reinforcing agglomeration.

For instance, 85% of the one million Greeks, who migrated to West Germany between 1960 and 1984, gradually returned to Greece (Glytsos, 1988). For Spain, return migration has outnumbered out migration since 1986 (Eurostat and Huntoon, 1998). In addition, according to the same IOM survey mentioned above, the majority of potential migrants from the new member countries indicated an intent to return to their home country within a few weeks or a few months (IOM, 1998). The models of Ludema and Wooton (1999) and Tabuchi and Thisse (2002) do not exhibit such temporary movements, since migration is not driven by intertemporal utility considerations as it is here.

Together, the inclusion of idiosyncratic adjustment costs and forward-looking migrants can also explain features of the integration process for new member countries. The model results in a gradual, rather than catastrophic, adjustment process to regional integration as has been the case in the EU. In addition, the model can account for real wage differences across countries long after the adjustment process has ended. This feature can be attributed to the presence of the fixed portion of the moving cost. Lastly, the model is consistent with evidence of resource reallocation in anticipation of EU accession (Freund and McLaren, 1999). Models with forward-looking migration decisions feature this announcement effect, while those with myopic migration decisions do not.

To incorporate these two key components into a model of agglomeration, I rely on an alternative to the Dixit-Stiglitz monopolistic competition NEG framework of Krugman (1991).[3] Referred to as the linear footloose-entrepreneur geography framework, this modification by Ottaviano et al. (2002) yields linear demand curves and, thus, analytical solutions. As a result, the framework is tractable and flexible enough to easily embed a labor market adjustment process using tools from dynamic programming. Furthermore, this model displays all the main forces of Krugman's core-periphery model while allowing for proper welfare comparisons.

More specifically, in each period, a skilled worker has the option to move from his current geographic location. If the worker chooses to move, he incurs a moving cost. While moving costs have been modeled using various approaches in the general trade literature, this paper models adjustment costs as in Cameron et al. (2007), which allows for both idiosyncratic and common costs.[4] In their paper, labor reallocation occurs across sectors or geographic regions in response to some random shock that hits labor demand. One key contribution

[3] These models, such as the core-periphery model of Krugman (1991), rely on special characteristics of Dixit-Stiglitz monopolistic competition, CES utility, and iceberg trade costs. Moreover, the core-periphery model does not provide a closed-form solution for the spatial distribution of industry, which is the principal focus of this literature. Therefore, general points must be illustrated with numerical examples. See [5] for detailed analysis of this type of specification.

[4] Other papers have also attempted to model imperfect labor mobility in the trade literature. Karp and Paul (1994), for example, adopt the convex adjustment cost of Mussa (1978) reinterpreting it as a cost of retraining. Davidson et al. (1999) use an approach based on search theory.

of their work is that the moving cost parameters can be estimated empirically, facilitating trade policy analysis. In contrast to Cameron et al. (2007), this paper aims to examine the adjustment process in the presence of agglomeration forces that draw workers and firms into a single region.

Modeling moving costs in this way results in two main theoretical contributions. First, the steady-state properties are affected by the forward-looking migration decision via the presence of the adjustment costs. This result is not only in contrast to that in the standard NEG models, but also in contrast to that in Baldwin (2001) and Ottaviano (2001), which model forward-looking migration decisions of homogeneous workers (as opposed to the heterogeneous tastes that are modeled here). The distribution of costs not only determines whether or not agglomeration occurs, but also determines the extent to which it occurs. Complete agglomeration in one region never occurs in this model because of these costs. No matter the size of the utility disadvantage of living in a particular region, there is at least one person who receives yet a stronger benefit from staying. When partial agglomeration is possible, it occurs at intermediate levels of trade costs.

Second, now that dynamics are introduced in the model, the welfare implications of regional integration are not clear cut. In static models, it is always better for a region to attract firms from the other region, hurting that region in the process. However, simulations show that it is possible that policies fostering agglomeration in one region may improve the welfare of the other region as well. The other region may reap long-term gains from integration, which are not evident in static models.

The remainder of the paper proceeds as follows. Section 2 describes the quasi-linear geography framework. Section 3 derives the short-run equilibrium prices taking the distribution of labor as given. Section 4 describes the steady-state location of firms and skilled labor. Section 5 examines the simulation results showing the dynamics of the model. Section 6 concludes.

2 The Model

This paper builds upon the general equilibrium model of economic geography introduced by Ottaviano et al. (2002). The following description closely follows that presented in their paper.

There are two countries (or regions), H (Home) and F (Foreign), that are symmetric *a priori*. These countries are endowed with two factors, skilled (L) and unskilled labor (A). Skilled labor is interregionally mobile, but mobility comes at a cost to be described later.[5]

[5] The data on migration flows across the EU suggest that skilled workers are more mobile than unskilled workers (Shields and Shields, 1989). See Ottaviano and Thisse (2002) for detailed reasoning.

At any moment, the fraction s^H of skilled workers lives and works in country H and, the fraction s^F lives and works in country F, where $s^H + s^F = 1$. Unskilled labor is immobile and symmetrically distributed across countries.[6]

There are two types of goods, a homogeneous good and a horizontally differentiated good. The homogeneous good O is produced using only unskilled labor. This good is traded freely across countries and is chosen as the numeraire.

Each variety of the differentiated good i, where $i \in [0, N]$, is produced using only skilled labor. The unit trade cost of any variety is τ units of the numeraire, where τ represents all impediments to trade. There exists a continuum of firms of measure N producing these differentiated goods. Each firm is negligible such that it can ignore its influence on and the reaction from other firms.

The infinite-horizon model is described in discrete time. The time index is omitted from all static equations for ease of notation.

2.1 Consumers

Preferences for the differentiated and homogeneous goods are identical across individuals. As in Ottaviano et al. (2002), each individual in country $j \in \{H, F\}$ is endowed with one unit of labor and has the following quasi-linear utility function that is symmetric in all varieties of the horizontally differentiated good:

$$\begin{aligned} U^j(q_O^j, q^j(i)) &= q_O^j + \alpha \int_0^N q^j(i)di \\ &\quad - \frac{\beta - \gamma}{2} \int_0^N [q^j(i)]^2 di - \frac{\gamma}{2} \left[\int_0^N q^j(i)di \right]^2, \end{aligned} \tag{2.1}$$

where q_O^j is the quantity of the numeraire good consumed by an individual in country j, $q^j(i)$ is the quantity of variety i consumed by an individual in country j, α is some positive parameter expressing the degree of preference for the differentiated product, and $\beta - \gamma > 0$ reflects the consumer's love of variety.[7]

2.2 Firms

The homogeneous good is produced under constant returns-to-scale and perfect competition. The production of one unit of the numeraire requires one unit of unskilled labor.

[6] Given that trade occurs, having an immobile factor is necessary to serve as the centrifugal force.

[7] For a given value of β, the parameter γ expresses the substitutability between varieties. For higher γ, the varieties are closer substitutes: when $\beta = \gamma$ the varieties are perfect substitutes.

The horizontally differentiated good is produced under increasing returns-to-scale and monopolistic competition. The production of any amount of variety i requires ϕ units of skilled labor, implying that the marginal cost of each variety is equal to zero.[8] The parameter ϕ reflects the degree of increasing returns in the differentiated goods sector. Due to the assumption of increasing returns-to-scale, there is a one-to-one relationship between firms and varieties.

The market for skilled labor clears, resulting in the following:

$$n^j = \frac{s^j L}{\phi}, \tag{2.2}$$

where n^j is the mass of firms in country j. The total mass of firms, which equals the mass of varieties, is fixed and equal to $N = \frac{L}{\phi}$. The above condition (equation (2.2)) indicates that any change in the population of skilled workers requires a corresponding change in the mass of firms. Hence, the region with the larger skilled labor market must also host the larger proportion of firms.

Each unit of each variety of the differentiated good is traded at a cost $\tau > 0$ (in numeraire units). With positive trade costs, each firm can price discriminate and set prices specific to the market in which its product is sold.

Assuming that markets are segmented, the representative firm in country j faces the following maximization problem:

$$\max_{p^{jj}, p^{jk}} p^{jj} \cdot q^{jj}(p^{jj}) \cdot (\frac{1}{2}A + s^j L)$$
$$+ (p^{jk} - \tau) \cdot q^{jk}(p^{jk}) \cdot [\frac{1}{2}A + (1 - s^j)L] - \phi w^j,$$

where w^j is the wage paid to skilled labor in country j, p^{jj} is the consumer price for a variety produced and sold in country j, p^{jk} is the consumer price for a variety produced in country j sold in country k. The first term represents the total value sold in country j (price times quantity times number of residents in country j), the second term represents the total value sold in country k (price times quantity times number of residents in country k), and the last term represents the total wage cost.

[8] This simplifying assumption can be stated without loss of generality when the firm's marginal cost is incurred in the numeraire. (Ottaviano et al., 2002)

3 Price determination

To determine prices at each moment, the allocation of skilled labor in country j is taken as fixed (i.e., s^j is fixed).

The homogeneous good O is taken to be the numeraire. Given that O is freely traded, the equilibrium wage for unskilled labor w_A is equal in both countries: $w_A^j = w_A^k = 1$.[9]

For the differentiated good, prices are obtained by maximizing profits. Since each firm has a negligible impact on the market, a firm ignores the effect of its decision over the price indices P^j and P^k and maximizes profits holding these indices constant. Using the skilled labor market clearing condition (equation (2.2)) and solving the first-order conditions from profit maximization yields the following equilibrium prices:

$$\widehat{p}^{jj} = \frac{1}{2}\frac{2a + \tau c n^k}{2b + cN} \tag{3.1}$$

$$\widehat{p}^{jk} = \widehat{p}^{kk} + \frac{\tau}{2}, \tag{3.2}$$

where $\widehat{p}^{jj}$ is the equilibrium price in the local market for country j, $\widehat{p}^{jk}$ is the equilibrium price in the distant market for country j, and $a \equiv \frac{\alpha}{\beta+(N-1)\gamma}$, $b \equiv \frac{1}{\beta+(N-1)\gamma}$, and $c \equiv \frac{\gamma}{\beta-\gamma}\frac{1}{\beta+(N-1)\gamma}$ are composites of the utility parameters.

In order to ensure that any single firm finds it profitable to sell in the distant market, it is assumed that:

$$\tau < \frac{2a\phi}{2b\phi + cL} \equiv \tau_{trade}, \tag{3.3}$$

where τ_{trade} is defined as the prohibitive trade cost above which net prices for firms in the distant market are nonpositive. The same assumption yields positive demand for goods produced in the distant market. Thus, this assumption implies that intra-industry trade and reciprocal dumping occur regardless of the distribution of firms.[10]

Unlike the NEG models relying on Dixit-Stiglitz monopolistic competition, CES utility, and iceberg trade costs, this quasi-linear model of agglomeration results in prices that depend on the spatial distribution of firms and consumers.[11] In particular, prices in the local market (equation (3.1)) fall as price competition becomes fiercer with the increase in the number of local firms. This introduces two opposing forces: an agglomeration force called the cost-of-living effect, where consumers are drawn to the region with more firms since goods are cheaper, and a dispersion force called the market-crowding effect, where firms

[9] This assumes that the homogeneous good is produced and traded.

[10] Note that equation (3.3) also implies that it is necessary to have increasing returns for trade to occur ($\phi > 0$). When $\phi = 0$, each region produces all potential varieties and becomes autarkic.

[11] In the economic geography models à la Dixit-Stiglitz, equilibrium prices are determined by a constant markup rule. See Baldwin et al. (2003) for a detailed comparison of the different NEG models.

move away from the crowded market toward the region with relatively few competitors. Noting that these forces are tempered for lower trade costs, it becomes clear that lower trade costs affect the strength of the agglomeration forces relative to the dispersion force.[12]

From equation (3.1), it is also evident that higher trade costs lead to higher local prices, since these trade barriers protect the local market from competition. The effect is even stronger when more competitors are located in the distant market. Higher local prices, then, have an indirect upward effect on export prices. In addition, higher trade costs have a direct upward effect on export prices through the increased cost of reaching the distant markets (see equation (3.2)).

Assuming free entry, firms bid for skilled workers until no firm earns a strictly positive profit. Therefore, wages of skilled labor are determined by setting equilibrium profits equal to zero. Equilibrium wages (in terms of the numeraire) for skilled labor in country j are given by:

$$\begin{aligned} \widehat{w}^j(s^j) &= \frac{1}{\phi^2}\frac{b\phi+cL}{4(2b\phi+cL)^2}\{\left[2a\phi+\tau cL\left(1-s^j\right)\right]^2[\frac{1}{2}A+s^jL] \\ &\quad +\left[2a\phi-2\tau b\phi-\tau cL\left(1-s^j\right)\right]^2[\frac{1}{2}A+\left(1-s^j\right)L]\}. \end{aligned} \tag{3.4}$$

Note that the above equation is quadratic in s^j. Most notably, when trade costs are low, wages increase (but at a decreasing rate), and the wage gap between countries decreases as workers become more concentrated in a particular country. However, the opposite holds when trade costs are high.

The consumer surplus for each individual in country j is:

$$\begin{aligned} \widehat{S}^j(s^j) &= \frac{a^2L}{2b\phi}-a\frac{L}{\phi}\left[s^j\widehat{p}^{jj}+\left(1-s^j\right)\widehat{p}^{kj}\right] \\ &\quad +\frac{b\phi+cL}{2\phi}\frac{L}{\phi}\left[s^j\left(\widehat{p}^{jj}\right)^2+\left(1-s^j\right)\left(\widehat{p}^{kj}\right)^2\right] \\ &\quad -\frac{c}{2}\frac{L^2}{\phi^2}\left[s^j\widehat{p}^{jj}+\left(1-s^j\right)\widehat{p}^{kj}\right]^2. \end{aligned} \tag{3.5}$$

The assumption that trade does occur (equation (3.3)) implies that consumer surplus $\widehat{S}^j(s^j)$ is increasing and concave in s^j over the interval $[0,1]$. In other words, consumer surplus rises in country j with an increase in local competition as more firms enter country j, but this positive effect weakens as the number of firms increases. There are two effects at work here: the market-access effect, where more firms and workers create more local varieties,

[12] In the limit, as $\tau \to 0$, prices are independent of the spatial allocation of firms.

and the market-crowding effect, where consumers enjoy lower prices for all varieties sold locally. Both of these forces induce consumers to migrate toward country j, which in turn draws firms to the location where there are more consumers and higher demand.

Together, the consumer surplus and wage equations describe the mechanism by which trade costs affect the allocation of mobile workers. When trade costs are low, wages and consumer surplus for skilled workers in country j are increasing as more skilled workers locate in country j. On the other hand, when trade costs are high, consumer surplus for workers in country j increases with the concentration of workers in country j, but wages decrease at a faster rate and the dispersion forces become dominant.

4 Location choice

Here, the exposition of the model departs from that in Ottaviano et al. (2002). In Ottaviano et al. (2002), the authors assume that migration is driven by a worker's current utility differential between the two countries. In addition, they assume that markets adjust instantaneously to any change in the allocation of workers; wages in each region adjust such that labor market clearing conditions hold, and firms earn zero profits.

Instead I assume that risk-neutral, infinitely lived skilled workers move seeking the highest expected *lifetime* utility (as opposed to highest current utility). And I assume as well that they do not move freely; there exists some cost to moving. To be specific, labor market adjustment is modeled as a simple binomial choice problem following Cameron et al. (2007); each period skilled workers can choose to either move from or stay in their current residence.

The timing of events is as follows. The current fraction of mobile workers in each country (s^j in country j and $s^k = 1 - s^j$ in country k) follows from the events in the previous period (time $t-1$). Given s^j and s^k, wages adjust to clear the market. Production and consumption occurs. Then, at the end of the current period, the benefits of residing in each country are realized, and each mobile worker makes his location choice for the next period based on the expected present discounted value of locating in each country, net of common and idiosyncratic moving costs. In the aggregate, their decisions determine s^j and s^k for period $t+1$.

All skilled workers have rational expectations with a discount factor $\delta < 1$. Each skilled worker who chooses to relocate must pay a time-invariant common cost of moving, $M \geq 0$. The common component may include search costs or deterrents such as language and cultural barriers or training costs that do not change with time or across individuals. The common component may also capture the state of the policy environment such that stricter regulation of migration is represented by higher levels of M. This specification provides a role for government policy in influencing the location of industry.

Each skilled worker then receives an idiosyncratic benefit ε_t^j from residing in country $j \in \{H, F\}$ at the end of period t. This idiosyncratic benefit ε is independently and identically distributed across time, individuals, and regions for all $\varepsilon \in (-\infty, \infty)$. Variance is denoted by σ, pdf by $\psi(\cdot)$, and cdf by $\Psi(\cdot)$. It is assumed that $\psi(\cdot) > 0 \ \forall \varepsilon$ and that ε has mean zero, i.e. $E(\varepsilon) = 0$. Furthermore, I impose the boundedness assumption:

$$E\left[\max\left\{\varepsilon^j, \varepsilon^k\right\}\right] = 2\int \varepsilon\psi(\varepsilon)\Psi(\varepsilon)d\varepsilon < \infty,$$

where $j \neq k$, which is sufficient to prevent a worker from receiving infinite utility by making a location choice solely based on the higher value of ε each period.

These idiosyncratic benefits reflect why a skilled worker finds one country more personally attractive than the other. Implicitly, then, there is a cost to moving; by choosing to live in country j, for example, the skilled worker gains ε^j, but gives up ε^k. Thus what matters to each worker is the difference between ε^j and ε^k. Define $\mu_t^{jk} \equiv \varepsilon_t^j - \varepsilon_t^k$ to be the idiosyncratic cost of moving from country j to country k for each worker at time t; that is, μ^{jk} is the difference between the idiosyncratic benefit that a skilled worker would receive from staying in country j and the idiosyncratic benefit that he would receive instead by moving to country k. Given the distribution of ε, the idiosyncratic cost of moving μ has pdf denoted by $g(\cdot)$ and cdf by $G(\cdot)$. Note that the idiosyncratic cost can be negative, which allows for two-way migration flows.[13] That is, a fraction of workers may receive an idiosyncratic benefit (negative cost) from moving, and so be inclined to move even when market fundamentals imply otherwise.

As pointed out in Murata (2003) the inclusion of these non-market factors in explaining interregional differences in economic activities is not new, but was first suggested by Hicks (1932) which proposed that persistent wage differences between regions are at least partially attributed to "indirect interactions" specific to living in a particular location. The idiosyncratic cost in this model captures any non-market attribute of a region that might affect when or where a skilled worker locates, independent of prices, variety, and wages. For example, a worker may be tired of his job, in which case the move would be beneficial and $\mu^{jk} = \varepsilon_t^j - \varepsilon_t^k < 0$ for a skilled worker in country j. On the other hand, a worker in country j may have a family member in the hospital, in which case $\mu^{jk} = \varepsilon_t^j - \varepsilon_t^k > 0$. The time-varying feature of idiosyncratic moving costs plays an important role in the adjustment process of skilled workers.

In each period, a skilled worker has the option to either stay in country j or move to

[13] This feature is consistent with the empirical evidence which shows that gross flows of workers across geographical locations and industries are substantially larger than net flows (Jovanovic and Moffitt, 1990).

country k and incur moving costs of $\mu_t^{jk} + M$. Let $u^j(s_t, \varepsilon_t)$ represent the maximized value to a skilled worker of living in country j at time t given the current allocation of labor $s_t = (s_t^j, s_t^k)$ and the current realizations of idiosyncratic benefits, $\varepsilon_t = (\varepsilon_t^j, \varepsilon_t^k)$:

$$u^j(s_t,\varepsilon_t) = \underbrace{S^j(s_t) + w^j(s_t)}_{\substack{\text{current value}\\ \text{in country } j}} + \max\left\{ \underbrace{\varepsilon_t^j + \delta E_t\left[u^j(s_{t+1},\varepsilon_{t+1})\right]}_{\substack{\text{expected future value}\\ \text{in country } j}}, \underbrace{\varepsilon_t^k - M + \delta E_t\left[u^k(s_{t+1},\varepsilon_{t+1})\right]}_{\substack{\text{expected net future value}\\ \text{in country } k}} \right\}.$$

The above expression simplifies to:

$$u^j(s_t,\varepsilon_t) = S^j(s_t) + w^j(s_t) + \varepsilon_t^j + \delta V^j(s_{t+1}) + \max\left\{\mu_t^{jk}, \nu_t^{jk}\right\}, \tag{4.1}$$

where $\nu_t^{jk} \equiv \delta\left[E_t\left[u^k(s_{t+1},\varepsilon_{t+1})\right] - E_t\left[u^j(s_{t+1},\varepsilon_{t+1})\right]\right] - M$ is the common net benefit (net of moving costs) of moving from country j to country k for all skilled workers in country j.

Recall that the last two terms in equation (4.1) represent the maximum value of the worker's location choice for next period net of moving costs. Observe that when ν_t^{jk}, the common net benefit of moving to country k, is greater than the idiosyncratic cost of leaving country j, μ_t^{jk}, the worker receives the maximum value in country k. This suggests that the optimal decision rule for the skilled worker depends on the value of ν_t^{jk} relative to μ_t^{jk}. If $\nu_t^{jk} > \mu_t^{jk}$, then the worker should move from country j to k at the end of period t to receive the highest value. Therefore, ν_t^{jk} can also be interpreted to be the reservation cost above which skilled workers are unwilling to move. In other words, a skilled worker will not pay a cost higher than the common net value of moving.

Before the expression for ν_t^{jk} can be determined, the expected value of u^j conditional on s_t before idiosyncratic shocks are realized must be calculated. Taking the expectation of equation (4.1) with respect to ε's yields:

$$\begin{aligned} E_{t-1}\left[u^j(s_t,\varepsilon_t)\right] &= S^j(s_t) + w^j(s_t) + \delta V^j(s_{t+1}) + E_{t-1}\max\left\{\mu_t^{jk},\nu_t^{jk}\right\} \\ &= \underbrace{S^j(s_t) + w^j(s_t)}_{\text{current value in } j} + \underbrace{\delta E_t\left[u^j(s_{t+1},\varepsilon_{t+1})\right]}_{\text{future value in } j} + \underbrace{\Omega(\nu_t^{jk})}_{\substack{\text{additional value of}\\ \text{having option to move}}}, \end{aligned} \tag{4.2}$$

where $\Omega(\nu) \equiv E\left[\max\{\mu,\nu\}\right]$ can be interpreted as the additional value of having the option to relocate to the other region. As noted in brackets above, the value to a skilled worker of living in country j is the current value of living in country j, represented by the consumer surplus plus wage, the future value of staying in country j, and the option value.

4.1 Equilibrium Conditions

As shown above, the optimal decision rule for each mobile worker at time t is determined by the value of the idiosyncratic moving cost μ_t relative to the reservation cost ν_t. The equilibrium can be fully characterized then by how ν and s change with time.

The equation of motion governing the net allocation of labor is specified as follows:

$$m_t^{jj} L_t^j + m_t^{kj} L_t^k = L_{t+1}^j,$$

where m_t^{jj} denotes the fraction of workers in country j at the beginning of time t who stay in country j, and m_t^{kj} denotes the fraction of workers in country k at the beginning of time t who move to country j by the end of time t (i.e., the gross flow from k to j). Then, for country j, the allocation of workers in period $t+1$ is as follows:

$$m_t^{jj}\left(s_t^j L\right) + m_t^{kj}\left(s_t^k L\right) = s_{t+1}^j L. \tag{4.3}$$

Since a skilled worker moves from country j to k if and only if the idiosyncratic cost of moving μ_t^{jk} is less than the reservation cost ν_t^{jk}, the equilibrium re-allocation of mobile labor is:

$$\begin{aligned} m_t^{jk} &= \Pr(\mu_t^{jk} < \nu_t^{jk}) = G(\nu_t^{jk}) \\ m_t^{jj} &= \Pr(\mu_t^{jk} > \nu_t^{jk}) = 1 - G(\nu_t^{jk}) \end{aligned}$$

Therefore, skilled labor moves according to the following law of motion (derived from plugging the above conditions into the equation of motion (4.3) and noting that $\upsilon^{kj} = -\upsilon^{jk} - 2M$):

$$\left[1 - G(\nu_t^{jk})\right] s_t^j + \left[G(-\nu_t^{jk} - 2M)\right](1 - s_t^j) = s_{t+1}^j. \tag{4.4}$$

The first term is the fraction of skilled labor living in country j who choose to stay, while the second term represents skilled labor living in country k who choose to relocate to country j. The two terms add up to equal the total fraction of skilled workers residing in country j in the next period.

To finish characterizing the equilibrium conditions, it is necessary to describe how the reservation cost evolves over time. Recall that ν_t^{jk} is defined as follows:

$$\nu_t^{jk} \equiv \delta\left[E_t\left[u^k(s_{t+1}, \varepsilon_{t+1})\right] - E_t\left[u^j(s_{t+1}, \varepsilon_{t+1})\right]\right] - M$$

and note that ν_t^{kj} can be rewritten such that $\nu_t^{kj} = -\nu_t^{jk} - 2M$. Using the solution for

$E_t\left[u^j(s_{t+1},\varepsilon_{t+1})\right]$ as calculated in equation (4.2), ν_t^{jk} becomes:

$$\begin{aligned}\nu_t^{jk}+M &= \delta\left[S^k(s_{t+1})+w^k(s_{t+1})-S^j(s_{t+1})-w^j(s_{t+1})+\Omega(\nu_{t+1}^{kj})-\Omega(\nu_{t+1}^{jk})\right]+ \\ &\quad \delta^2\left[S^k(s_{t+2})+w^k(s_{t+2})-S^j(s_{t+2})-w^j(s_{t+2})+\Omega(\nu_{t+2}^{kj})-\Omega(\nu_{t+2}^{jk})\right]+... \qquad (4.5)\\ &= \delta\left[S^k(s_{t+1})+w^k(s_{t+1})-S^j(s_{t+1})-w^j(s_{t+1})+\Omega(\nu_{t+1}^{kj})-\Omega(\nu_{t+1}^{jk})+\nu_{t+1}^{jk}+M\right] \qquad (4.6)\end{aligned}$$

The marginal mover in country j faces an idiosyncratic cost exactly equal to the reservation cost, i.e. $\mu_t^{jk}=\nu_t^{jk}$. Thus the left-hand side of equation (4.6) can be interpreted as the total moving cost for the marginal mover in country j. The above Euler-type equation (4.6) states that in equilibrium this cost to the marginal mover must equal the discounted net expected common benefit of residing in country k instead of country j in the following period (right-hand side). The net expected common benefit can be divided into three components: (1) the utility differential in the next period, $S^k(s_{t+1})+w^k(s_{t+1})-S^j(s_{t+1})-w^j(s_{t+1})$, (2) the difference in option values in the next period, $\Omega(\nu_{t+1}^{kj})-\Omega(\nu_{t+1}^{jk})$, and (3) the expected future benefit for the marginal mover. The first component indicates that where other skilled workers locate, which determines s, plays an important role in determining the level of net expected benefits of moving, $\nu_{t+1}^{jk}+M$. As important as where other skilled workers locate is when other skilled workers relocate, since not all workers move at once. This is clear from the time subscript on the s's in equation (4.5); specifically, the net allocation of workers in the next period is the most important determinant of the reservation cost for the current period.

The timing of events is specified such that production and consumption occur in each period given the current allocation of labor, which is determined in the preceding period. The Euler-type equation (4.5) and the law of motion for skilled labor (4.4) can be further solved then because skilled workers know the wage and the consumer surplus that they receive in period $t+1$ given s_{t+1}^j. Thus, using the wage (3.4) and consumer surplus (3.5) equations calculated in Section 3, the Euler-type equation can be rewritten as:

$$\nu_t^{jk}+M=\delta\left[-C\tau(\tau^*-\tau)(s_{t+1}^j-\frac{1}{2})+\Omega(-\nu_{t+1}^{jk}-2M)-\Omega(\nu_{t+1}^{jk})+\nu_{t+1}^{jk}+M\right], \qquad (4.7)$$

where

$$C\equiv\left[2b\phi(3b\phi+3cL+cA)+c^2L(A+L)\right]\frac{L(b\phi+cL)}{2\phi^2(2b\phi+cL)^2}>0$$

and

$$\tau^*\equiv\frac{4a\phi(3b\phi+2cL)}{2b\phi(3b\phi+3cL+cA)+c^2L(A+L)}>0.$$

The critical value τ^* serves as an important reference point for comparison with Ottaviano et al. (2002), which presents a model without adjustment costs or forward-looking workers. The value of τ^* is the same as in the standard NEG models, but there τ^* is interpreted as both the "break" point at which the symmetric equilibrium ceases to be stable and the "sustain" point at which full agglomeration arises. Here, by contrast, τ^* carries with it no interpretation; it is no longer the break/sustain point. Since mobile workers face an additional cost of moving, they are prevented from agglomerating until they receive a benefit from integrating that outweighs these costs. As a result, in this model, the break/sustain point occurs at a lower level of integration than that represented by τ^*.

I restrict τ^* to be less than τ_{trade} in order to consider the full range of values for s^j. For this inequality to hold, I must further assume that the population of unskilled labor is large relative to the population of skilled labor such that the following is satisfied:

$$3 < \frac{6b^2\phi^2 + 8bc\phi L + 3c^2L^2}{cL(2b\phi + cL)} < \frac{A}{L}. \tag{4.8}$$

In sum, the equilibrium of this system is an infinite sequence $(\nu_t, s_t)_{t=0}^{\infty}$ that satisfies equations (4.6) and (4.4) keeps $s_t \geq 0$ for all t, and conforms to a given initial condition $s_0 \geq 0$ for the fraction of workers in country j and to some boundary condition for ν_t.

4.2 Characteristics of the steady state

What follows is a characterization of the steady-state equilibria, which are defined as the constant solutions where $\nu_{t+1} = \nu_t = \overline{\nu}$ and $s_{t+1} = s_t = \overline{s}$ for all t. These solutions correspond with the economic idea of long-run equilibria from which an economy does not want to move.

The steady state only determines the net allocation of workers across regions. As discussed in Cameron et al. (2007), skilled workers are continually reallocating themselves even in the steady state. Since each skilled worker receives an idiosyncratic benefit ε every period, workers are continually responding to the benefit with a decision to move or stay.

While the emphasis of this paper is on the adjustment path, the steady-state analysis is presented in order to compare results with the existing literature. Trade costs determine the relative strength of the agglomeration and dispersion forces. Therefore trade costs, representing the degree of economic integration, are key in determining the geography of economic activity.

Recall that $-\nu^{jk} - 2M = \nu^{kj}$, as in equation (4.6). I simplify notation by dropping the superscripts j and k on ν such that $\nu^{jk} = \nu$ and $\nu^{kj} = -\nu - 2M$ throughout the rest of the analysis. Similarly I simplify notation such that $s^j = s$ and $s^k = 1 - s^j = 1 - s$.

After dropping the time subscripts in equation (4.6), the steady-state equation for ν

becomes:

$$\overline{\nu} = \frac{\delta}{1-\delta}\left[-C\tau(\tau^* - \tau)(\overline{s} - \frac{1}{2}) + \Omega(-\overline{\nu} - 2M) - \Omega(\overline{\nu})\right] - M. \tag{4.9}$$

Similarly, the steady-state equation for s is obtained:

$$\overline{s} = \frac{G(-\overline{\nu} - 2M)}{G(\overline{\nu}) + G(-\overline{\nu} - 2M)}. \tag{4.10}$$

With two equations and two unknowns, this system of equations (4.9 and 4.10) yields the steady-state solution(s).

According to equation (4.10), the proportion of workers in country j equals the fraction of workers who move from country k to j divided by the total gross flow of workers, the fraction of workers who move from k to j and j to k. This solution suggests that the long-run steady-state allocation is one of symmetry in which all activity is equally split between the two regions, or one of asymmetry in which two regions contain unequal levels of economic activity. From equation (4.10), the following is evident:

Result 1 *Full agglomeration, where all skilled workers are located in one country or the other ($s = 0$ or 1), cannot occur.*

To see this, notice that a necessary condition for full agglomeration in country k to be a long-run equilibrium, for example, is $G(-\overline{\nu} - 2M) = 0 = \overline{s}$. This equality cannot hold since $\psi(\cdot)$ (from which G is derived) is constrained to be greater than zero for all ε. To illustrate, assume that skilled labor is distributed symmetrically initially. Once these workers are allowed to move, at least one worker draws a cost μ that is too high, and so he waits to move in hopes of a lower draw in the near future. This result is attractive because it seems more plausible than the extreme result in the standard NEG models that all skilled workers locate in one country or another when trade costs are low enough.

Upon inspection of the steady-state equations, the following lemma is also immediate:

Result 2 *The solution $s = \frac{1}{2}$ is one steady-state equilibrium (although not necessarily stable) regardless of the values of the parameters, which are symmetric across countries.*

In particular, for any level of trade costs, symmetry is a steady-state solution. The long-run allocation is symmetric only when the net expected benefit of moving for the mobile worker is equal to minus the common cost of moving, $\nu = -M$. This result is intuitive; the net benefit of moving for the marginal worker ($\nu + M$) is zero since he faces a reservation cost ν equal to $-M$, which implies that the marginal worker has no incentive to move. Since the marginal mover determines any change in net migration when workers are in a dispersed steady state, having no incentive to move is consistent with the steady-state allocation remaining at dispersion.

In relation to the reference point τ^*, a closer look reveals that $s = \frac{1}{2}$ and $\nu = -M$ is the only steady-state equilibrium when $\tau = 0$ or $\tau \geq \tau^*$.[14] On the other hand, when $0 < \tau < \tau^*$, multiple steady-state equilibria can occur. Since small perturbations lead to qualitative changes in the system's orbit structure for some critical values of some parameter (in this case τ), a bifurcation occurs in this model.

The set of stable steady-state solutions depends on the variance of moving costs μ, as well as the level of trade costs τ. The variance of μ reflects the importance of the idiosyncratic component in determining the net allocation of workers. When the variance is low, the idiosyncratic component is weak, while the opposite holds when the variance is high.

[Figure 1: Stable steady-state proportions of skilled labor given trade costs]

First, consider the limiting case: $var(\mu) \longrightarrow 0$. Given that $E[\mu] = 0$, the idiosyncratic component effectively disappears as $var(\mu) \longrightarrow 0$. Then skilled workers make their location decision only based on differences in wage and consumer surplus net of common moving costs, as in the basic NEG model without adjustment costs (assuming $M = 0$). The steady-state results from Ottaviano et al. (2002) are depicted in Figure 1a. For each value of τ, the steady-state allocation of workers is given. The figure shows that when $\tau > \tau^*$, the symmetric equilibrium ($s = \frac{1}{2}$) is the only stable allocation, whereas when $\tau < \tau^*$, full agglomeration in either region ($s = 0$ or 1) is stable.

On the other hand, as $var(\mu) \longrightarrow \infty$, the reverse holds. The idiosyncratic component is so strong that skilled workers choose their location with equal probability. As a result, only the symmetric equilibrium is stable ($s = \frac{1}{2}$); this steady-state result is identical to the case when there is no labor mobility (see Figure 1b).

For intermediate values of $var(\mu)$, partial agglomeration is possible. More precisely, partial agglomeration arises when the following condition is met:

A 1 *The variance of* μ *is such that:* $\frac{\tau^*}{2} > 1 - \sqrt{\beta} + 2\sqrt{\beta}G(-M)^2 > 0.$

For a given level of common costs M, the degree of variance in μ must be small enough so that the agglomeration forces are not overpowered by the presence of the idiosyncratic component.

As solved in the Appendix, the resulting set of steady-state solutions is summarized below:

Result 3 *Assume that* $\tau < \tau_{trade}$ *and that* $\tau^* < \tau_{trade}$*. Then, when (A1) holds, we have the following: There exist a* τ^a *and a* τ^b*, where* $\tau^a < \tau^b$*, such that (i) only the symmetric allocation of skilled labor (*$s = \frac{1}{2}$*) is a stable steady-state equilibrium with trade and (ii) for*

[14] Recall that τ^* is a critical value in the standard NEG literature. Above τ^*, dispersion is the stable steady-state allocation. Below τ^*, full agglomeration is the stable steady-state allocation.

$0 \leq \tau^a < \tau < \tau^b \leq \tau^*$, *there are two stable steady-state equilibria in which skilled labor is concentrated either in country H or F with trade.*

Result 4 *The degree of concentration in either country H or F depends on the level of trade costs. The "core" retains the highest concentration of skilled labor when* $\tau = \frac{1}{2}\tau^*$.

Figure 1c illustrates the stable steady-state levels of s (the proportion of workers in country j) given a particular level of trade costs τ. For high trade costs, only one stable equilibrium – the symmetric one – exists. The reasoning is the same as that in the standard NEG literature; when trade costs are too high, the dispersion force overpowers the agglomeration forces. For intermediate levels of trade costs, there exist two stable steady-state equilibria. On the other hand, for low levels of trade costs, again only the symmetric steady-state equilibrium is stable. Below a critical value, adjustments costs overpower the importance of agglomeration forces, weakening self-reinforcing agglomeration.

This characterization of the stable steady-state equilibria is generally consistent with models adding an extra dispersion force to the standard NEG model. In Ottaviano et al. (2002), at lower trade costs, the market-access and the market-crowding effects are weakened, but not the congestion effect, which becomes the driving force of location when trade costs are low enough. In Ludema and Wooton (1999) and Tabuchi and Thisse (2002) taste heterogeneity acts as a strong dispersion force that results in the same pattern of steady-state equilibria with respect to the level of trade costs τ.

Comparison with the standard NEG models yields the following:

Corollary 1 *The model does not exhibit catastrophic movements of skilled workers as emphasized in the core-periphery model (Krugman, 1991).*[15]

Ludema and Wooton (1999) and Tabuchi and Thisse (2002) focus on this point. As long as it is assumed that there is some intermediate variance in adjustment costs, the most celebrated feature of the standard NEG models (according to Baldwin et al., 2003) – the catastrophic movement of labor – does not occur. The difference between the results of the standard NEG model and this model with limited labor mobility becomes most apparent when comparing Figure 1a to Figure 1c. As seen in Figure 1a, the relationship between s and τ is not smooth, in contrast to what is shown in Figure 1c. Thus, it can be concluded that idiosyncratic costs have a smoothing effect that induces workers to behave gradually on net rather than in extreme motions.

[15] Catastrophic in the sense that once symmetry becomes unstable, the only stable outcome is full agglomeration.

5 Simulations and Dynamics

In this section, I simulate numerically the model described above to illustrate the adjustment process of mobile labor. It is assumed that the economy is initially in a steady state with some positive level of trade costs. Then, goods market integration occurs, as represented by a drop in τ.

For these simulations, I must make functional form assumptions about the distribution of the idiosyncratic benefit ε. Following Anderson et al. (1992), it is assumed to have an extreme-value distribution, with a mean of zero and a variance equal to $\frac{\pi^2\xi^2}{6}$, where ξ is some positive, constant parameter determining the size of the variance.

Given this distribution for ε, the following cdf can be derived for μ:

$$G(\mu) = \frac{\exp\left(\frac{\mu}{\xi}\right)}{1+\exp\left(\frac{\mu}{\xi}\right)}.$$

Knowing the distribution for μ, the option value $\Omega(\nu)$ can be calculated as follows (Cameron et al., 2007):

$$\begin{aligned}\Omega(\nu) &= \int_{-\infty}^{\nu} G(\mu)d\mu \\ &= \xi \log\left(1+\exp\left(\frac{\mu}{\xi}\right)\right)\end{aligned}$$

Note that the option value is decreasing in ξ, which represents the degree of variance in ε's.

Using these functional forms, the equilibrium conditions (equations (4.6) and (4.4)) can be rewritten as:

$$\begin{aligned}\nu_t^{HF} + M &= \delta[-C\tau_{t+1}(\tau^* - \tau_{t+1})(s_{t+1} - \frac{1}{2}) \\ &\quad +\xi \log\left(1+\exp\left(\frac{-\nu_t^{HF} - 2M_{t+1}}{\xi}\right)\right) \\ &\quad -\xi \log\left(1+\exp\left(\frac{\nu_t^{HF}}{\xi}\right)\right) + \nu_{t+1}^{HF} + M_{t+1}]\end{aligned}$$

and

$$s_{t+1} = s_t\left[1 - \frac{\exp\left(\frac{\nu_t^{HF}}{\xi}\right)}{1+\exp\left(\frac{\nu_t^{HF}}{\xi}\right)}\right] + (1-s_t)\left[\frac{\exp\left(\frac{-\nu_t^{HF}-2M_{t+1}}{\xi}\right)}{1+\exp\left(\frac{-\nu_t^{HF}-2M_{t+1}}{\xi}\right)}\right].$$

The initial allocation of labor in each country is determined by the steady-state conditions of the system (previously solved in equations (4.9) and (4.10)), given the distribution of the idiosyncratic moving cost μ and the level of trade costs τ. Recall that Figure 1c illustrates two stable steady states when $\tau_a < \tau < \tau_b$. With multiple stable steady states, it is not clear which path the economy follows after receiving a shock, due to the possibility of overlap in the paths leading to each steady state. For these simulations, it is assumed that, if the initial steady-state equilibrium involves an agglomeration in one country, then the agglomeration remains in that country even after any changes in the parameters occur.

The present discounted value of lifetime welfare for a skilled worker in country j, who has the option to move to country k, at the date of the policy announcement is calculated as:

$$\sum_{t=0}^{\infty} \delta^t \left(S^j(s_t) + w^j(s_t) + \Omega(\nu_t^{jk}) \right).$$

In order to determine whether the skilled worker is made better or worse off by the announced policy, the above is compared to his lifetime welfare (in present discounted value terms) had there been no policy change:

$$\frac{S^j(s_0) + w^j(s_0) + \Omega(\nu_0^{jk})}{1-\delta},$$

where s_0 is the allocation of skilled labor at the initial steady state and ν_0^{jk} is the reservation cost for a skilled worker in country H at the initial steady state. Analogous equations hold for an unskilled worker in country j.

5.1 Baseline simulations

In these simulations, the economy faces an initial level of trade costs such that the economy is in a steady state where more skilled workers are concentrated in country H. Then, either an anticipated or unanticipated reduction in trade costs occurs at time $t = 15$.

To give these baseline simulations a European context, the discount factor δ is set to equal 0.98. Since inflation in the EU has been hovering around two percent (according to Eurostat), this specification allows each period in the simulation to be interpreted as a year.

Additionally, I assume that there are eight units of unskilled labor and two units of skilled labor in the economy so that 20% of the total workforce is considered skilled labor. This percentage approximates the proportion of employees who have attained a tertiary education according to the 1995 Labor Force Survey administered by Eurostat. It also fulfills the requirement that the ratio of unskilled to skilled labor is high enough to assure that $\tau^* < \tau_{trade}$, where τ_{trade} is the prohibitive trade cost above which trade does not occur (see equation (4.8)).

[Table 1. Value of key parameters in the baseline simulations.]

The remaining parameters are chosen to illustrate the following: (i) the "core" (assumed to be country H) initially holds some concentration of skilled labor, and (ii) the lowering of trade costs leads to a steady-state result in which only 1.5% of the "periphery" (country F) relocate into the "core", as found by Puga (2002) and Brücker (2002). The chosen parameters are presented in Table 1.

[Figure 2. Adjustment of skilled labor to anticipated and unanticipated reduction in τ at time $t = 15$.]

Figure 2 shows the time path of s (the proportion of skilled labor in country H) under two scenarios – an unanticipated reduction in τ at time $t = 15$ (solid line) and a credible announcement at time $t = 5$ of a reduction in τ at time $t = 15$ (hatched line). As expected, the adjustment of skilled labor under both scenarios is gradual. There are always some workers who wait to see if their moving costs are lower in the next period.

The figure also shows that the adjustment process can take quite a long time given reasonable parameter values. This is true even when the magnitude of net labor reallocation is small; in this case, s changes by less than a half percent. When the policy change is unanticipated, the economy reaches about 95% of the distance to the new steady state in thirteen years.

When the policy change is anticipated, the adjustment process for skilled labor proceeds even more slowly and begins as soon as the announcement is made. Workers with low moving costs begin to move right away so as to avoid the possibility of high moving costs later. Indeed, more than 60% of the adjustment occurs before the policy change actually occurs.

These results are empirically relevant, for they are qualitatively consistent with the findings of Freund and McLaren (1999) on trade reorientation. Their study finds evidence of resource reallocation occurring in anticipation of accession into the EU, typically beginning four years before the accession date and continuing for eight to nine years after the date in each country. Furthermore, the simulation of the anticipated case depicts an s-shaped adjustment process, with acceleration followed by deceleration, as found in Freund and McLaren (1999).

Goods market integration is welfare-improving for skilled workers in both countries when the policy change is either anticipated or unanticipated. However, they gain slightly more when the policy change is anticipated because these skilled workers are able to take advantage of the gains from agglomeration sooner. In addition, skilled workers in the "core" (country H) do slightly better than those in the "periphery" (country F) (less than one-half percent better).

[Figure 3. Adjustment of skilled wages to anticipated reduction in τ.]

Looking more closely at the components of welfare for the skilled worker, recall that wages in country H are convex and decreasing in s for small τ. Since wages change with s, a credibly announced policy can also affect wages in advance of the actual change. Figure 3 shows that, as more skilled labor move into country H (i.e. as s increases), wages in country H fall gradually in anticipation of the reduction in trade costs. Wages in country F rise gradually and then suddenly fall to below the level of country H at the time the policy change occurs.[16] It is evident from this figure that the wage gap changes from higher relative wages in country F to higher relative wages in country H, the host of the "core". However, this wage gap narrows as the difference in prices across countries becomes smaller with the lowering of trade costs.

[Figure 4. Adjustment of consumer surplus to anticipated reduction in τ.]

The loss in wages is somewhat offset by the gain in consumer surplus, which is increasing and concave in s due to more intense competition among firms. Therefore, as s gradually increases as shown in Figure 2, consumer surplus should be gradually increasing. Then, when the policy change occurs, there should be a discrete rise in consumer surplus with the reduction in trade costs as goods are now more cheaply accessible. This is indeed what is shown in Figure 4 for the scenario when the policy change is anticipated.

[Figure 5. Adjustment of welfare for skilled labor to anticipated reduction in τ.]

The overall effect on the welfare of a skilled worker is shown in Figure 5. In this figure, the current level of welfare (undiscounted) is mapped for each point in time. Despite the fall in wages, skilled workers in both countries have higher welfare after goods market integration occurs. However, the present discounted value of lifetime gain is higher for the skilled workers in the "core" than in the "periphery".

For unskilled workers, the overall welfare effect of goods market integration is determined by consumer surplus. Looking back at Figure 4, welfare of the unskilled worker in Country H is gradually increasing with the inflow of skilled workers, while welfare of the unskilled worker in Country F is gradually decreasing with the outflow of skilled workers. Then, the welfare of workers in both countries increase with the reduction in trade costs. As indicated in the figure, over their lifetime, unskilled workers in both countries gain from goods market liberalization, but unskilled workers in the "periphery" gain more.

In this baseline case, skilled and unskilled workers in both countries gain from goods market integration. While it is still the case that it is better to live in the "core" than in the "periphery", these simulations illustrate an example when a policy fostering agglomeration in one country does not do so to the detriment of the other country. Workers in the "periphery" reap long-term gains from being part of this integrated region. The welfare of both countries improve with the policy change, even though the policy fosters further concentration of economic activity in the "core" region. In contrast, in static models, the

[16] In the case of an unanticipated reduction in τ, there will be no change in wage until the policy change actually occurs at time $t = 15$. At that point, there will be a large drop in wage with the drop in trade costs.

country who gains the agglomeration does so to the detriment of the country sending skilled workers to the agglomerated region.

5.2 Importance of idiosyncratic moving costs

The presence of idiosyncratic moving costs drives the dynamics of the model. In order to examine the importance of these costs to the system's dynamics, the cases with high and low variances are also considered. All parameters, except ξ, are specified as in the baseline case. The same experiments are performed, beginning from the same initial level of trade costs and lowering costs to the same level, as in the baseline case. In general, the higher the variance, the more likely the dispersed configuration.

In the high-variance case, ξ is now triple the baseline level. Here, the variance is so high, given the level of common costs M, that dispersion is the only market outcome. Labor, on net, looks unresponsive, as the idiosyncratic moving costs are now much more important than in the baseline case.

[Figure 6. High-variance case: Adjustment of wage and consumer surplus to anticipated reduction in τ.]

While this example illustrates one extreme case, it clearly shows how assumptions about the extent of labor mobility can affect the equilibrium and welfare implications of integration. The allocation of skilled labor does not change over time with the fall in trade costs. Thus, all changes is welfare are once and for all at the time the policy change actually occurs. As shown in Figure 6, wages and consumer surplus absorb the effect of the reduction in trade costs (welfare is the same for skilled labor in both countries H and F, since $s^H = 1/2$). Compared to the baseline case, the welfare of skilled workers is worse whether the reduction in trade costs is anticipated or unanticipated.

[Figure 7. Low-variance case: Adjustment of skilled labor to anticipated and unanticipated reduction in τ.]

In the low-variance case, adjustment of skilled labor is gradual as in the baseline case (see Figure 7). Recall that weaker variance yields the core-periphery structure in the limiting case. Since the initial steady state is already near full agglomeration in country H, there is little adjustment in the net allocation of skilled workers, and the adjustment occurs more rapidly than in the baseline case.

6 Conclusions

Within an economic geography framework, this paper introduces costly migration into a dynamic model of location choice that is both consistent with forward-looking behavior and amenable to welfare analyses. At any moment, a skilled worker has the option to relocate, which involves a moving cost with an idiosyncratic and a common component. This moving cost not only varies across individuals, but is also specific to each period, and it captures any non-market attribute of a location that might affect a mobile worker's location decision.

In my model, skilled workers adjust gradually to a policy change, since some workers wait to relocate for a lower cost in a later period. Labor reallocation in the aggregate then persists even after a change in policy occurs, although on net the allocation of workers reaches some steady state. Similarly, since skilled workers are forward-looking, they react to foreseen policy changes before the change actually occurs.

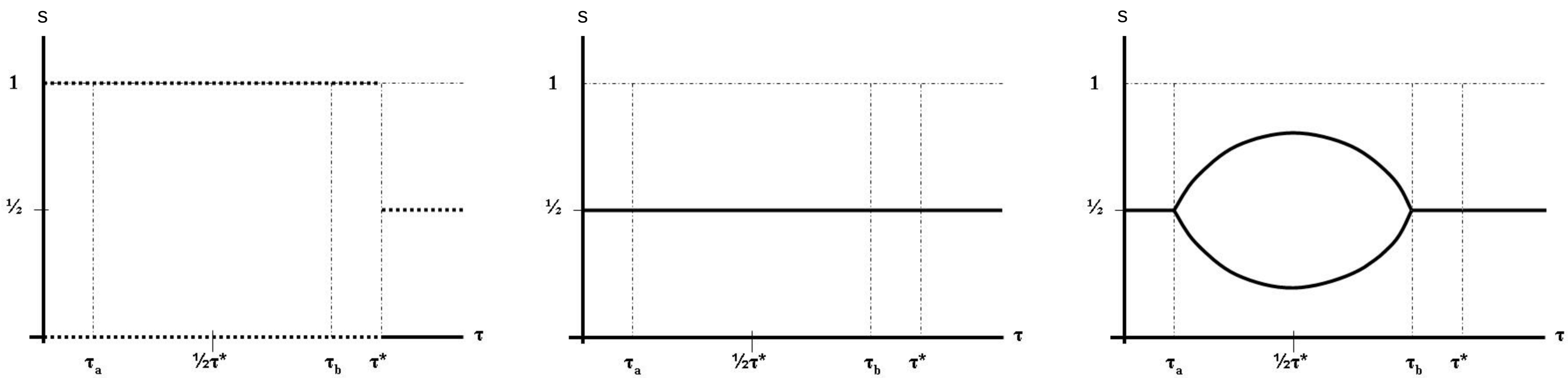
The model is loosely calibrated to show how assumptions on labor mobility can affect the equilibrium allocation of skilled labor. When the idiosyncratic adjustment cost is distributed across workers with higher variance, then a more dispersed allocation of skilled labor occurs. Furthermore, the simulation exercise shows that allowing for costly migration can affect the welfare implications of regional integration. It could be the case that a policy fosters net outward migration of skilled labor from a country without hurting that country's welfare.

A more meaningful policy analysis of regional integration, or enlargement of the EU, for example, should involve more rigorous calibration of the model. That study is left for future work.

Table 1. Value of key parameters in the baseline simulations

Parameter	Assigned Value
δ	0.98
A	8
L	2
τ	4
M	250
ξ	145
a	3
b	0.048
c	0.048
φ	0.1

Figure 1. Stable steady-state proportions of skilled labor given trade costs



(a) var(μ)→0

(b) var(μ)→∞

(c) Intermediate values of var(μ)

Figure 2. Adjustment of skilled labor to anticipated and unanticipated reduction in trade costs at time t=15

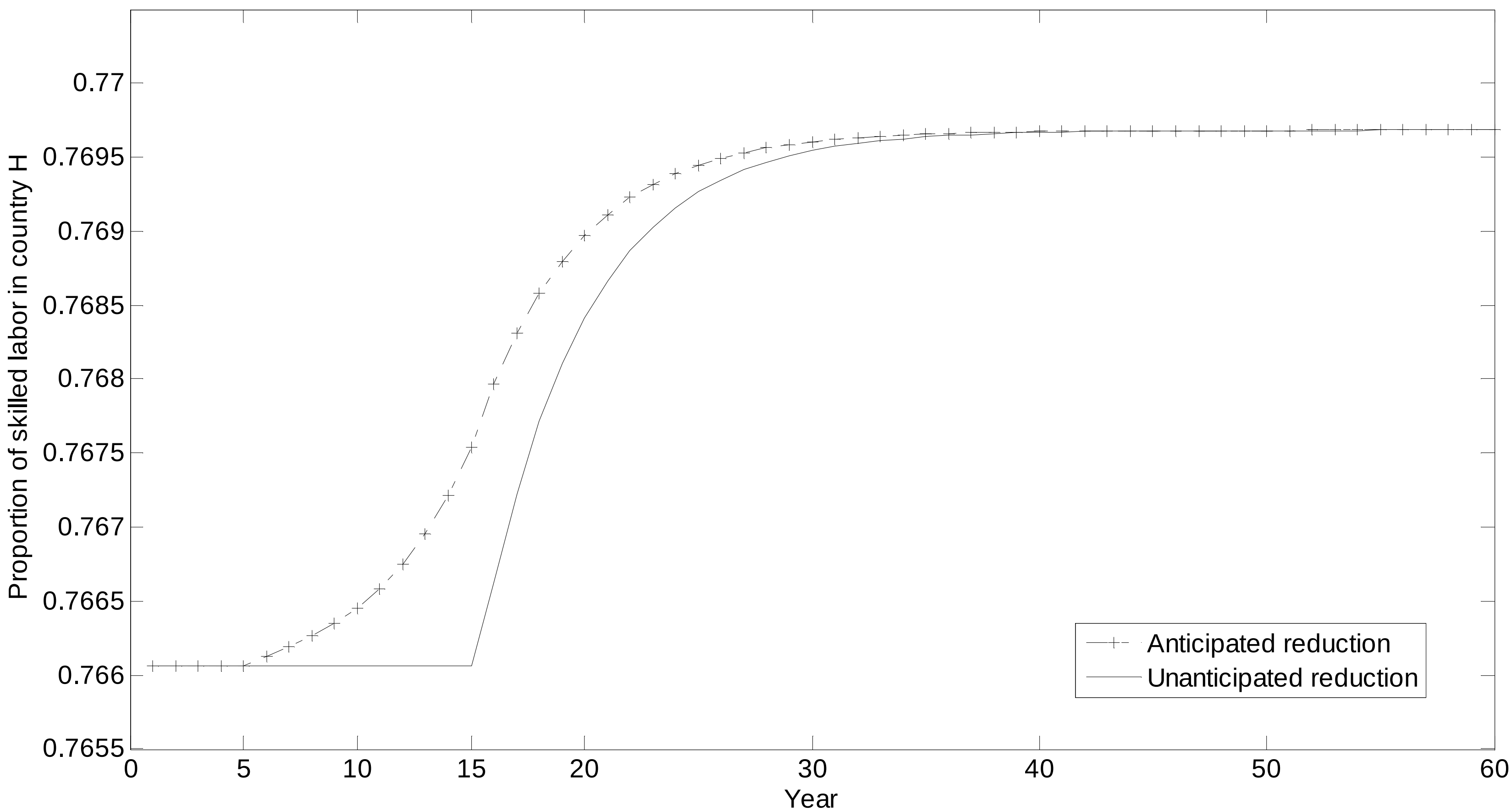


Figure 3. Adjustment of skilled wages to anticipated reduction in trade costs

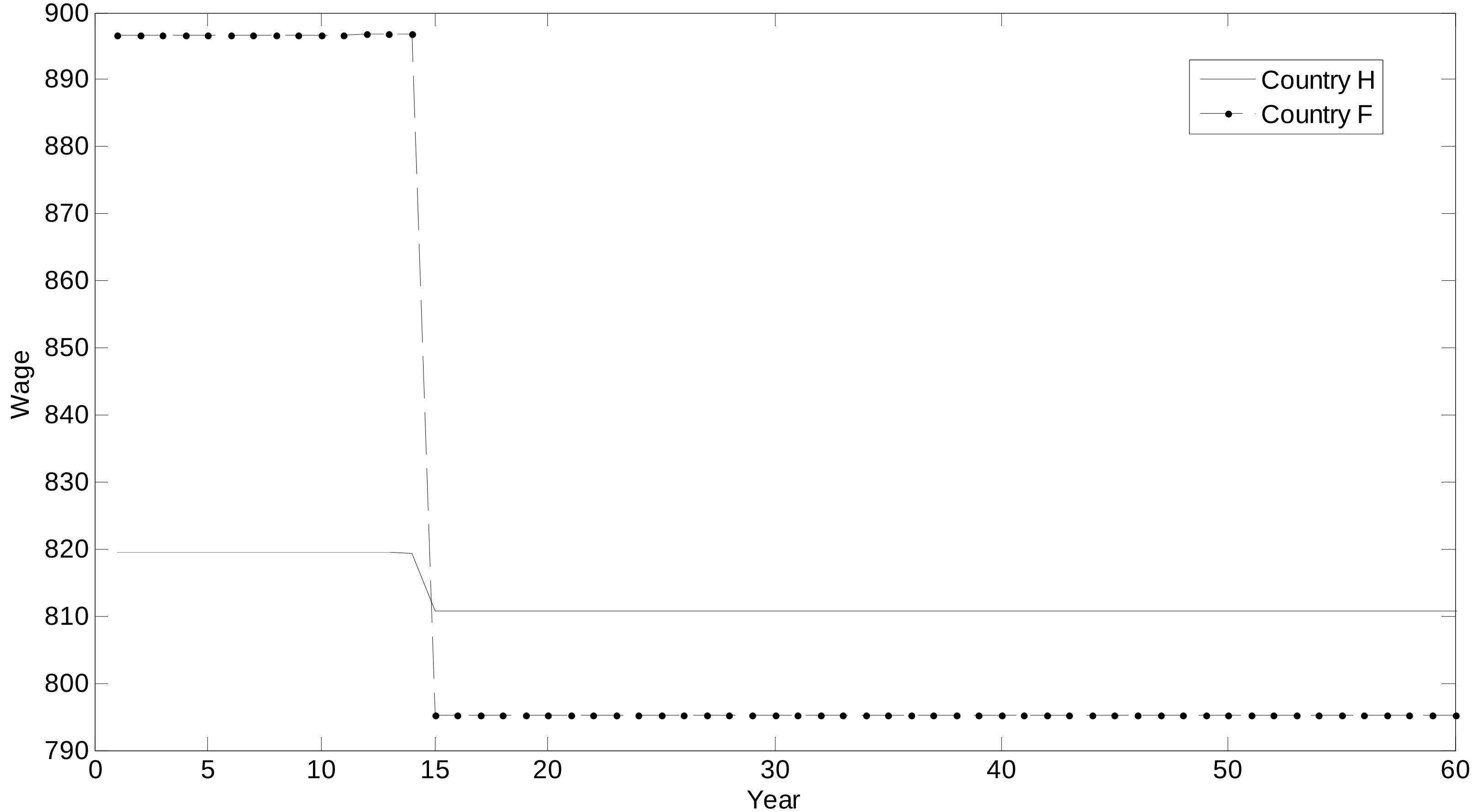
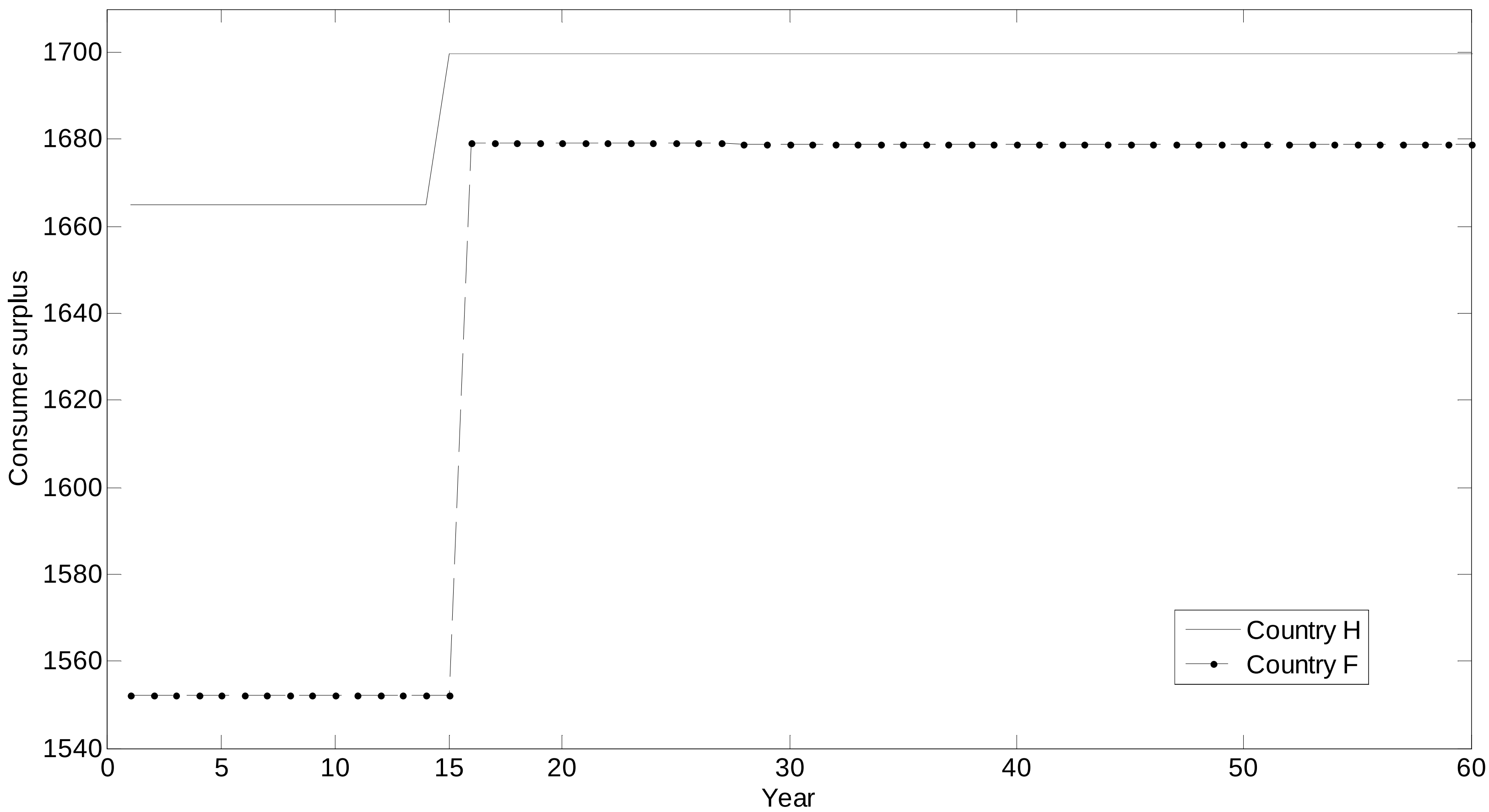


Figure 4. Adjustment of consumer surplus to anticipated reduction in trade costs



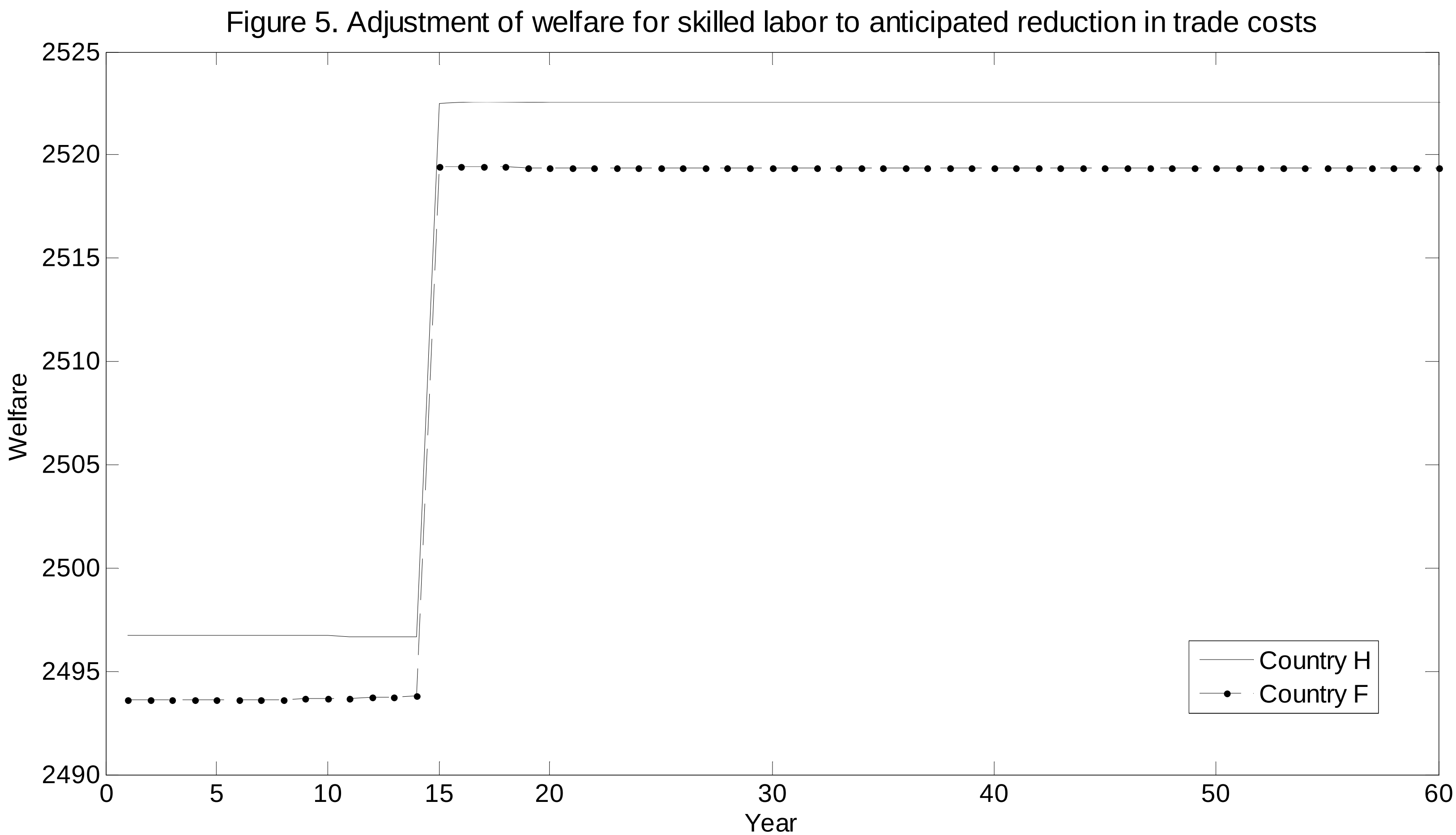


Figure 5. Adjustment of welfare for skilled labor to anticipated reduction in trade costs
Welfare
2525
2520
2515
2510
2505
2500
2495
2490
0
5
10
15
20
30
40
50
60
Year
Country H
Country F

Figure 6. High-variance case: Adjustment of wage and consumer surplus to anticipated reduction in trade costs

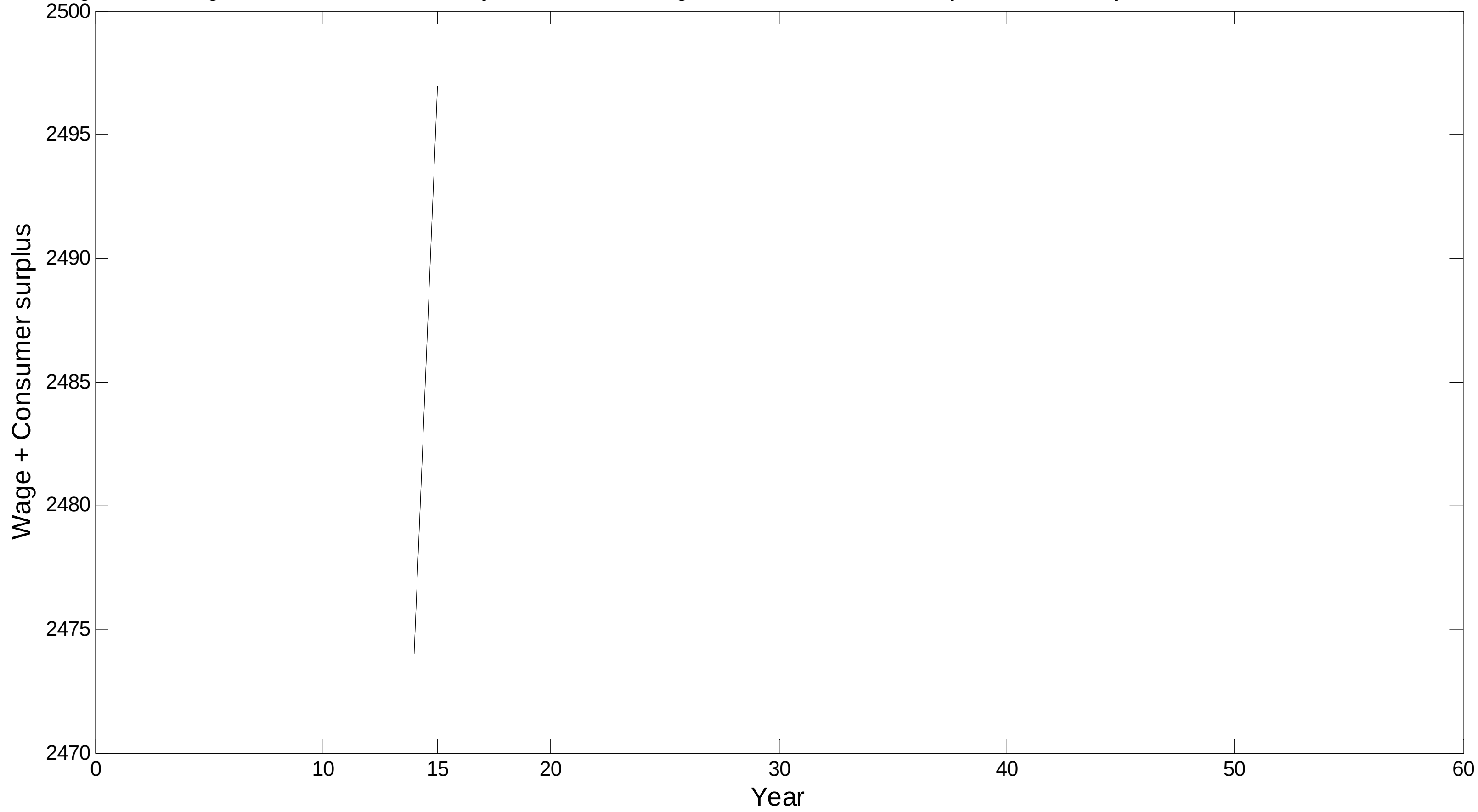
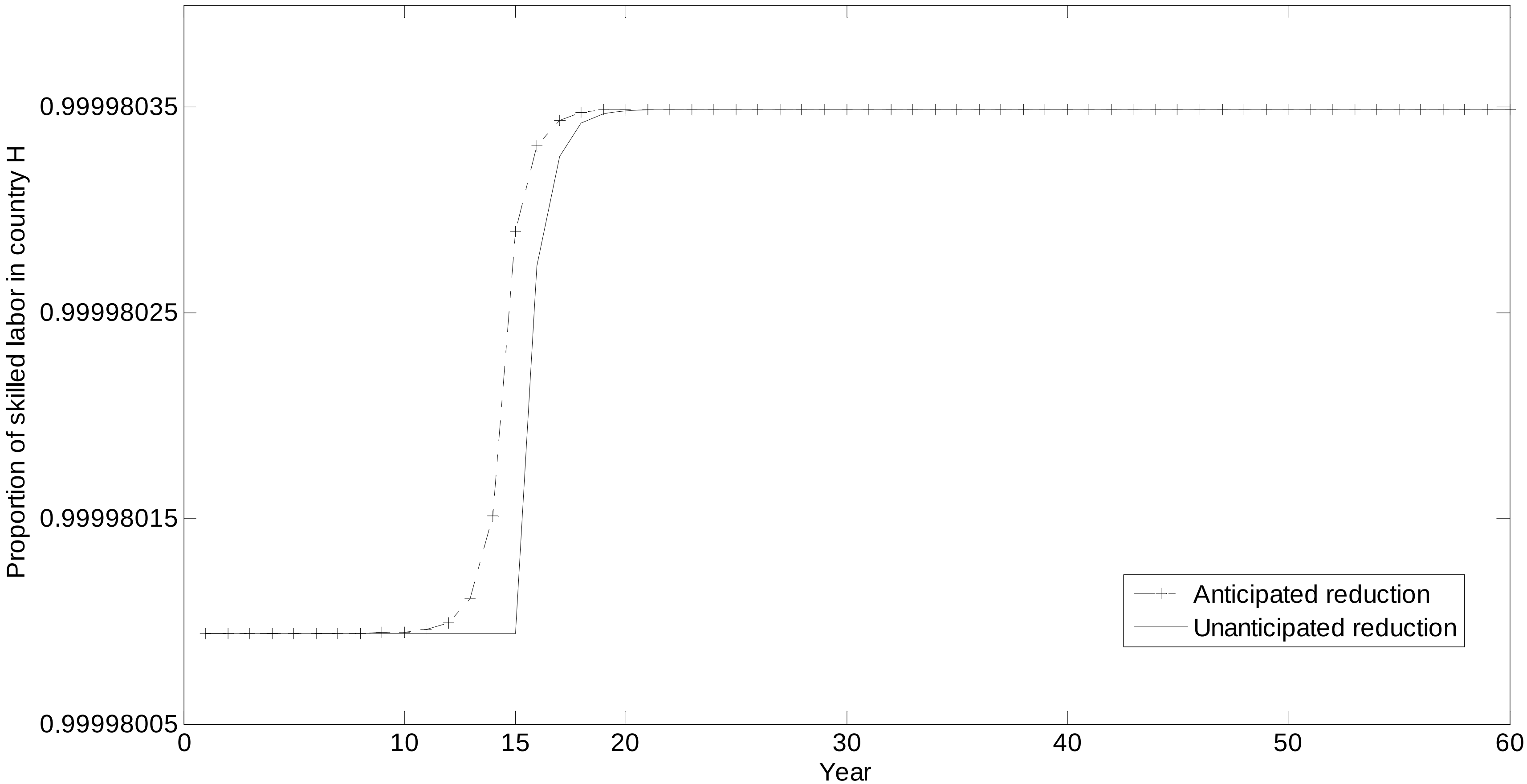


Figure 7. Low-variance case: Adjustment of skilled labor to anticipated and unanticipated reduction in trade costs



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A Appendix

Given the complexity of the system described by equations (4.6) and (4.4), a phase diagram can be useful in graphically identifying other equilibria. Each steady-state condition (equations (4.9) and (4.10)) describes one phaseline. Solving equation (4.9) for λ and relabeling gives:

$$s_1(\nu) = \frac{\beta \left[C\tau(\tau^* - \tau)\frac{1}{2} + \Omega(-\nu - 2M) - \Omega(\nu) \right] - (1-\beta)(\nu + M)}{\beta C\tau(\tau^* - \tau)}. \tag{A.1}$$

Similarly, equation (4.10) is relabeled:

$$s_2(\nu) = \frac{G(-\nu - 2M)}{G(\nu) + G(-\nu - 2M)}. \tag{A.2}$$

These phaselines can be drawn in a diagram with ν on the x-axis and s on the y-axis, and the intersection of the two phaselines indicates the steady state(s). The phaseline $s_2(\nu)$ is always decreasing in ν, no matter the level of trade costs τ. On the other hand, the phaseline $s_1(\nu)$ is increasing or decreasing in ν, depending on the parameter values, particularly the level of trade costs τ.

As shown in Figure A.1, the phaseline $s_1(\nu)$ is increasing in ν when $\tau > \tau^*$. In contrast, when $\tau < \tau^*$, the phaseline $s_1(\nu)$ is decreasing in ν, which is illustrated in Figure A.2. Depending on the parameter values, the phaseline $s_1(\nu)$ can have an inflection point, as shown in Figure A.3, in which case there are three intersections when trade costs are low enough.

Assuming some amount of variance in adjustment costs, the steady-state allocations of labor, given trade costs, is illustrated in Figure A.4. On the x-axis is trade costs τ and on the y-axis is the s, the proportion of skilled labor in country H. For high trade costs, only one equilibrium – the symmetric one – exists. For intermediate levels of trade costs between τ_a and τ_b, there exist three steady-state equilibria. On the other hand, for low levels of trade costs, again only the symmetric equilibrium exists. The exact determination of τ_a and τ_b is discussed below.

First, it is necessary to identify the regions in the state space (ν, s) for which ν is increasing and s is increasing. From equation (4.6), the following can be solved:

$$\begin{aligned} \nu_{t+1} \quad &\geq \quad \nu_t && \text{(A.3)} \\ \Longrightarrow \quad & \nu_{t+1} \geq \beta[-C\tau(\tau^* - \tau)(s_{t+1} - \frac{1}{2}) \\ & +\Omega(-\nu_{t+1} - 2M) - \Omega(\nu_{t+1}) + \nu_{t+1} + M] - M && \text{(A.4)} \\ \Longrightarrow \quad & \beta C\tau(\tau^* - \tau)s_{t+1} \geq \beta\left[C\tau(\tau^* - \tau)\frac{1}{2} + \Omega(-\nu_{t+1} - 2M) - \Omega(\nu_{t+1})\right] \\ & -(1-\beta)(\nu_{t+1} + M) \\ \Longrightarrow \quad & \beta C\tau(\tau^* - \tau)s_t \geq \beta\left[C\tau(\tau^* - \tau)\frac{1}{2} + \Omega(-\nu_t - 2M) - \Omega(\nu_t)\right] \\ & -(1-\beta)(\nu_t + M) \\ \Longrightarrow \quad & s_t \geq s_1(\nu). \end{aligned}$$

Continuing with equation (4.4),

$$\begin{aligned} s_{t+1} \quad &\geq \quad s_t && \text{(A.5)} \\ \Longrightarrow \quad & s_t[1 - G(\nu_t)] + (1 - s_t)G(-\nu_t - 2M) \geq s_t \\ \Longrightarrow \quad & s_2(\nu) = \frac{G(-\nu_t - 2M)}{G(\nu_t) + G(-\nu_t - 2M)} \geq s_t. \end{aligned}$$

Figures A.5, A.6, and A.7 illustrate the steps necessary to construct a phase diagram for the system described by equations (4.6) and (4.4). Figure A.5 shows inequality (A.3), which says that $\nu_{t+1} \geq \nu_t$ if $s_t \geq s_1(\nu)$. Figure A.6 does the same for inequality (A.5), showing that s decreases whenever s lies below the phaseline $s_2(\nu)$. Figure A.7 combines the first two and shows that the phaselines have one intersection in this case.

However, the phase diagram alone does not provide enough information to analyze many aspects of the system's behavior. Since the orbits are sequences of points, not continuous curves in the state space, the vector fields say more about the direction of change in a state variable than about the position of those variables the next period. Qualitative information drawn from discrete phase diagrams is therefore tentative and results must be supplemented by local information contained in the Jacobian matrix of partial derivations.

The stability type of a steady-state solution depends on the eigenvalues of the Jacobian for the system of equations (4.4) and (4.7) evaluated at any steady state (v, s):

$$J(\nu, s) = \begin{pmatrix} \frac{1-\beta C\tau(\tau^*-\tau)[sg(\nu)+(1-s)g(-\nu-2M)]}{\beta[1-G(\nu)-G(-\nu-2M)]} & C\tau(\tau^*-\tau) \\ \\ -[sg(\nu)+(1-s)g(-\nu-2M)] & 1-G(\nu)-G(-\nu-2M) \end{pmatrix}.$$

In particular, the steady state is a sink if both eigenvalues have modulus less than one, a source if both have modulus greater than one, and a saddle if one eigenvalue is inside the unit circle in the complex plane and the other is outside.

Eigenvalues are the roots of the characteristic polynomial $p(s)$:

$$p(s) = s^2 - (trJ)s + \det J = 0,$$

where trJ and $\det J$ are the trace and determinant of the Jacobian matrix, respectively. The trace is calculated as follows:

$$\begin{aligned} trJ &= \frac{1-\beta C\tau(\tau^*-\tau)\left[sg(\nu)+(1-s)g(-\nu-2M)\right]}{\beta\left[1-G(\nu)-G(-\nu-2M)\right]} \\ &\quad +\left[1-G(\nu)-G(-\nu-2M)\right]. \end{aligned}$$

The determinant is:

$$\begin{aligned} \det J &= \frac{1-\beta C\tau(\tau^*-\tau)\left[sg(\nu)+(1-s)g(-\nu-2M)\right]}{\beta} \\ &\quad +C\tau(\tau^*-\tau)\left[sg(\nu)+(1-s)g(-\nu-2M)\right] \\ &= \frac{1}{\beta} > 1. \end{aligned}$$

For the eigenvalues to be real, the discriminant of the characteristic polynomial $p(s)$ must be positive; otherwise, the eigenvalues are complex. It can be shown that $(trJ)^2 - 4\det J > 0$ when $\tau > \tau^*$, which means that J has two positive real eigenvalues at the steady state $(-M, \frac{1}{2})$. Since $trJ > 0$ when $\tau > \tau^*$, the only steady state $(-M, \frac{1}{2})$ is a saddle point.

For trade costs below τ^*, stability analysis becomes more complicated. At the steady state $(-M, \frac{1}{2})$, the discriminant $(trJ)^2 - 4\det J > 0$ when:

$$\begin{aligned} \tau_a &< \frac{\tau^*}{2} - \sqrt{\frac{\tau^{*2}}{4} - \left[1-\sqrt{\beta}+2\sqrt{\beta}G(-M)\right]^2} \\ \text{or } \tau_b &> \frac{\tau^*}{2} + \sqrt{\frac{\tau^{*2}}{4} - \left[1-\sqrt{\beta}+2\sqrt{\beta}G(-M)\right]^2} \end{aligned}$$

and the distribution function $G(v)$ is such that $\frac{\tau^*}{2} > 1 - \sqrt{\beta} + 2\sqrt{\beta}G(-M)^2 > 0$. It can be verified that $0 < \tau_a \leq \frac{\tau_a+\tau_b}{2} = \frac{\tau^*}{2} \leq \tau_b < \tau^* < \tau_{trade}$. It can also be shown that the only existing steady state $(-M, \frac{1}{2})$ in the regions $[0 < \tau_a]$ and $[\tau_b < \tau^*]$ is a saddle point. On the other hand, in the region $[\tau_a < \tau_b]$, the discriminant $(trJ)^2 - 4\det J < 0$ at the steady state $(-M, \frac{1}{2})$, and the eigenvalues are complex. Since $\det J > 1$, the steady-state $(-M, \frac{1}{2})$ is an unstable source.

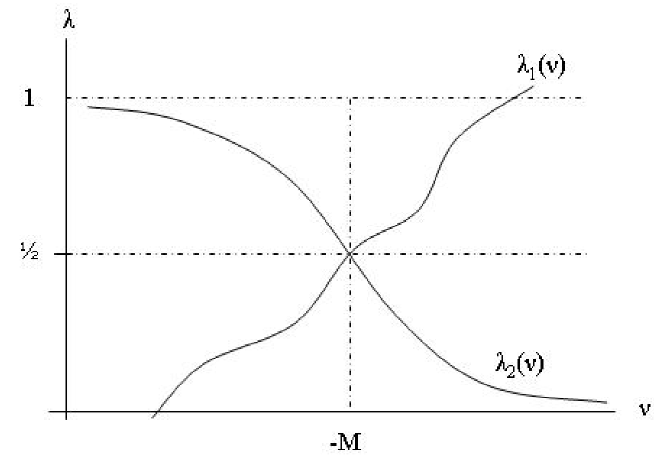

Figure A.1: Phase diagram showing the steady-state equilibrium when $\tau > \tau^*$

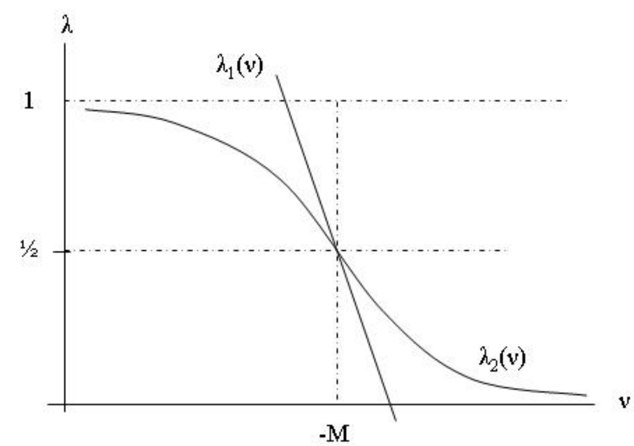

Figure A.2: Phase diagram showing the steady-state equilibrium when $\tau < \tau^*$

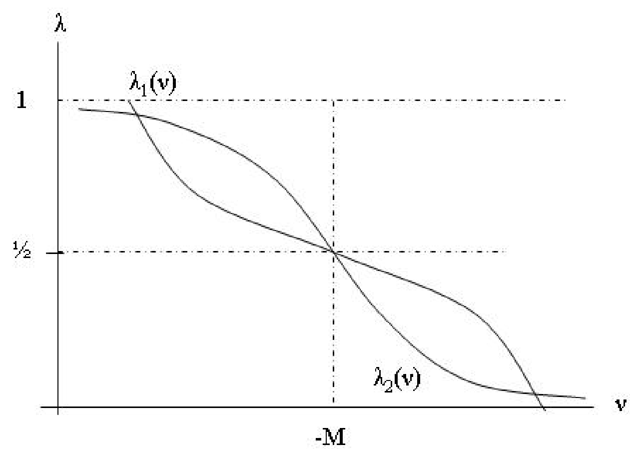

Figure A.3: Phase diagram showing the steady-state equilibria when $\tau < \tau^*$

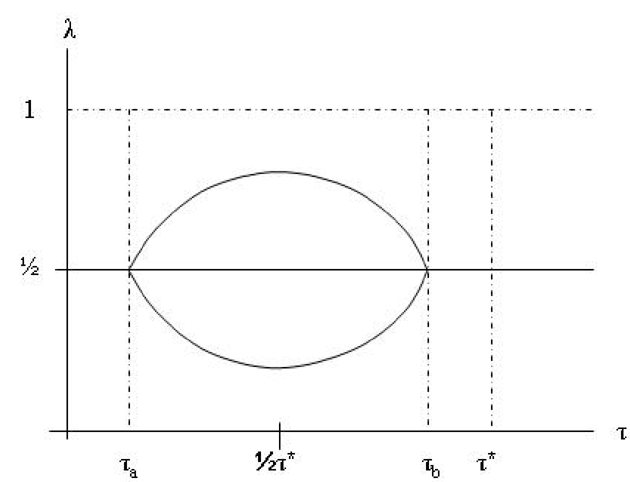

Figure A.4: Steady-state allocation of skilled labor given trade costs τ

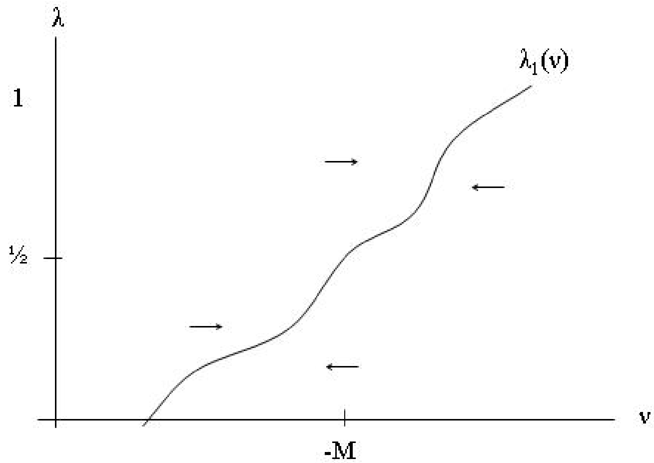

Figure A.5: Phaseline for $s_1(\nu)$ when trade costs are such that $\tau > \tau^*$

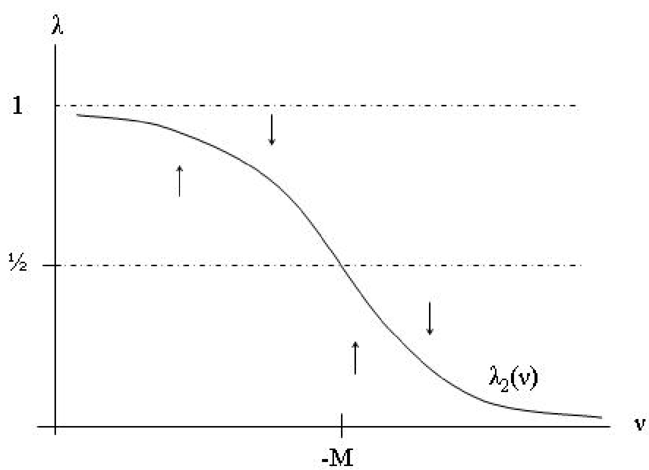

Figure A.6: Phaseline for $s_2(\nu)$ given any level of trade costs τ

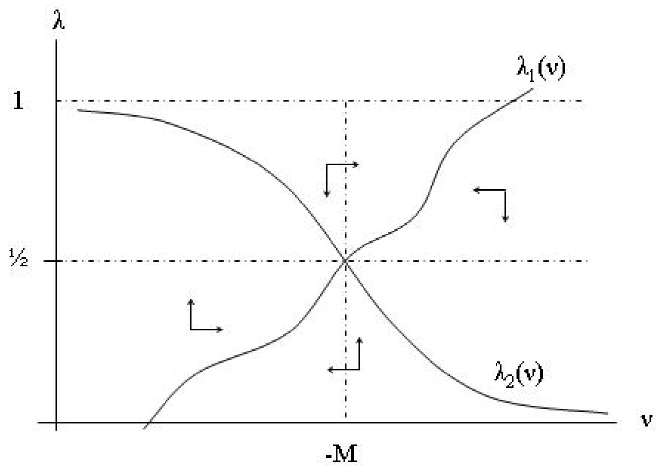

Figure A.7: Complete phase diagram for trade costs $\tau > \tau^*$