Internal Migration, Sectoral Reallocation, and Large Devaluation*

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Abstract

How do internal migration and its frictions affect sectoral reallocation of labor in the aftermath of a large devaluation? Following the 1998 Korean devaluation, using cross-sectional variation in industrial composition and event-study specifications, I provide empirical evidence on relative increases in sectoral reallocation of labor to more export-intensive sectors and migration inflows to regions whose industrial composition was more export-oriented. This evidence suggests that sectoral reallocation of labor and migration could have been interlinked. To quantify the aggregate effects of migration frictions, I build a dynamic spatial general equilibrium model of migration and trade. The model is calibrated to region-sector level data. Had there been no migration after the devaluation, the aggregate employment shares and export intensity of the five most export-intensive sectors would have decreased by 1.1 and 1.2% compared to the baseline economy with the observed migration flows. The empirically observed reductions in migration frictions would have increased these aggregate outcomes by 1.2 and 0.6% relative to the baseline.

Keywords: migration, sectoral reallocation, devaluation, trade
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1 Introduction

When hit by sector-specific shocks, any barriers in sectoral reallocation of labor hinder workers from flexibly reallocating across sectors and decrease aggregate efficiency of an economy.[1] Understanding spatial aspects of these barriers can be important because many sectors tend to be geographically concentrated in a few regions.[2] When sectors are geographically concentrated, workers may have to migrate to other regions to reallocate themselves into different sectors and any frictions in internal migration can decrease amounts of sectoral reallocation of workers accompanied by such migration.

This paper studies how internal migration and its frictions affect amounts of sectoral reallocation of labor after large devaluations. Large devaluations are associated with a large depreciation of the real exchange rate that increases exports. After large devaluations, higher allocative efficiency can be achieved if labor can be flexibly reallocated to more export-intensive sectors that experience relatively larger increases in exports. However, when these export-intensive sectors are geographically concentrated, migration frictions can hinder reallocation of labor to these sectors through the migration channel. Migration frictions can work as even bigger barriers in emerging market economies in which large devaluations occur more frequently and migration frictions are known to be higher than those of developed economies.[3]

I use Korean data after its 1998 devaluation episode. I document two patterns of the data after the devaluation. First, there were relatively larger increases in exports among more export-intensive sectors after the devaluation. Second, these export-intensive sectors were highly geographically concentrated in a few regions and there were large cross-sectional variation in regional export intensity across regions defined as the weighted average of sectoral export intensity, where the weights are given by employment shares in the initial period. I refer regions with higher regional export intensity as more export-oriented regions.

Using cross-sectional variation in the regional export intensity and event-study specifications, I provide two empirical evidence: sectoral reallocation of labor within regions and spatial reallocation of labor across regions. First, after the devaluation occurred, there were relative increases in reallocation of workers to more export-intensive sectors in more export-oriented regions (sectoral reallocation of labor within regions). Second, there were relative increases in migration inflows to more export-oriented regions (spatial reallocation of labor across regions). The documented patterns and the empirical evidence suggest that sectoral and spatial reallocation of labor could have been interlinked

[1] Many economists and policymakers have examined barriers for sectoral reallocation of labor to improve labor market flexibility. See, for example, Heckman and Pages (2000), Kambourov (2009), Helpman et al. (2010), Petrin and Sivadasan (2013), and Cosar et al. (2016) for labor institutions such as firing costs and search frictions; and Neal (1995) and Dix-Carneiro (2014) for sector-specific human capital. In terms of the policy, for example, the German government implemented a set of labor market reforms to improve mobility of workers and labor market flexibility in the mid-2000s, known as the Hartz reforms.

[2] See Ellison and Glaeser (1997) for geographic concentration of manufacturing sectors in the US.

[3] For example, Bryan and Morten (2019) document higher internal migration frictions in Indonesia when compared to the US. They find that if Indonesia's migration frictions were at the US level, the aggregate labor productivity of Indonesia would increase by 7.1%.

through migration after the devaluation.

For sectoral reallocation, I regress region-sector employment shares in the top five most export-intensive manufacturing sectors (the top 5 sectors) on the regional export intensity interacted with event time dummies. For spatial reallocation, I similarly regress migration inflows between origin and destination regions on the regional export intensity of destinations interacted with event time dummies while controlling for origin-year fixed effects. I find that three years after the devaluation, the employment share in the top 5 sectors of one region increased 3.6% higher relative to another with one standard deviation lower regional export intensity three years after the devaluation; and migration inflows of one region increased by 4.8% when compared to another whose regional export intensity of its destination were a one standard deviation lower. For both event specifications, there were no pre-trends, implying that relatively more export-oriented regions did not exhibit differential trends in the top 5 employment shares and migration inflows in the years leading up to the devaluation. This evidence suggests that sectoral and spatial reallocation of labor could have been interlinked.

Second, guided by the two empirical evidence, I build a dynamic spatial general equilibrium model with trade and forward-looking migration and investment. I use this model to quantify the aggregate effects of migration frictions on sectoral reallocation of labor after the devaluation. The devaluation is modeled in a reduced-form fashion as four exogenous time-varying shocks: productivity, foreign demand, import price, and trade deficit shocks. These four shocks rationalize big drops in total factor productivity (TFP), expansion of exports, collapse in imports, and rapid decreases in trade deficits that are common features of emerging market economies after large devaluation episodes.[4]

There are two agents in the model: workers and landlords. In each period, workers make decisions on which sectors to work (sectoral labor supply) and where to live (migration). Workers have a continuum of members. Each member receives idiosyncratic labor productivity shocks across different sectors. Given region-sector wages and members' idiosyncratic productivity shocks, workers optimally allocate their members across different sectors to maximize the total sum of wages of their members, similar to the Roy model of sector choice (Lagakos and Waugh, 2016; Hsieh et al., 2019). This decision determines sectoral labor supply within regions conditional on population. The migration decision is modeled as a dynamic discrete choice (Artuc et al., 2010; Caliendo et al., 2019). When households make location decisions, they consider current real income, their option value of being in a current location, and migration frictions measured in terms of utility. Landlords are geographically immobile and make forward-looking investment decisions for the accumulation of local capital from which they earn capital income (Kleinman et al., 2021).

In the model, aggregate sectoral employment is determined by region-sector employment shares and population distribution across regions. Workers' sectoral labor supply decision characterizes region-sector employment shares, governed by the elasticity of region-sector employment shares to

[4]For example, see Kehoe and Ruhl (2008), Pratap and Urrutia (2012), Kim (2014), and Queralto (2020) for big TFP drops; see Alessandria et al. (2010), Gopinath and Neiman (2014) and Blaum (2018) for large changes in imports and exports; and see Kehoe and Ruhl (2009) for rapid changes in trade deficits.

region-sector specific wages. Workers' migration decision characterize population distribution across regions, governed by the elasticity of migration inflow shares to the discounted lifetime utilities net of migration frictions.

Increased exports due to the devaluation can increase aggregate employment in more export-intensive sectors by affecting both region-sector employment shares and population distribution. If increased exports relatively increases wages of more export-intensive sectors within regions, workers will allocate more members to these export-intensive sectors, which in turn increases regional employment shares in these export-intensive sectors. This is related to the first empirical evidence on sectoral reallocation of labor within regions. Also, increased exports increase the average real income of more export-oriented regions, which in turn induces more workers to migrate to these export-oriented regions. This is related to the second empirical evidence on spatial reallocation of labor across regions. However, despite the higher real income, if migration frictions are sufficiently high, workers opt to stay in their initial locations instead of moving. In such a case, less workers will be populated in these export-oriented regions, which in turn decreases aggregate employment in export-intensive sectors after the devaluation.

The model is calibrated to region-sector level data. I derive two regression models from the model and estimate the two key elasticities related to the two decisions of workers. When estimating these two model-driven regression models, I use the instrumental variable (IV) strategy. The IVs for both regression models exploit the cross-sectional variation in the sectoral and regional export intensity of the initial period interacted with a dummy of the devaluation periods. These IV strategies can consistently estimate the two key elasticities when demand shocks due to the devaluation's expansionary effects on exports are uncorrelated with shocks to productivity and migration frictions conditional on controls.

I calibrate the four exogenous shocks that model the devaluation in a reduced-form fashion by fitting the quantitative model to the observed data. The productivity shocks are backed out from region-sector gross output and sectoral producer price indices; the foreign demand shocks from sectoral exports; the import price shocks from sectoral imports; and the exogenous trade deficits directly from the observed trade data.

To quantify the effects of migration frictions, I compare transition paths of the baseline and counterfactual economies with different migration friction levels. I consider hypothetical reductions in migration frictions similar to Bryan and Morten (2019). I make the migration frictions of the counterfactual economies temporarily differ from those of the baseline only up to 2002, which is five years after the devaluation, and move back to the baseline level in 2003. By doing so, I focus on the effects of migration frictions on short-run labor adjustment after the devaluation rather than their long-run consequences.

I indirectly infer migration frictions from the observed migration flows following Head and Ries (2001) and compute the empirical distribution of reductions in migration frictions between 1997 and

2017. As in Monte et al. (2018), I use this distribution to compute empirically plausible changes in migration frictions. I consider three counterfactual scenarios. In the first scenario, migration is temporarily not allowed. In the remaining two, I consider common temporary decreases by the 50 and 75th percentile of the empirical distribution for all regions, which are equivalent to a 11 and 28% reduction, respectively. In all scenarios, migration frictions move back to the original level in 2003.

If migration were temporarily not allowed after the devaluation, aggregate employment shares and export intensity of the top 5 sectors would have been 1.1 and 1.2% lower than those of the baseline economy with the observed migration flows. With the 50th percentile temporary decrease of the empirically observed reductions, these aggregate outcomes would have increased by 1.2 and 0.6% higher relative to the baseline. These aggregate effects are mostly driven by changes in population distribution due to increased workers' migration inflows to more export-oriented regions rather than changes in region-sector employment shares. With lower migration frictions, there are larger increases in these inflows, which in turn increases the aggregate employment in the top 5 sectors.

Related literature This paper contributes to several strands of the literature. First, this paper contributes to the large literature that studies local labor market adjustment to trade shocks (see, among many others, Topalova, 2010; Menezes Filho and Muendler, 2011; Autor et al., 2013; Kovak, 2013; Adão, 2015; Hakobyan and McLaren, 2016; Pierce and Schott, 2016; Dix-Carneiro and Kovak, 2017; Benguria et al., 2018; Kondo, 2018; Bloom et al., 2019; Caliendo et al., 2019; Dix-Carneiro and Kovak, 2019; Greenland et al., 2019; Traiberman, 2019; Kim and Vogel, 2021; Lake and Liu, 2021; Adão et al., 2022). I contribute to this literature by providing the novel empirical findings of short-run sectoral and spatial adjustment of labor to the transitory trade shocks induced by the devaluation and quantifying the effects of migration frictions on sectoral labor adjustment.[5]

Second, I contribute to the literature that quantifies effects of internal migration frictions (see, for example, Morten and Oliveira, 2016; Lagakos et al., 2018; Fan, 2019; Monras, 2015; Schmutz and Sidibé, 2019; Tombe and Zhu, 2019; Hao et al., 2020; Imbert and Papp, 2020; Gai et al., 2021; Heise and Porzio, 2021; Pellegrina and Sotelo, 2021; Nakamura et al., 2022). Unlike previous papers that study long-run consequences of migration frictions, I study the effects of migration frictions on short-run labor adjustment in the aftermath of the large devaluation.

Third, I contribute to the literature that studies the effects of large devaluations, surveyed by Burstein and Gopinath (2014) (see, e.g., Burstein et al., 2005; Cravino and Levchenko, 2017; Blanco et al., 2019; Bonadio et al., 2020; Auer et al., 2022). Alessandria et al. (2010) study inventory behavior of importers and trade dumpiness, Gopinath and Neiman (2014) large TFP drops due to decreased

[5]There is mixed empirical evidence on how internal migration flows respond to trade shocks. For example, Autor et al. (2013) and Adão et al. (2022) find limited evidence of changes in internal migration flows to the China shock in the US. Adão (2015) and Benguria et al. (2018) find limited evidence to the commodity price shocks in Brazil. Topalova (2010) and Dix-Carneiro and Kovak (2017) also find limited evidence after the trade liberalization episodes in India and Brazil, respectively. On the other hand, Greenland et al. (2019) find increased migration flows among young or less-educated workers into regions that were less exposed to the China shock in the US. Hakobyan and McLaren (2016) find that migration outflows of high school dropouts increased from regions negatively affected by NAFTA.

imports, and Blaum (2018) joint import and export decisions of big firms after large devaluation episodes. House et al. (2020) study regional effects of changes in the real exchange rate on state-level exports, unemployment, and interstate migration in the US. Unlike these papers, I examine labor market adjustment margins across sectors and regions after the devaluation and find that internal migration was an important adjustment mechanism.

The structure of this paper is as follows. Section 2 describes the data. Section 3 presents empirical evidence on sectoral and spatial reallocation of labor after the Korean devaluation in 1998. In Section 4, I build a quantitative model to quantify the effects of migration frictions. Section 5 concludes.

2 Data

The final data set has information on region-sector employment, gross output, and real capital stock, region-to-region migration flows, and sectoral trade. I aggregate data to 121 regions and 15 sectors. The sample period is between 1995 and 2004. See Appendix Section A for more detail on construction of the final data set.

Region-sector data I construct region-sector employment shares from the Census on Establishment which covers the universe of formal establishments in Korea at a finely disaggregated geographic level for all sectors.[6] I compute region-sector employment shares by summing up employment across establishments within region-sectors and dividing the sum by total regional employment.

I construct region-sector gross output by combining the Census of Establishment, the state-sector gross output obtained from the Statistics Korea, and the IO tables from the World Input-Output Database (WIOD) 2013 release (Timmer et al., 2015). I allocate sectoral gross output across states after merging the state-sector gross output and the WIOD data. Then, I allocate state-sector gross output across regions using region-sector employment shares obtained from the Census of Establishment.

I construct region-sector real capital stock by combining the Census of Establishment, the Mining and Manufacturing Survey, WIOD Socio Economic Accounts (WIOD-SEA), and IMF Investment and Capital Stock Database (IMF-ICSD). I allocate the aggregate real capital stock series from the IMF-ICSD across sectors based on the sectoral nominal capital stock series obtained from the WIOD-SEA. For the manufacturing sectors, I calculate region-sector nominal capital stock by summing fixed assets across establishments within region-sectors, which comes from the Mining and Manufacturing Survey. Then, I allocate region-sector real capital stock using the calculated region-sector nominal capital stock for the manufacturing sectors and the region-sector employment shares for the non-manufacturing sectors.

[6] The Census on Establishment covers the universe of formal establishments with one or more employees except for agriculture, forestry, and fisheries businesses by individual owners and establishments related to national defense, housekeeping service, and international and foreign organizations. On average, approximately 2.9 million establishments are covered by the data set across the sample period. The data set has information on geographical location, sectors, and employment of establishments.

Region-to-region migration data I obtain data sets on the number of internal migrants between regions and regional population from the Statistics Korea. I calculate migration shares as the total number of migrants between origin and destination regions divided by lagged populations of origin regions.

Sectoral trade data I obtain sectoral trade data from the WIOD and the Bank of Korea before 1995. I aggregate countries except for Korea as the rest of the world (ROW).

3 Empirical Evidence on Sectoral and Spatial Reallocation of Labor

In this section, I provide two empirical evidence: (i) relative increases in reallocation of workers to more export-intensive sectors in more export-oriented regions and (ii) relative increases in migration inflows to more export-oriented regions after the devaluation.

3.1 Sectoral and Regional Heterogeneity

Panel A of Figure 1 displays sectoral export intensity and shares of exports to the total exports in 1993. The figure illustrates that there were large variation in the export intensity across sectors and manufacturing sectors tend to be relatively more export-intensive in South Korea. Panel B plots changes in the export intensity of the top 5 most export-intensive manufacturing sectors and those of the other remaining sectors after the devaluation.[7] I normalize the export intensity by the median between 1995 and 1997 before the devaluation. The top 5 export intensity increased about 10 percentage points higher than the intensity of the other sectors after the devaluation relative to the pre-devaluation periods.[8]

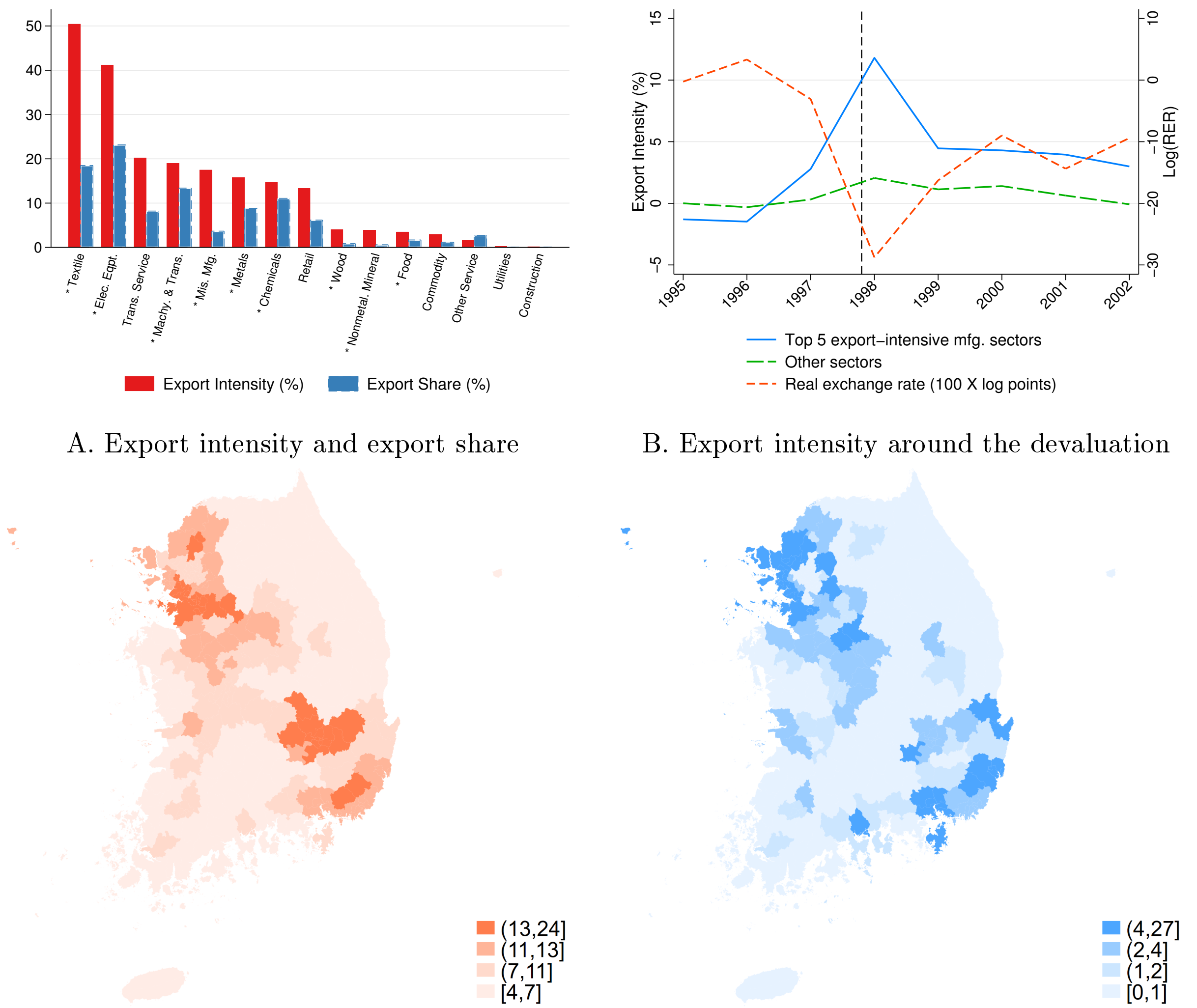
Panel C illustrates regional export intensity defined as the weighted average of the sectoral export intensity in Panel A, where the weight is given by employment shares in 1994:

$$RegEX_{nt_0} = \frac{\sum_j Emp_{njt_0} \times SecEX_{jt_0}}{\sum_j Emp_{njt_0}}, \tag{3.1}$$

where $SecEX_{jt_0}$ is the sectoral export intensity. Regional differences in employment shares generate variation in $RegEX_{nt_0}$ across regions. The figure illustrates that there were large variation in the regional export intensity across regions and export-intensive sectors were geographically concentrated in the northwestern and southeastern regions. Panel D shows that more export-oriented regions tended to be ones with the higher top 5 employment shares.

[7] I define the top 5 most export-intensive manufacturing sectors based on the export intensity in Panel A, which includes textile, electrical equipment, machinery and transportation equipment, metals, and chemicals. Although the miscellaneous manufacturing sector had higher export intensity than machinery and transportation equipment, metal, and chemicals sectors, I did not include it as one of the top 5 sectors because its export shares were low and its classification is ambiguous.

[8] Consistent with the increases in the export intensity, between 1997 and 2000, aggregate employment, GDP, and gross output shares in the top 5 sectors increased from 18.2 to 18.7%, 22.8 to 25.7%, and 35.3 to 39.5%, respectively. See Appendix Figure A6.



A. Export intensity and export share

B. Export intensity around the devaluation

C. Regional export intensity

D. Top 5 mfg. emp share

Figure 1. Sectoral and Regional Heterogeneity in Export Intensity

Note. Panel A plots the sectoral export intensity and export shares in 1993. An asterisk * denotes manufacturing sectors. Plot B plots changes in the sectoral export intensity around the devaluation. The blue solid and green dashed lines are the export intensity of the top 5 most export-intensive manufacturing sectors and the other sectors. The export intensity is normalized by the median between 1995 and 1997 for both groups. The red dotted line is log of the real exchange rate. Panels C and D plot the regional export intensity defined in Equation (3.1) and the top 5 employment shares, respectively. Regions are colored based on the quartiles and colored darker with higher values.

3.2 Sectoral Reallocation of Labor

The differential expansionary effects on exports across sectors (Panels A and B of Figure 1) could have induced workers to reallocate to more export-intensive sectors. In order to provide evidence on such sectoral reallocation of workers, I exploit cross-sectional variation in the regional export intensity documented in Panel C of Figure 1. I run the following event-study specification:

$$y_{nt} = \Big[\sum_{\tau=-3}^{7} \beta_\tau (D_t^\tau \times RegEX_{nt_0}) + (D_t^\tau \times \mathbf{X}_{nt_0})' \boldsymbol{\gamma}_\tau \Big] + \delta_n + \delta_t + \epsilon_{nt}. \tag{3.2}$$

$RegEX_{nt_0}$ is the regional export intensity of the initial period in 1994. I standardize $RegEX_{nt_0}$ for ease of interpretation. D_t^τ are event-time dummies: $D_t^\tau \equiv \mathbb{1}[\tau = t - 1998]$. y_{nt} are the dependent variables: log of employment shares in the top 5 and the overall manufacturing sectors. δ_n and δ_t are region and calendar year fixed effects. ϵ_{nt} is the error term. $\mathbf{X}_{nt_0}$ are observables of the initial period that allow for heterogeneous trends based on the observables, which includes log of total employment in 1994. I normalize β_0 and $\boldsymbol{\gamma}_0$ to be zero.

Figure 2 reports the results. In Panels A and B, dependent variables are log of the top 5 and the overall manufacturing employment shares, respectively. Three years after the devaluation, a region experienced 3.6 and 1.4% higher increases in the top 5 and overall manufacturing employment shares than a region whose regional export intensity was a one standard deviation lower. There were no pre-trends before the devaluation.

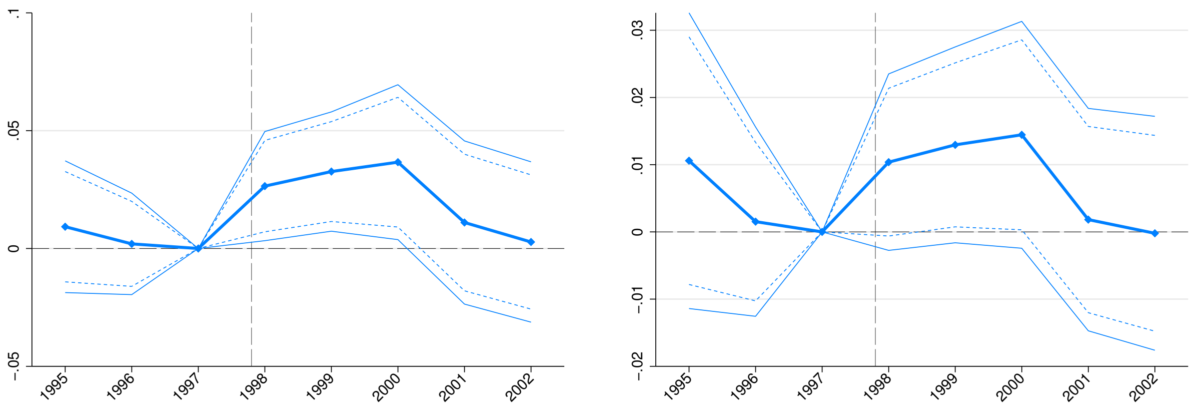
3.3 Spatial Reallocation of Labor

Because relatively more export-intensive manufacturing sectors were geographically concentrated (Panels C and D of Figure 1), workers might move to more expor-oriented regions to reallocate themselves to these more export-intensive sectors. To examine this spatial reallocation of labor, I consider the following event-study specification:

$$\ln \mu_{nmt} = \Big[\sum_{\tau=-3}^{7} \beta_\tau (D_t^\tau \times RegEX_{mt_0}) + (D_t^\tau \times \mathbf{X}_{mt_0})' \boldsymbol{\gamma}_\tau \Big] + \delta_{nm} + \delta_{nt} + \epsilon_{nmt}. \tag{3.3}$$

The dependent variables are changes in log of migration shares μ_{nmt} from region n to m.[9] $RegEX_{mt_0}$ is the standardized regional export intensity of destination region m. δ_{nm} and δ_{nt} are time-invariant pair and origin-year fixed effects. $\mathbf{X}_{mt_0}$ are observables of destination region m in the initial period, which includes log of total employment in 1994. I normalize β_τ and $\boldsymbol{\gamma}_0$ to be zero. To deal with statistical zeros, I estimate Equation (3.3) using Poisson Pseudo-maximum likelihood (PPML) (Silva and Tenreyro, 2006).

[9]Because the regression model is at the bilateral pair level, the regression model incorporates the bilateral nature of location choices and does not suffer from the critique proposed by Borusyak et al. (2022).

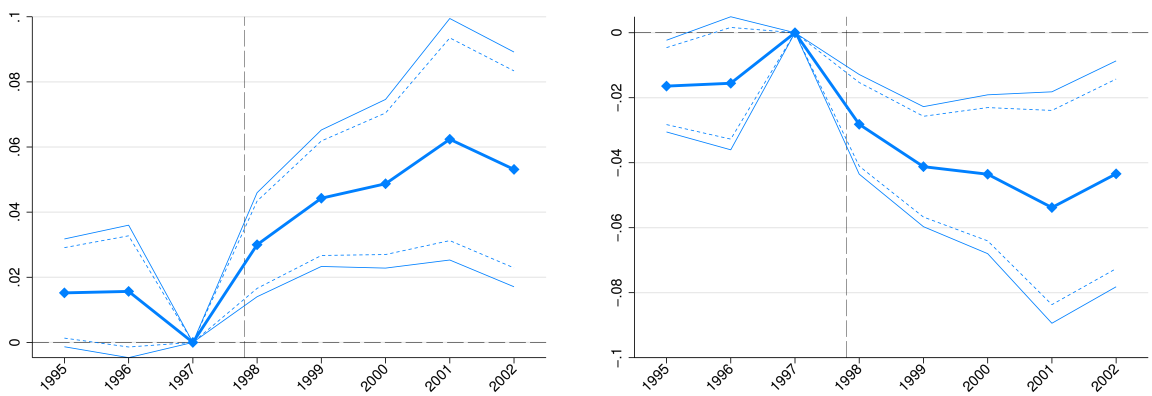


A. Top 5 mfg.

B. All mfg.

Figure 2. Event Study. Sectoral Reallocation of Labor. Workers Reallocated to More Export-Intensive Sectors within Regions

Note. This figure illustrates the estimated β_τ in Equation (3.2). In Panels A and B, the dependent variables are log of employment shares in the top 5 and all manufacturing sectors, respectively. The black dashed line indicates the start of the devaluation. The figure reports 90 and 95 percent confidence intervals based on standard errors clustered at the regional level.



A. Destination $RegEX_{mt_0}$

B. Origin $RegEX_{nt_0}$

Figure 3. Event Study. Spatial Reallocation of Labor. Workers Migrated to More Export-Oriented Regions.

Note. This figure illustrates the estimated β_τ in Equation (3.3). The dependent variables are log of migration shares between origin and destination regions. In Panels A and B, the estimated coefficients of destination's $RegEX_{mt_0}$ and origin's $RegEX_{nt_0}$ are plotted, respectively. I estimate Equation (3.3) using PPML to deal with statistical zeros (Silva and Tenreyro, 2006). The black dashed line indicates the start of the devaluation. The figure reports 90 and 95 percent confidence intervals based on standard errors two-way clustered at the origin and destination levels.

The results are reported in Panel A of Figure 3. Three years after the devaluation, migration inflows to a destination increased 6% higher than another whose destination region had a one standard deviation lower regional export intensity three years after the devaluation. In Panel B, I focus on migration outflows instead of migration inflows and run an event-study specification analogous to Equation (3.3). In this specification, the variable of interest is the regional export intensity of the origins interacted with the event dummies and I control for destination-year fixed effects. I find migration outflows decreased by 4% when compared to another with a one standard deviation lower regional export intensity of origins three years after the devaluation.

4 Quantitative Framework

4.1 Model

Motivated by the empirical evidence, I develop a dynamic spatial general equilibrium model to quantify the aggregate effects of migration frictions on sectoral reallocation of labor after the large devaluation. Given that the devaluation was a transitory shock, understanding transitional dynamics is important.

4.1.1 Environment

The world is divided into Home and Foreign, which corresponds to Korea and the rest of the world. Home is a small open economy where it takes the world import price as given but faces downward-sloping demand for its products in the international market. There are $N+1$ regions. Home is composed of N regions, indexed by $n, m \in \mathcal{N} = \{1, \ldots, N\}$. There are J sectors, indexed by $j, k \in \mathcal{J} = \{1, \ldots, J\}$. Each region has different natural productivity across different sectors, and they are spatially linked through costly trade and migration. Internal and international trade are subject to iceberg trade costs. For a unit of any sector j variety good shipped from n to m $(n, m \in \mathcal{N} \cup \{F\})$, $d^j_{nm} \geq 1$ units has to be shipped. I normalize $d^j_{nn} = 1$, $\forall n \in \mathcal{N}$.

There are two types of infinitely-lived agents: workers and landlords. Both agents are forward-looking and have perfect foresight. Each worker has a continuum of members who supply labor inelastically. Each member has different amounts of labor efficiency units across sectors. A worker optimally allocates her members across different sectors based on sectoral wages and her members' labor efficiency units. The total labor income earned by each worker is the sum of wages earned by her members. Workers also make migration decisions subject to migration frictions. Workers live hand-to-mouth.

Landlords are geographically immobile and own capital stock in each region. They make forward-looking consumption and investment decisions in local capital stock that depreciates at a rate δ. Labor and capital markets are segmented across regions, and capital is freely mobile across sectors within regions. Population and capital (L_{nt}, K_{nt}) are state variables of the model, which are derived from the optimal forward-looking migration decisions of workers and investment decisions of landlords, respectively. I normalize the total population $L_t \equiv \sum_{n \in \mathcal{N}} L_{nt}$ to be one.

4.1.2 Production

Intermediate goods producer Each region n produces a unique sector j intermediate good (Armington, 1969). A representative intermediate good producer of each region-sector produces an intermediate good using labor and material inputs. Her output is produced using a Cobb-Douglas technology:

$$q_{njt} = A_{njt} H_{njt}^{\gamma_j^H} K_{njt}^{\gamma_j^K} \prod_{k=1}^{J} (M_{njt}^k)^{\gamma_j^k}, \qquad \gamma_j^H + \gamma_j^K + \sum_k \gamma_j^k = 1, \tag{4.1}$$

where A_{njt} is region-sector productivity, H_{njt} and K_{njt} are labor and capital inputs, M_{njt}^k is material input of sector k used by sector j, γ_j^H and γ_j^K are labor and capital shares, and γ_j^k is share of sector j goods spent on intermediate input from sector k. The value-added shares are the sum of the labor and capital shares: $\gamma_j^V \equiv \gamma_j^H + \gamma_j^K$. Under cost minimization, the unit cost of production is

$$c_{njt} = \frac{1}{A_{njt}} \left(\frac{W_{njt}}{\gamma_j^H} \right)^{\gamma_j^H} \left(\frac{r_{nt}}{\gamma_j^K} \right)^{\gamma_j^K} \prod_{k=1}^{J} \left(\frac{P_{nk,t}}{\gamma_j^k} \right)^{\gamma_j^k}, \tag{4.2}$$

where W_{njt} is region-sector wages, R_{nt} is a rental rate of local capital common within regions, and P_{njt} is the price of intermediate inputs.

Final goods producer Final goods are non-tradable, which can be used as material inputs and final consumption goods. Final goods are the CES aggregate of sector j intermediate goods of domestic regions (q_{njt}) and Foreign (q_{Fjt}):

$$Q_{njt} = \left(\sum_{m \in \mathcal{N}} q_{mjt}^{\frac{\sigma-1}{\sigma}} + q_{Fjt}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \tag{4.3}$$

where σ is the elasticity of substitution. Final goods market is perfectly competitive, and free entry ensures zero profits. The associated price index is

$$P_{njt}^{1-\sigma} = \sum_{m \in \mathcal{N}} (d_{mn}^j c_{mjt})^{1-\sigma} + (d_{Fn}^j P_{jt}^F)^{1-\sigma}, \tag{4.4}$$

where P_{jt}^F are import prices that are exogenous to the Home regions.

Trade Region n's sector j expenditure shares on intermediate goods from region m and Foreign are given by

$$\pi_{mnt}^j = \frac{(d_{mnt}^j c_{mjt})^{1-\sigma}}{\sum_{m' \in \mathcal{N}} (d_{m'n}^j c_{m'jt})^{1-\sigma} + (d_{Fn}^j P_{jt}^F)^{1-\sigma}} \text{ and } \pi_{Fnt}^j = \frac{(d_{Fn}^j P_{jt}^F)^{1-\sigma}}{\sum_{m \in \mathcal{N}} (d_{mn}^j c_{mjt})^{1-\sigma} + (d_{Fn}^j P_{jt}^F)^{1-\sigma}}. \tag{4.5}$$

Total sector j export values of region n are

$$EX_{njt} = (d^j_{nF} c_{njt})^{1-\sigma} D^F_{jt},$$

where D^F_{jt} are the Foreign market demands exogenous to Home.

4.1.3 Workers

Preferences Workers' preferences are Cobb-Douglas with expenditure shares α_j:

$$U(C_{nt}) = \ln C_{nt}, \qquad C_{nt} = \prod_{j \in \mathcal{J}} (C_{njt})^{\alpha_j}$$

where C_{nt} is region n workers' consumption at time t. The ideal price index is $P_{nt} = \prod_{j \in \mathcal{J}} (P_{njt}/\alpha_j)^{\alpha_j}$. The budget constraint is $P_{nt} C_{nt} = I_{nt}$, where I_{nt} is income earned by workers. Because workers are hand-to-mouth, they spend all of their labor income for consumption each period.

Sectoral labor supply Each worker is made up of a continuum of members with measure one, $i \in [0, 1]$. Sectoral labor supply is determined by workers' allocation of its members across sectors within regions. Each member is ex-ante identical but ex-post heterogeneous due to different ability draws across sectors. Members receive new draws every period after workers make migration decisions. Each member is characterized by ability vector $\boldsymbol{\epsilon}^i_t \equiv (\epsilon^i_{n1t}, \ldots, \epsilon^i_{nJt})$ where ϵ^i_{njt} is amounts of efficiency units of labor of member i that can be supplied to sector j.

I assume that skills of each member in region n are independently and identically drawn from a multivariate Frechét distribution across regions and time: $F_{nt}(\boldsymbol{\epsilon}_t) = exp(-\sum_{j \in \mathcal{J}} E_{njt} \epsilon^{-\theta}_{njt})$ with $\theta > 1$ (Eaton and Kortum, 2002; Lagakos and Waugh, 2016; Hsieh et al., 2019). θ is the shape parameter of the Frechét distribution that governs the dispersion of skills across members, with the higher value of θ corresponding to smaller dispersion. E_{njt} is the location parameter that varies at the region-sector-time level. E_{njt} can be interpreted as time-varying region-sector labor productivity. I introduce this labor productivity to account for rapid decreases in manufacturing employment shares but increases in manufacturing GDP shares around the sample period.[10] This pattern can be rationalized by decreases in labor productivity E_{njt} and increases in overall productivity A_{njt} of the manufacturing sectors. If I do not incorporate such trends, quantitative results may overstate the effects of migration frictions on labor reallocation to export-intensive manufacturing sectors after the devaluation.

Given sectoral wages, a worker allocates its available members across sectors to maximize the total sum of wages earned by her members. A worker allocates member i to sector j only if sector j generates the highest labor income over other sectors, that is, $\epsilon^i_{njt} \in \Omega_{njt}$, where $\Omega_{njt} = \{\boldsymbol{\epsilon}_t | W_{njt} \epsilon_{njt} \geq$

[10] Between 1995 and 2006, employment shares in the top 5 sectors decreased from 20 to 17% but their value-added shares to total GDP increased from 23 to 25% and their gross output shares to total gross output increased from 36 to 42%. Similar results also hold for the overall manufacturing sectors.

$W_{nkt}\epsilon_{nkt}, \forall k \in \mathcal{J}\}$. Shares of members allocated to sector j are expressed as:

$$\lambda_{njt} = \int_0^1 \left[\int_{\Omega_{njt}} dF_{njt}(\boldsymbol{\epsilon}_t^i) \right] di = \frac{E_{njt} W_{njt}^{\theta}}{\sum_{j'} E_{nj't} W_{nj't}^{\theta}}, \tag{4.6}$$

which is equal to the share of members whose earnings are the highest in sector j.

Labor supply of sector j in the unit of effective labor in region n is expressed as:[11]

$$H_{njt} = L_{nt} \int_0^1 \left[\int_{\Omega_{njt}} \epsilon_{njt}^i dF(\boldsymbol{\epsilon}_t^i) \right] di = \Gamma^1 \lambda_{njt}^{\frac{\theta-1}{\theta}} L_{nt}.$$

A labor supply curve is upward sloping and increases in W_{njt}. The total labor income of a worker in region n is the sum of wages across members:

$$W_{nt} = \int_0^1 \max_{j \in \mathcal{J}} \{W_{njt}\epsilon_{njt}^i\} di = \Gamma^1 \Big(\sum_{j \in \mathcal{J}} E_{njt} W_{njt}^{\theta} \Big)^{\frac{1}{\theta}}. \tag{4.7}$$

Migration At the end of each period, workers can migrate to another location where they work in the next period after they earn labor income and make consumption decisions in the current location. Migration frictions are measured in terms of utility. These costs are origin-destination specific and can be time-varying, represented by the bilateral cost matrix τ_{nmt}. Workers are forward-looking and discount the future with discount factor $\beta \in (0,1)$. Workers choose a region that gives the highest utility net of migration frictions. Workers have idiosyncratic preference shocks η_{nt} for each location, independently and identically distributed across workers, regions, and time.

The dynamic problem of workers is

$$\mathrm{v}_{nt} = \ln C_{nt} + \max_{m \in \mathcal{N}} \{\beta \mathbb{E}[\mathrm{v}_{m,t+1}] - \tau_{nmt} + \eta_{mt}\},$$

where v_{nt} is the lifetime utility of a household in region n and $\mathbb{E}[\mathrm{v}_{m,t+1}]$ is the future lifetime utility where the expectation is taken over realization of all future shocks. I assume that η_{mt} is distributed Type-1 Extreme Value with zero mean with the parameter ν.[12] Let $V_{nt} = \mathbb{E}_{\eta}[\mathrm{v}_{nt}]$, where the expectation is taken over the idiosyncratic preference shocks, which is life time expected utility before realization of the preference shocks. Under the distributional assumption, V_{nt} is expressed as:

$$V_{nt} = \ln C_{nt} + \nu \ln \sum_{m \in \mathcal{N}} exp(\beta V_{m,t+1} - \tau_{nmt})^{\frac{1}{\nu}}. \tag{4.8}$$

Equation (4.8) implies that the value of being in region n is the sum of the current utility and the option value of moving into other regions.

[11] Γ^1 is a constant defined as $\Gamma^1 \equiv \Gamma(1 - \frac{1}{\theta})$ where $\Gamma(\cdot)$ is the Gamma function.

[12] η_{mt} follows the Gumbel distribution with parameters, $(-\gamma\nu, \nu)$, where γ is Euler's constant.

The fraction of workers that migrate from region n to m at the end of time t admits the following closed form:

$$\mu_{nmt} = \frac{exp(\beta V_{m,t+1} - \tau_{nmt})^{\frac{1}{\nu}}}{\sum_{m' \in \mathcal{N}} exp(\beta V_{m',t+1} - \tau_{nm't})^{\frac{1}{\nu}}}. \tag{4.9}$$

The above expression indicates that all things equal, workers migrate more into regions with higher expected lifetime utility net of migration frictions, with the migration elasticity $1/\nu$. The migration elasticity governs how migration shares are sensitive to changes in expected lifetime utilities and migration frictions with the lower value corresponding to more persistent location choices. With the distribution of population, region n's population in the next period evolves as

$$L_{n,t+1} = \sum_{m \in \mathcal{N}} \mu_{mnt} L_{mt}. \tag{4.10}$$

I allow for trade imbalances by incorporating exogenous trade deficits. ι_t is an exogenous tax of workers that rationalizes trade deficits observed in the data and is common across regions. ι_t makes the ratio of per capital expenditure to per capital income to vary exogenously over time: $\iota_t \equiv \frac{\sum_{n \in \mathcal{N}} \sum_{j \in \mathcal{J}} IM_{njt} - EX_{njt}}{\sum_{n \in \mathcal{N}} W_{nt} L_{nt}}$ where IM_{njt} is sector j import values of region n. With exogenous trade deficits, workers' income is given as $I_{nt} = (1 + \iota_t) W_{nt}$.

4.1.4 Capital Accumulation

Landlords in each region can produce one unit of capital using one unit of final goods. They choose their consumption and investment to maximize their intertemporal utility:

$$\nu_{nt}^k = \mathbb{E}_t \sum_{s=0}^{\infty} \beta^{t+s} \frac{(C_{n,t+s}^k)^{1-1/\psi}}{1 - 1/\psi}, \tag{4.11}$$

subject to the budget constraint: $r_{nt} K_{nt} = P_{nt}(C_{nt}^k + K_{n,t+1} - (1-\delta) K_{nt})$ where r_{nt} is the rental rate of capital. $r_{nt} K_{nt}$ is the total income from the existing capital stock. $P_{nt} C_{nt}^k$ is the total value of their consumption and $P_{nt}(K_{n,t+1} - (1-\delta) K_{nt})$ is the total value of their investment.

Their optimal investment decisions are characterized by the following law of motion for capital:

$$K_{n,t+1} = (1 - \zeta_{nt}) R_{nt} K_{nt}, \tag{4.12}$$

where $R_{nt} \equiv 1 - \delta + r_{nt}/P_{nt}$ and ζ_{nt} is recursively defined as

$$\zeta_{nt}^{-1} = 1 + \beta^{\psi} \left(R_{n,t+1}^{\frac{\psi-1}{\psi}} \zeta_{nt}^{-\frac{1}{\psi}} \right)^{\psi}.$$

R_{nt} is the gross return on capital, so landlords save the fraction of $(1 - \zeta_{nt})$ out of current period wealth $R_{nt} K_{nt}$. The optimal consumption of region n's landlords satisfies $C_{nt}^k = \zeta_{nt} R_{nt} K_{nt}$.

4.1.5 General Equilibrium

Market clearing Goods market clearing of final goods requires that

$$GO_{njt} = \sum_{m \in \mathcal{N}} \pi^j_{mnt} \left[\sum_{k=1}^{J} \gamma^j_k GO_{mkt} + \alpha_j((1+\iota_t)W_{mt}L_{mt} + r_{mt}K_{mt}) \right] + EX_{njt}, \tag{4.13}$$

where GO_{njt} is region n's total sales of sector j intermediate goods. The term inside the bracket is region m's total expenditure on sector j goods. Labor market clearing condition is

$$W_{njt}H_{njt} = \gamma^H_j GO_{njt}. \tag{4.14}$$

Capital market clearing requires that landlords' capital income equal rental payments for its use. Cost-minimization of intermediate goods producers and the zero profit condition imply that the capital market clearing condition is

$$r_{nt} = \frac{\sum_{j \in \mathcal{J}} (\gamma^K_j / \gamma^L_j) W_{njt} H_{njt}}{K_{nt}}. \tag{4.15}$$

Equilibrium Let $\mathbf{\Psi}_t = \{A_{njt},\ P^F_{jt},\ D^F_{jt},\ \iota_t, E_{njt}\}$. Given the state variables $\{L_{nt}, K_{nt}\}$ and $\mathbf{\Psi}_t$, allocation in each period is determined as in a static trade and spatial model. The population and capital stock evolve according to the optimal migration and investment decisions of workers and landlords. I formally define the equilibrium as follows:

Definition 1. *Given the parameters of the model, $\{\mathbf{\Psi}_t\}^\infty_{t=t_0}$, $\{\tau_{nmt}\}^\infty_{t=t_0}$, and initial allocations of the state variables $\{L_{nt_0}, K_{nt_0}\}$, the competitive equilibrium of the model is the set of population, sectoral allocation of members, wages, expected lifetime utilities, rental rate of capital, and capital stock $\{L_{nt},\ \lambda_{njt},\ W_{njt},\ V_{nt},\ r_{nt},\ K_{n,t+1}\}^\infty_{t=t_0}$ that satisfies the following condition for each region n, each sector j, and all time periods t: (i) Given W_{njt}, a worker optimally allocates her members across different sectors (Equation (4.6)); (ii) $\{V_{nt}\}$ satisfies Equation (4.8); (iii) L_{nt} evolves according to Equation (4.10); (iv) $\{K_{n,t+1}\}$ evolves according to Equation (4.12); (v) goods, labor, and capital market clearing conditions are satisfied (Equations (4.13), (4.14), and (4.15)).*

4.2 Devaluation and Sectoral Reallocation

I model the devaluation as four time-varying exogenous shocks $\{A_{njt}, D^F_{jt}, P^F_{jt}, \iota_t\}$ in a reduced-form fashion that capture common features of emerging market economies after devaluation episodes: Decreases in A_{njt} rationalize large TFP drops; increases in D^F_{jt} (P^F_{jt}) large increases (decreases) in exports (imports) due to depreciated real exchange rates; and ι_t rapid decreases in trade deficits.

These four devaluation shocks affect workers' sectoral labor supply and migration decisions, and therefore sectoral reallocation of labor at both regional and aggregate levels. The total amounts of members working in sector j in region n (L_{njt}) is given by:

$$L_{njt} = \underbrace{\lambda_{njt}}_{\substack{\theta\text{ : Sectoral reallocation}\\ \text{within regions}}} \times \underbrace{\sum_{m \in \mathcal{N}} \mu_{nm,t-1} L_{m,t-1}}_{\substack{1/\nu\text{ : Spatial reallocation}\\ \text{across regions}}} . \tag{4.16}$$

Both θ and $1/\nu$ govern two conceptually distinct decisions of workers on which sector to work (sectoral labor supply) and where to live (migration), respectively.[13] θ governs changes in region-sector employment shares conditional regional population in time t, related to the first empirical finding. $1/\nu$ governs the evolution of regional population through migration flows, related to the second empirical finding.

4.3 Counterfactual

I examine how amounts of sectoral reallocation and transition path of the baseline economy would have differed from the counterfactual economies with different migration friction levels after the devaluation. Our counterfactuals consider hypothetical reductions in migration frictions rather than specific migration policies.

To perform counterfactuals and solve for transition paths, I utilize a dynamic hat algebra developed Caliendo et al. (2019). For any variable x, I denote time differences as $\hat{x}_{t+1} = x_{t+1}/x_t$. To perform counterfactuals, I require the initial allocation in 1997; the exogenous shocks; structural parameters including sectoral labor supply and migration elasticities (θ and $1/\nu$); and migration friction shocks ($\hat{m}_{nmt} \equiv \exp(\tau_{nm,t+1} - \tau_{nmt})$).

For the baseline, I assume there are no changes in migration frictions and feed in the exogenous shocks $\hat{\mathbf{\Psi}}_t$ and compute the transition path of the economy. Given that my focus is the transitory effects of migration frictions on transition paths after the devaluation, I consider the counterfactual economies in which their migration frictions only temporarily differ from those of the baseline only up to five years and move back to the original level six years after the devaluation. To do so, I feed in transitory migration friction shocks jointly with $\hat{\mathbf{\Psi}}_t$ and compute transition paths of the counterfactual economies. More precisely, these transitory migration friction shocks occur when the devaluation occurred in 1998: $\hat{m}^c_{mn,98} = exp(\tau^c_{nm} - \tau_{nm,98})$ where τ^c_{nm} is the counterfactual friction level. These frictions are held constant between 1999 and 2002 and set back to the original level in 2003: $\hat{m}^c_{nmt} = 1$ for $t \in \{99, 00, 01, 02\}$ and $\hat{m}^c_{nm,03} = 1/\hat{m}^c_{nm,98}$. Below I also conduct robustness checks by setting these changes in migration frictions to be permanent.

[13] Alternatively, I can model workers to make migration decisions from one region-sector to other region-sectors similar to Caliendo et al. (2019). Such modeling requires data on transitions between region-sectors and frictions of reallocating across different sectors can be inferred from the observed sector-to-sector transition flows combined with the model. However, unlike the model of Caliendo et al. (2019) where workers' decisions are governed by a single elasticity, workers' decisions in my model are governed by two elasticities.

Table 1: Summary of Calibration

Parameters	Value	Description	Target
Elasticities			
$1/\nu$	0.7	Migration elasticity	IV estimates, Equation (4.17)
θ	1.3	Sectoral labor supply elasticity	IV estimates, Equation (4.19)
σ	6	Elasticity of substitution	Costinot and Rodríguez-Clare (2014)
Geographic Frictions			
$\{\xi_j\}$	0.26, 0.4	Trade cost	Monte et al. (2018), Eckert (2019)
Shocks			
$\{A_{njt}\}$		Productivity shock	Gross output, PPI
$\{D^F_{jt}\}$		Foreign demand shock	Aggregate exports
$\{P^F_{jt}\}$		Import price shock	Aggregate imports
Preferences			
β	0.96	Discount factor	Literature
$\{\alpha_j\}$		Final consumption shares	IO table
Production			
$\{\gamma^k_j\}$		IO coefficients	IO table
$\{\gamma^V_j\}$		Value-added shares	IO table
$\{\gamma^H_j/\gamma^V_j\}$	0.66	Labor share	Literature
δ	0.05	Depreciation rate	Literature

Notes. This table summarizes the calibration results.

4.4 Taking the Model to the Data

This section discusses the calibration procedure for the structural parameters, the initial allocation in 1997 one year before the devaluation, the exogenous shocks, and migration friction shocks. I aggregated 121 regions up to 54 regions for the quantitative analysis based on their electoral district and industrial composition, so that each region has positive employment shares for 15 sectors and all region-to-region migration flows are positive. Table 1 reports a summary of the calibration procedure. See Appendix Section C for detail.

4.4.1 Initial Allocation

I need the initial allocation of $\{GO_{njt_0}, \lambda_{njt_0}, \mu_{nmt_{-1}}, L_{nt_0}, K_{nt_0}, K_{n,t_0+1}, EX_{njt_0}, \pi^j_{nmt_0}, \pi^j_{Fnt_0}\}$ to apply the dynamic hat algebra. I obtain region-sector employment shares, gross output, and real capital stock, and region-to-region migration shares from the data described in Section 2. Region-sector exports and imports and region-to-region trade flows are not directly observable from the data. Therefore, I indirectly infer these variables from sectoral exports and imports, region-sector gross output, and the gravity structure of trade.[14]

4.4.2 Structural Parameters

Sectoral labor supply elasticity From Equation (4.6), I can derive the following estimable regression model:

$$\ln \lambda_{njt} = \theta \ln W_{njt} + \delta_{nj} + \delta_{nt} + \delta_{jt} + \tilde{e}_{njt}. \tag{4.17}$$

$\tilde{e}_{njt}$ is the structural error term that is a function of labor productivity E_{njt}.[15] I obtain data on region-sector nominal wages W_{njt} from the Mining and Manufacturing Survey. Because this survey only covers establishments of the mining and manufacturing sectors, I run the above regression only for the mining and manufacturing sectors. δ_{nj}, δ_{nt}, and δ_{nj} are region-sector, region-year, and sector-year fixed effects. δ_{nt} absorb region n's average wage W_{nt}. I cluster standard errors at the region-sector level.

Equation (4.17) suffers from the endogeneity problem because wages are correlated with labor productivity shocks of the structural error term. To deal with the endogeneity problem, I estimate the equation using the following IV:

$$RegEX_{nt_0} \times SecEX_{jt_0} \times \mathbb{1}[t \geq 1998]. \tag{4.18}$$

The IV exploits relatively higher demand shocks for more export-intensive sectors (higher $SecEX_{jt_0}$) in more export-oriented regions (higher $RegEX_{nt_0}$) due to increased exports after the devaluation, supported by the first empirical evidence (Figure 2). The identifying assumption is that the differential demand shocks due to the devaluation are uncorrelated with time-varying region-sector labor productivity shocks conditional on fixed effects and controls.

To use the data more efficiently, I estimate Equation (4.17) using overlapping 3-year long-differences: 1996-1999 and 1997-2000. The estimated coefficient is 1.34 and statistically significant at 5%. The first stage F-statistics is 9.4, which is below the rule of thumb value of 10. Therefore, I conduct inference based on the Anderson-Rubin (AR) statistic that is robust to weak instruments following the recommendation of Andrews et al. (2019). The AR statistic also rejects the null at 1% and its 95% confidence interval covers the estimated value of 1.34. The estimated value of 1.34 is also in line with the previous estimates in the literature.[16]

[14]Under the gravity structure, there exists a unique set of trade shares that rationalize observed region-sector gross output and sectoral exports and imports (Allen et al., 2020). Gervais and Jensen (2019) and Eckert (2019) also indirectly infer trade flows using region-sector gross output (or value-added) and the gravity structure of trade.

[15]See Appendix Section C.1 for derivation and estimation procedure in detail.

[16]For example, Burstein et al. (2019) report values of 1.26–1.81, Hsieh et al. (2019) of 1.5–2.6, Lee (2020) of 1.05–1.47, and Galle et al. (2022) of 2.

Migration elasticity Following Artuc et al. (2010), I can derive the following regression model[17]:

$$\ln \frac{\mu_{nmt}}{\mu_{nnt}} = \frac{\beta}{\nu} ln \frac{I_{mt}/P_{mt}}{I_{nt}/P_{nt}} + \beta \ln \frac{\mu_{nm,t+1}}{\mu_{mm,t+1}} + \delta_{nm} + \delta_t + \tilde{\epsilon}_{nmt}. \tag{4.19}$$

δ_{nm} and δ_t are pair and year fixed effects. $\tilde{\epsilon}_{nmt}$ is the structural error term that is a function of migration friction shocks.

To run the above regression, I need data on I_{nt} and P_{nt}. After imposing that labor shares of value-added are 0.66 constant across regions and sectors as standard in the literature, I calculate I_{nt} by dividing the labor share of the total sum of the value-added across sectors in region n by the total number of the employed multiplied by observed $(1 + \iota_t)$ that rationalizes trade deficits.[18] Regional price levels P_{nt} are obtained from the regional Consumer Price Index (CPI) data. The Korean statistical agency only reports CPI data of the selected regions, so I impute regional CPI data for regions with missing information using housing price data available for all regions following Moretti (2017).[19]

Because differences in real income are correlated with shocks to migration frictions, this regression model also suffers from the endogeneity problem. Therefore, similar to Equation (4.18), I estimate the regression model using the following IV:

$$(RegEX_{mt_0} - RegEX_{nt_0}) \times \mathbb{1}[t \geq 1998]. \tag{4.20}$$

The identifying assumption of the IV holds when migration frictions shocks are uncorrelated with the differences in regional demand shocks due to increased exports after the devaluation. I estimate Equation (4.19) in first differences for the sample period between 1997 and 2000. The estimated coefficient is 0.69 and is statistically significant at 1% level. With the assumed value of the discount factor, this estimate implies $1/\nu$ is around 0.7 which is in line with the estimates from the previous papers.[20]

Trade costs I parametrize domestic bilateral trade costs as a function of physical distance: $d^j_{nm} = (dist_{nm})^{\xi_j}$ where $dist_{nm}$ is distance between regions and ξ_j are parameters that potentially vary

[17] The expression captures that current migration flows reflect the futures values of expected real income and the option values, where the future migration flows are the sufficient statistics for the option values. Conditioning on the option values, the variation of wage differences across regions identify the migration elasticity $1/\nu$.

[18] Specifically, I construction regional workers' income as follows: $I_{nt} = 0.66 \times (1 + \iota_t) \times \sum_{j \in \mathcal{J}} VA_{njt}$ where VA_{njt} is sector j's value-added in region n. Because 0.66 and $(1 + \iota_t)$ are common across regions, they are absorbed out by year fixed effects.

[19] One concern with using CPI in this regression is that CPI is comparable across times within regions but not cross-sectionally across regions because CPI is normalized to be one in the base year which is 1992 in the data set. However, controlling for δ_{nm} makes the cross-sectional comparisons available by absorbing out the differences in price levels of the base year under the log utility function. Specifically, $P_{nt} = (P_{nt}/P_{n,92}) \times P_{n,92}$ holds and the CPI data only records $(P_{nt}/P_{n,92})$ but not $P_{n,92}$. Under the log utility, $\ln P_{m,92}/P_{n,92}$ are absorbed by δ_{nm}.

[20] Among many previous papers that estimated migration elasticity, Caliendo et al. (2021) report a value of 0.5 and Caliendo et al. (2019) of 0.2 at the quarterly frequency.

across sectors. I set $(\sigma-1)\xi_j$ to be 1.29 for commodity and manufacturing sectors and 2 for service sectors based on the estimates from Monte et al. (2018) and Eckert (2019), respectively. I parametrize international trade cost $d^j_{Fn} = (pdist_n)^{\xi_j}$ where $pdist_n$ is the minimum distance to port of region n. International trade costs that are common across regions are not separately identifiable from P^F_{jt} and D^F_{jt}, so d^j_{Fn} are interpreted as the costs relative to those of regions with ports.

Remaining parameters I obtain value-added shares, input-output coefficients, and final consumption good shares from the WIOD. I set the shares of labor in value-added to be 0.66. I assume a trade elasticity $\sigma-1=5$ following Costinot and Rodríguez-Clare (2014). I set the 1-year discount factor β and depreciation rate to the conventional values 0.96 and 0.05.

4.4.3 Shocks

I back out five time-varying exogenous shocks $\hat{\mathbf{\Psi}}_t$ by fitting the model to the data between 1997 and 2002 following the inversion logic (Allen and Arkolakis, 2014). Productivity shocks are identified from gross output and sectoral producer price indices (PPI); foreign demand shocks from aggregate exports; foreign import price shocks from aggregate imports; and labor productivity shocks from region-sector employment shares.[21] Trade deficits are taken directly from the data.

Figure 4 presents the weighted average of the three devaluation shocks: productivity, foreign demands, and import price shocks, where the weights are given by region-sector gross output, sectoral imports, and sectoral exports of the previous period, respectively. When the large devaluation occurred in 1998, the average productivity, foreign demands, and import prices decreased by 6.8%, increased by 19%, and increased by 7.5%, relative to 1997. There were decreasing trends in labor productivity of the manufacturing sectors that account for decreasing trends in the manufacturing employment shares of the data.

4.4.4 Migration Frictions

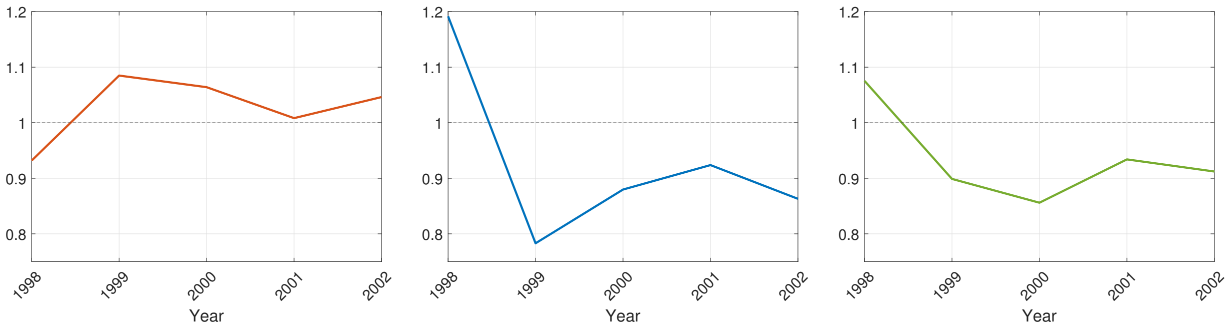
Following Head and Ries (2001), I infer migration frictions from the observed migration flows after imposing the symmetry ($\tau_{mnt} = \tau_{nmt}$, $\forall n, m \in \mathcal{N}$):

$$\mathfrak{m}_{nmt} \equiv exp(\tau_{nmt})^{\frac{1}{\nu}} = \left(\frac{\mu_{nmt}\mu_{mnt}}{\mu_{nnt}\mu_{mmt}}\right)^{0.5}, \tag{4.21}$$

where $\mathfrak{m}_{nmt}$ captures the ease of migration in year t. I compute $\mathfrak{m}_{nmt}$ between 1997 and 2017 and find that there were reductions in migration frictions on average between these periods. At the 50th and 75th, there was a reduction by 11 and 28%, respectively.[22] In Appendix Section C.6, I also show that these backed-out frictions are highly correlated with observed proxies for migration frictions

[21] E_{njt} are identified up to normalization within each region, so I normalize E_{njt} of the reference sector to be one for all regions and periods.

[22] The magnitude of 11 and 28% is consistent with Monte et al. (2018) who find that there were a 12 and 21% reduction at the 50 and 75th of the empirical distribution of commuting cost changes in the US between 1990 and 2010.



A. Productivity $\hat{A}_{njt}$ B. Foreign demand $(\hat{D}^F_{jt})^{\frac{1}{\sigma-1}}$ C. Import price $\hat{P}^F_{jt}$

Figure 4. Backed Out Shocks

Notes. The figure presents the weighted average of the shocks. The weights are given by region-sector gross output, sectoral imports, and sectoral exports of the previous period for productivity, import price, and foreign demand shocks, respectively. See Appendix Section C.5 for the calibration procedure in more detail.

such as the Euclidean distance and a proxy for regional conflicts.

Using these calculated $\mathfrak{m}_{nmt}$ and the estimated value of ν, I compute counterfactual changes in migration frictions for each region-to-region pair:

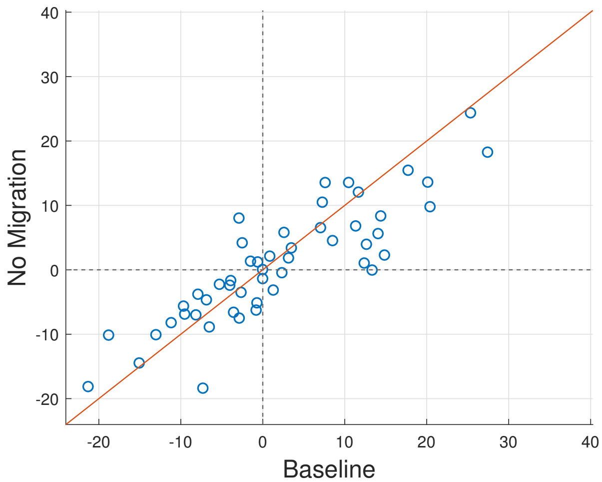
$$\hat{m}^c_{mnt} \equiv (\hat{\mathfrak{m}}^c_{nmt})^{\nu} = exp(\tau^c_{nmt} - \tau_{nmt}), \tag{4.22}$$

where τ^c_{nmt} is the counterfactual migration friction. I consider three counterfactual scenarios. In the first scenario, migration is not allowed. In the remaining two scenarios, following Monte et al. (2018), I use the distribution of the inferred $\hat{\mathfrak{m}}_{nmt}$ to conduct counterfactuals for empirically realistic changes in migration frictions. I consider a common decrease by the 50th and 75th percentile of the observed changes between 1997 and 2017 across all regions. In all the counterfactual scenarios, migration frictions move back to the original level in 2003.

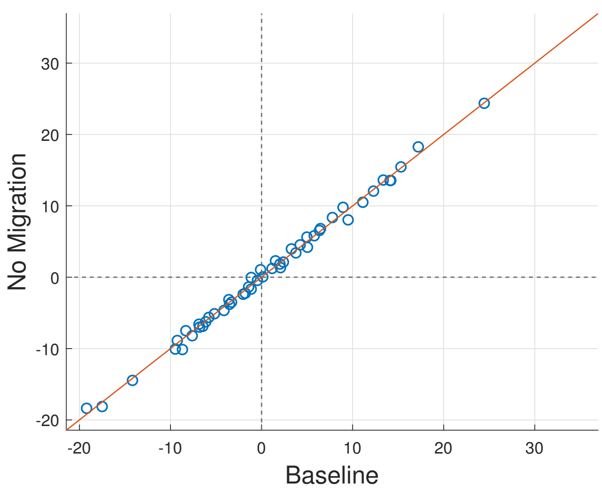
4.5 Quantitative Results

Table 2 reports the aggregate top 5 employment shares, top 5 export intensity, and overall export intensity three years after the devaluation.[23] Column (1) reports the results of the baseline economy. In the baseline with no changes in migration frictions, the aggregate top 5 employment shares, top 5 export intensity, and overall export intensity are 18.47, 34.85, and 17.19%, respectively. In column (2), where migration is temporarily not allowed, these aggregate outcomes are 1.3, 1.0, and 1.4% lower than those in the baseline. In columns (3) and (4), I consider temporary decreases in migration frictions based on the empirically observed reductions. With the temporary decrease by the 50th and

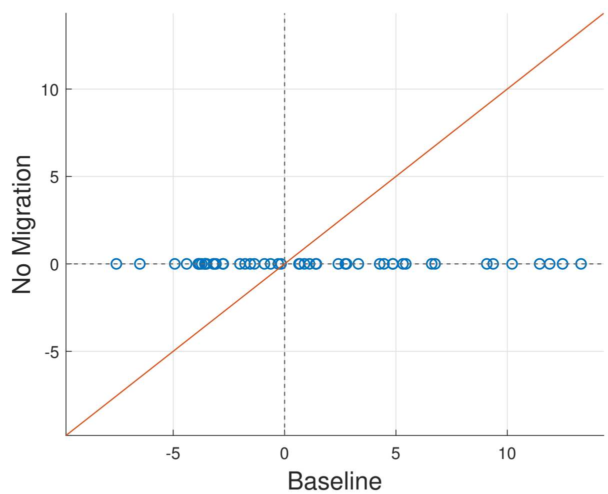
[23]Because I normalize the total population to be one, the aggregate top 5 employment shares are equivalent to the aggregate top 5 employment.



A. Growth of the top 5 employment



B. Growth of the top 5 employment shares



C. Growth of population

Figure 5. Baseline vs. No Migration Counterfactual

Notes. Panels A, B, and C report the growth of the top 5 employment, the top 5 employment shares, and the population between 1997 and 2000. Each dot represents a region. X- and y-axes are the baseline and the no-migration counterfactual economies. The red line is the 45-degree line.

Table 2: Aggregate Effects of Migration Frictions

	Baseline	No migration	Decrease by p50	Decrease by p75
	(1)	(2)	(3)	(4)
Top 5 emp. shares (%)	18.4	18.2	18.6	18.8
Top 5 export intensity (%)	34.9	34.5	35.1	35.6
Overall export intensity (%)	17.2	17.0	17.4	17.7

Notes. Column (1) reports the results of the baseline economy. Column (2) reports the counterfactual economy in which migration is not allowed. Columns (3) and (4) report the results of the counterfactual economies where migration frictions decrease by the p50 and p75 of the empirical distribution, respectively. The first, second, and third rows report the aggregate-level employment shares in the top 5 sectors, the aggregate export intensity of the top 5 sectors, and the overall export intensity, respectively. These results are based on the calibrated values reported in Table 1.

Table 3: Regional Effects of Migration Frictions

	Baseline	No migration	Decrease by p50	Decrease by p75
$\triangle \ln y_{nt} = \beta^{reg} RegEX_{nt_0} + \epsilon_{nt}$	(1)	(2)	(3)	(4)
Growth top 5 emp.	8.7	6.3	9.8	11.8
Growth pop.	2.7	0	3.9	6.1
Growth top 5 emp. shares	6.0	6.3	5.9	5.7

Notes. The table reports the estimated coefficients of β^{reg} from the regression model $\triangle \ln y_{nt} = \beta^{reg} RegEX_{nt_0} + \epsilon_{nt}$ where $RegEX_{nt_0}$ is the standardized regional export intensity defined in Equation (3.1). Column (1) reports the results of the baseline economy. Column (2) reports the counterfactual economy in which migration is not allowed. Columns (3) and (4) report the results of the counterfactual economies where migration frictions decrease by the p50 and p75 of the empirical distribution, respectively. In the first, second, and third rows, the results for the top5 total employment, total population, the top 5 employment shares are reported, respectively. These results are based on the calibrated values reported in Table 1.

75th in columns (3) and (4), these aggregate outcomes are 1.2, 0.6, and 1.1%, and 2.2, 2, and 2.9% higher than those in the baseline, respectively.

The aggregate effects of migration frictions of Table 2 are driven by migration of workers to more export-oriented regions. I regress the growth rate of regional outcomes of interest between 1997 and

2000 on the standardized regional export intensity defined in Equation (3.1):

$$\triangle \ln y_{nt} = \beta^{reg} RegEX_{nt_0} + \epsilon_{nt}$$

and report the estimated $\hat{\beta}^{reg}$. β^{reg} can be interpreted as changes in growth rate when the regional export intensity is a one standard deviation higher. I consider the regional growth of the top 5 employment, the population, and the top 5 employment shares.

Table 3 reports the results. In all baseline and counterfactual economies, the estimated coefficients are positive for the three variables, implying that regions with higher $RegEX_{nt_0}$ tend to experience relatively higher growth in these three variables. However, the magnitude of the coefficients differs across the economies depending on levels of migration frictions. With lower migration frictions, there are larger increases in population and employment in the top 5 sectors in regions with higher $RegEX_{nt_0}$ due to increased migration. These results are reflected by higher $\hat{\beta}^{reg}$ with lower migration frictions for the top 5 employment and the population. However, at the same time, the increased migration inflows increase labor supply in these regions and therefore decrease wages and the top 5 employment shares, reflected by lower $\hat{\beta}^{reg}$ with lower migration frictions for the top 5 employment shares.

Figure 5 illustrates the regional growth of the top 5 employment, the population, and the top 5 employment shares under the baseline and the counterfactual where migration is not allowed. There are large variation in the growth of the top 5 employment between these two economies (Panel A). Because $L_{njt} = \lambda_{njt} L_{nt}$, the variation in the growth of the top 5 employment can come from the variation in the top 5 employment shares (λ_{njt}) or population (L_{nt}). The figure shows that most of the variation in the top 5 employment comes from the variation in population rather than those in the top 5 employment shares (Panels B and C). The variation in the top 5 employment shares explains about 1.1% of the total variation in the top 5 employment growth.[24]

I conduct robustness analysis with different values of elasticity of substitution σ, sectoral labor supply elasticity θ, and migration elasticity $1/\nu$. I also conduct robustness analysis that feeds permanent migration friction shocks instead of the temporary shocks. Appendix Tables C7 and C8 report the results. The quantitative results are robust to different values of the parameters and the permanent migration friction shocks.

5 Conclusion

This paper studies the role of internal migration and its frictions on sectoral reallocation of labor after the 1998 Korean devaluation. Using cross-sectional variation in industrial composition and event-study specifications, I provide empirical evidence that relative increases in reallocation of labor to

[24] The variation in the top 5 employment growth can be expressed as $Var(\ln L^{b,t5}_{nt}/L^{c,t5}_{nt}) = Var(\ln \lambda^{b,t5}_{nt}/\lambda^{c,t5}_{nt}) + Var(\ln L^{b}_{nt}/L^{c}_{nt}) + 2 \times Cov(\ln L^{b}_{nt}/L^{c}_{nt}, \ln \lambda^{b,t5}_{nt}/\lambda^{c,t5}_{nt})$ where L^{t5}_{nt} and π^{t5}_{nt} are the top 5 employment and the top 5 employment shares and subscripts b and c denote for the baseline and the counterfactual economies.

more export-intensive sectors and to more export-oriented regions. This empirical evidence motivates that sectoral and spatial reallocation of labor could have been interlinked.

I build the dynamic spatial general equilibrium model to quantify the effects of migration frictions on short-run adjustment of labor. I infer migration frictions from the observed migration flows and compute the empirical distribution of changes in migration frictions between 1997 and 2017. I use this distribution to conduct counterfactual analysis. When migration is not allowed, aggregate employment shares and export intensity of the top five most export-intensive sectors would have decreased by 1.1 and 1.2%, respectively. With reductions in migration frictions for all regions by the median of the empirical distribution, I find that these aggregate outcomes would have decreased by 1.2 and 0.6%. These findings suggest that spatial linkages across factor markets can affect how an economy adjusts to large sector-specific shocks at the aggregate level.

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ONLINE APPENDIX

(NOT FOR PUBLICATION)

A Appendix: Data

A.1 Data Construction

Region-sector employment I use the Census on Establishment to construct region-sector employment shares. The Census on Establishment covers the universe of formal establishments with one or more employees except for agriculture, forestry, and fisheries businesses by individual owners and establishments related to national defense, housekeeping services, and international and foreign organizations. On average, approximately 2.9 million establishments are covered by the data set across the sample period from 1994 to 2002. The data set has information on geographical location, sectors, and employment of establishments. I convert Korean Sector Industry Code (KSIC) to ISIC Rev 3.

Region-sector gross output In order to construct region-sector gross output, I combine three main data sets: (i) state-sector gross output obtained from the Statistics Korea, (ii) the WIOD IO tables, and (iii) the Census of Establishment. From the WIOD IO tables, I obtain country-level sectoral gross output. I allocate this sectoral gross output across sectors using the state-sector gross output. There are 16 states. Then, I allocate state-sector gross output across regions using the region-sector employment shares obtained from the Census of Establishment. More specifically, region-sector gross output is calculated as follows:

$$GO_{njt} = \tilde{\omega}_{n(s)jt} \times \tilde{\omega}_{s(n)jt} \times GO_{jt}.$$

GO_{jt} is sector j's gross output obtained from the WIOD. $s(n)$ denotes for a state in which region n is located. $\tilde{\omega}_{s(n)jt}$ is a share of sector j gross output of state $s(n)$ to total sector j gross output:

$$\tilde{\omega}_{sjt} = \frac{GO_{sjt}}{\sum\limits_{s' \in \mathcal{S}} GO_{s'jt}},$$

where $\mathcal{S}$ is the set of states. $\tilde{\omega}_{n(s)jt}$ is a share of sector j employment of region n to total sector j employment of state s in which region n is located:

$$\tilde{\omega}_{njt} = \frac{Emp_{njt}}{\sum\limits_{n' \in s(n)} Emp_{njt}}.$$

Region-sector real capital stock To construct region-sector real capital stock series, I combine the four data sets: the Census of Establishment, the Mining and Manufacturing Survey, WIOD Socio Economic Accounts (WIOD-SEA), and IMF Investment and Capital Stock Database (IMF-ICSD). I first allocate the aggregate real capital stock from the IMF-ICSD using country-sector level nominal capital stock shares from the WIOD-SEA:

$$K_{jt} = \tilde{\omega}_{jt}^{K} \times K_t,$$

where K_t is the aggregate real capital stock and $\tilde{\omega}_{jt}^{K}$ is a share of sector j nominal capital stock to the total nominal capital stock across sectors.

Using the Mining and Manufacturing Survey that has information on nominal fixed assets of manufacturing establishments, I calculate region-sector fixed asset shares:

$$\tilde{\omega}_{njt}^{K} = \frac{\text{FAssets}_{njt}}{\sum_{n' \in \mathcal{N}} \text{FAssets}_{n'jt}},$$

where FAssets_{njt} is the sum of fixed assets of sector j establishments in region n. Then, I allocate region-sector real capital stock using these computed shares: $K_{njt} = \tilde{\omega}_{njt}^{K} \times K_{jt}$. For the non-manufacturing sectors, I do not have information on region-sector level fixed assets. Therefore, for these non-manufacturing sectors, I use region-sector employment shares to allocate region-sector real capital stock.

Region-to-region migration flows I construct region-to-region migration flows using the internal migration and population data sets obtained from the Statistics Korea. Migration flows are calculated as the total number of migrants between origin and destination regions divided by lagged populations of origin regions. Own migrants are calculated as the lagged population minus the sum of migrants to other regions. Given that my focus is the working population, I restrict the samples of populations and migration flows to people aged between 20 and 55 years.

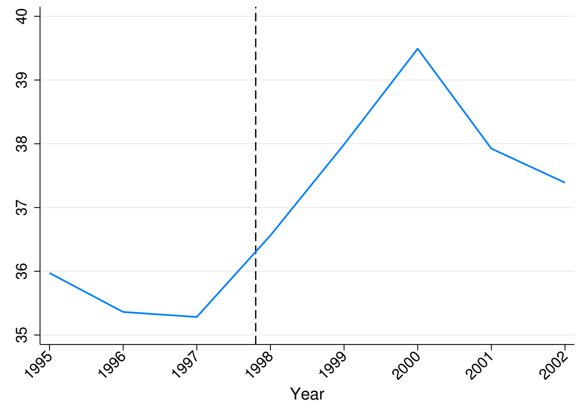
Sectoral imports and exports Sectoral imports and exports are obtained from the World Input-Output Database (WIOD).

Sector classification I categorize sectors into 15 sectors. This grouping is reported in Table A4.

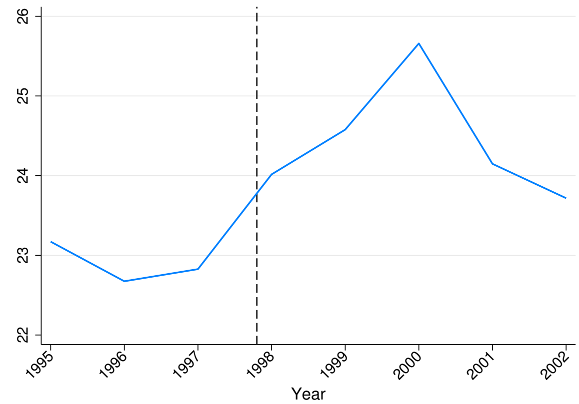
Table A4: Sector Classification

Aggregated Industry	Industry
1. Commodity	Agriculture, hunting and forestry (A), Fishing (B) Mining and quarrying (C)
2. Food, Beverages, and Tobacco	Food products and beverages (15), Tobacco products (16)
3. Textiles, Apparel, & Leather	Textiles (17), Apparel (18) Leather, luggage, handbags, saddlery, harness, and footwear (19)
4. Wood, Paper & Printing	Wood and of products, cork (20) Paper and paper products (21) Publishing and printing (22)
5. Chemicals, Petrochemicals, and Rubber and Plastic Products	Coke, refined petroleum products and nuclear fuel (23) Chemicals and chemical products (24) Rubber and plastics products (25)
6. Non-Metallic Mineral Products	Other non-metallic mineral products (26)
7. Basic and Fabricated Metals	Basic metals (27), Fabricated metals (28)
8. Electrical Equipment	Office, accounting and computing machinery (30) Electrical machinery and apparatus n.e.c. (31) Ratio, television and communication equipment and apparatus (32) Medical, precision, and optical instruments, watches and clocks (33)
9. Machinery and Transport Equipment	Machinery and equipment n.e.c. (29) Motor vehicles, trailers and semi trailers (34) Other transport equipment (35)
10. Manufacturing n.e.c.	Manufacturing n.e.c. (36), Recycling (37)
11. Utilities	Electricity, gas and water supply (E)
12. Construction	Construction (F)
13. Whole and Retail	Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods (G)
14. Transport Service	Land transport; transport via pipelines (60) Water transport (61), Air transport (62) Supporting and auxiliary transport activities; activities of travel agencies (63)
15. Other Service	Hotels and restaurants (H) Post and telecommunications (64), Financial intermediation (J) Real estate, renting and business activities (K) Public administration and defense (L); compulsory social security (L) Education (M), Health and social work (N) Other community, social and personal service activities (O) Activities of private households as employers and undifferentiated production activities of private households (P)

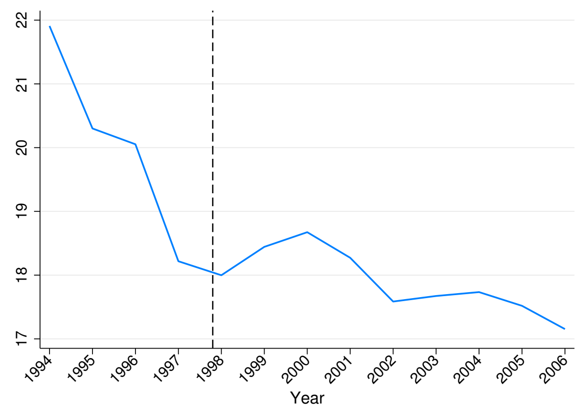
Note. The codes inside the parenthesis denote for ISIC rev 3.1. industry codes.



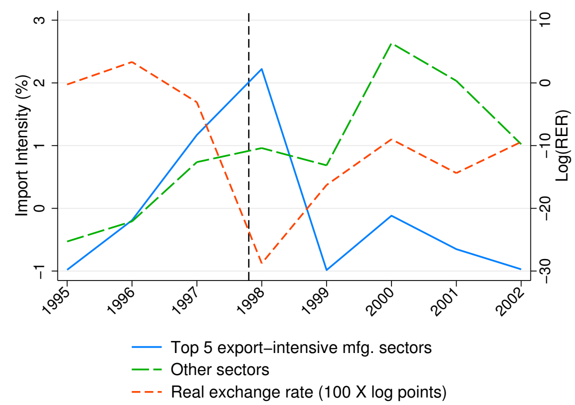
A. Top 5 gross output shares (%)



B. Top 5 value-added shares (%)



C. Top 5 emp. shares (%)



D. Import intensity (%)

Figure A6. Aggregate Patterns after the Devaluation

Notes. Panels A, B, and C plot aggregate gross output, value-added, and employment shares of the top 5 sectors. Panel D plots import intensity defined as shares of total import values of the intermediate inputs to total costs of the top 5 sectors and the other sectors.

B Appendix: Theory

B.1 Landlords' Intertemporal Utility Maximization Problem

Landlords' utility maximization problem can be written as:

$$\max_{C^k_{ns},K_{n,s+1}} \sum_{s=t}^{\infty} \beta^{t+s} U(C^k_{ns}) \qquad \text{subject to} \qquad P_{nt}C^k_{nt} + P_{nt}(K_{n,t+1} - (1-\delta)K_{nt}) = r_{nt}K_{nt}.$$

I can rewrite this problem as the following Lagrangian:

$$\mathcal{L} = \sum_{s=t}^{\infty} \beta^{s+t} U(C^k_{ns}) + \mu_t[r_{nt}K_{nt} - P_{nt}C^k_{nt} - P_{nt}(K_{n,t+1} - (1-\delta)K_{nt})].$$

The first order conditions are

$$\beta^{s+t}U'_{nt} = \mu_t P_{nt}$$

and

$$P_{nt}\mu_{nt} = \mu_{t+1}(r_{n,t+1} - P_{n,t+1}(1-\delta)).$$

Combining these two first-order conditions, I obtain the Euler equation:

$$U'_{nt} = \beta R_{n,t+1} U'_{n,t+1}.$$

Substituting $U(C^k_{nt}) = \frac{(C^k_{nt})^{1-1/\psi}}{1-1/\psi}$, I obtain

$$(C^k_{nt})^{-1/\psi} = \beta R_{n,t+1}(C^k_{n,t+1})^{-1/\psi}.$$

Following Kleinman et al. (2021), using the guess-and-verify method, I show that $C^k_{nt} = \zeta_{nt}R_{nt}K_{nt}$ where

$$\zeta_{nt}^{-1} = 1 + \beta^{\psi}\left(R_{n,t+1}^{\frac{\psi-1}{\psi}}\zeta_{n,t+1}^{-\frac{1}{\psi}}\right)^{\psi}.$$

The budget constraint implies that $K_{n,t+1} = (1-\zeta_{nt})R_{nt}K_{nt}$. Substituting guessed $K_{n,t+1}$ and C^k_{nt} into the Euler equation, it can be checked that the guess satisfies the Euler equation.

C Appendix: Quantification

C.1 Regression Model of Sectoral Labor Supply Elasticity

In this section, I describe derivation and estimation procedure of Equation (4.17). By taking log of Equation (4.6), I can derive the following regression model:

$$\ln \lambda_{njt} = \theta \ln W_{njt} + \sum_{k \in \mathcal{J}} W_{nkt}^{\theta} + \ln E_{njt}.$$

The labor productivity shock $\ln E_{njt}$ can be decomposed into four components that are varying at region-year, sector-year, region-sector, and region-sector-year levels: $e_{njt} \equiv \ln E_{njt} = \tilde{e}_{nt} + \tilde{e}_{jt} + \tilde{e}_{nj} + \tilde{e}_{njt}$, where $\tilde{e}_{nt}$ and $\tilde{e}_{jt}$ are region- and sector-year components, $\tilde{e}_{nj}$ is time-invariant region-sector components, and $\tilde{e}_{njt}$ is region-sector-year components. Then, the above regression model can be re-expressed as in Equation (4.17):

$$\ln \lambda_{njt} = \theta \ln W_{njt} + \underbrace{\delta_{nt}}_{=\sum_{k \in \mathcal{J}} W_{nkt}^{\theta} + \tilde{e}_{nt}} + \underbrace{\delta_{jt}}_{=\tilde{e}_{jt}} + \underbrace{\delta_{nj}}_{=\tilde{e}_{nj}} + \tilde{e}_{njt}.$$

Region-year fixed effects δ_{nt} absorb $\tilde{e}_{nt}$ and $\sum_{k \in \mathcal{J}} W_{nkt}^{\theta}$. δ_{nj} absorb $\tilde{e}_{nj}$. Sector-year fixed effects δ_{jt} absorb $\tilde{e}_{jt}$. Because the residual labor productivity shocks affect determination of wages, W_{njt} and $\tilde{e}_{njt}$ are correlated, leading to the endogeneity problem. Therefore, I estimate the equation using the IV defined in Equation (4.18).

To estimate the regression model in Equation (4.17), I need data on region-sector wages. I obtain these wages from the Mining and Manufacturing Survey, which contains wage bill information for mining and manufacturing establishments. Using the information on wage bills and location of production, I calculate region-sector wages as the mean of wage bills divided by total employment across establishments within region-sectors. The Mining and Manufacturing Survey only has information on wages for the mining and manufacturing sectors, so I estimate Equation (4.17) only for the mining and manufacturing sectors.

To use the data more efficiently, I use overlapping 3-year long-differences: 1996-1999 and 1997-2000. Table C5 reports the second and first stage results in columns (1) and (2), respectively. The estimated θ is around 1.3, which is statistically significant at 5%. The first stage F-statistics is 9.4, slightly below the rule of thumb value of 10. This suggests that the estimates may suffer from the weak IV problem. Therefore, I conduct the inference based on Anderson-Rubin (AR) statistics which are robust to the weak IV problem. The AR statistics clearly reject the null that $\theta = 0$ at 5% and its confidence interval covers the value of the second-stage estimates.

Table C5: Estimation of Sectoral Labor Supply Elasticity θ

	Second-stage	First-stage
	(1)	(2)
Wage	1.34**	
	(0.63)	
IV		3.10***
		(1.65)
AR	10.14	
AR-p	(0.00)	
AR-CI	$[0.50, \infty)$	
KP-F	9.4	
N	1076	1076

Notes. This table reports the second- and first-stage estimation results of Equation (4.17). The IV is defined in Equation (4.18). AR, AR-p, and AR-CI are Anderson-Rubin statistics, its p-values, and confidence intervals. KP-F is the Kleinbergen-Paap F-statistics. Standard errors are reported in parentheses, clustered at the region-sector level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

C.2 Regression Model of Migration Elasticity

In this section, I describe derivation and estimation procedure of Equation (4.19). From Equations (4.8) and (4.9), I can derive the following equation:

$$V_{nt} = \ln C_{nt} - \nu ln(\mu_{nm,t}) + \beta V_{m,t+1} - \tau_{nm,t}, \quad \forall n, m.$$

Using that the above equation holds for both nn and nm pairs and subtracting one from the other,

$$\ln \frac{\mu_{nmt}}{\mu_{nnt}} = \frac{\beta}{\nu}(V_{m,t+1} - V_{n,t+1}) - \frac{1}{\nu}\tau_{nmt}$$

Using Equation (4.8), this can be written as

$$\ln \frac{\mu_{nmt}}{\mu_{nnt}} = \frac{\beta}{\nu} \ln \frac{W_{mt}/P_{mt}}{W_{nt}/P_{nt}} + \frac{\beta}{\nu}\left(\nu \ln \sum_{n'} exp(\beta V_{n',t+1} - \tau_{mn',t+1}) - \nu \ln \sum_{n'} exp(\beta V_{n',t+1} - \tau_{nn',t+1})\right) - \frac{1}{\nu}\tau_{nmt}.$$

Using Equation (4.9) and subtracting and adding $\beta V_{m,t+2} - \tau_{mn,t+1}$ from the above equation, I obtain that

$$\ln \frac{\mu_{nmt}}{\mu_{nnt}} = \frac{\beta}{\nu} \ln \frac{W_{mt}/P_{mt}}{W_{nt}/P_{nt}} + \beta \ln \frac{\mu_{mn,t+1}}{\mu_{mm,t+1}} + \frac{1}{\nu}(\tau_{nm,t} - \beta\tau_{mn,t+1}).$$

Migration frictions can be decomposed into time-invariant and time-varying components: $\tau_{nmt} = \tilde{\tau}_{nm} + \tilde{\tau}_{nmt}$. This gives me the following estimable regression model:

$$\ln \frac{\mu_{nmt}}{\mu_{nnt}} = \frac{\beta}{\nu} \ln \frac{W_{mt}/P_{mt}}{W_{nt}/P_{nt}} + \beta \ln \frac{\mu_{mn,t+1}}{\mu_{mm,t+1}} + \delta_{nm} + \tilde{\epsilon}_{nmt},$$

where δ_{nm} absorbs $(1-\beta)/\nu\tilde{\tau}_{nm}$ and $\tilde{\epsilon}_{nmt}$ is the structural error term: $\tilde{\epsilon}_{nmt} \equiv 1/\nu \times (\tilde{\tau}_{nmt} - \tilde{\tau}_{nm,t+1})$.

Estimating Equation (4.17) requires information on regional price levels. I construct the regional price levels using the data on the regional consumer price index (CPI) and housing prices which are obtained from the Statistics Korea. The regional CPI data is only available for a few regions whereas the regional housing prices are available for all regions. Therefore, following Moretti (2017), I impute the CPI for regions with missing CPI. For the subset of regions with non-missing CPI, I run the following regression:

$$CPIg_{nt} = \pi \times HPg_{nt} + \delta_t + \epsilon_{nt},$$

where $CPIg_{nt}$ and HPg_{nt} are growth of CPI and housing price in region n between $t-1$ and t, respectively. Using the estimated coefficients $\hat{\pi}$ and $\hat{\delta}_t$ and housing prices, I impute the growth of CPI for all regions. Then, using these growth rates, I compute CPI after normalizing the 1992 level to be one. For example, the CPI level in 1993 is obtained by multiplying the imputed growth

Table C6: Estimation of Migration Elasticity $1/\nu$

	Second-stage	First-stage
	(1)	(2)
$\ln I_{nt}/P_{nt}$	0.69***	
	(0.25)	
IV		0.03***
		(0.00)
KP-F	21.62	
# clusters (Origin)	54	54
# clusters (Dest.)	54	54
N	5830	5830

Notes. This table reports the second- and first-stage estimation results of Equation (4.19). The IV is defined in Equation (4.20). AR, AR-p, and AR-CI are Anderson-Rubin statistics, its p-values, and confidence intervals, respectively. KP-F is the Kleinbergen-Paap F-statistics. Standard errors are reported in parentheses, two-way clustered at the origin and destination levels. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

between 1992 and 1993, and the CPI level in 1992 which is normalized to be one: $CPI_{n,1993} = CPIg_{n,1993} \times CPI_{n,1992}$.

Shocks to migration frictions are correlated with real income because these shocks affect migration flows and therefore, labor supply. Thus, I estimate the equation using the IV defined in Equation (4.20). Table C6 reports the results. The estimated coefficient is 0.62 and is statistically significant at 5% level.

C.3 Shock Formulation of the Model

Following Caliendo et al. (2019), I break down the equilibrium into two parts: a static equilibrium in which goods and factor market clearing conditions hold, taking populations and capital stock as given, and a dynamic equilibrium that solves forward-looking migration and investment decisions of workers and landlords.

Static equilibrium Unit costs are expressed as:

$$\hat{c}_{nj,t+1} = \frac{1}{\hat{A}_{nj,t+1}}(\hat{W}_{nj,t+1})^{\gamma_j^V}\left(\frac{\hat{H}_{nj,t+1}}{\hat{K}_{nj,t+1}}\right)^{\gamma_j^K}\prod_{k=1}^{J}(\hat{P}_{nj,t+1})^{\gamma_j^k}.$$

Price indices are expressed as:

$$\hat{P}_{nj,t+1}^{1-\sigma}\sum_{m\in\mathcal{N}}\pi_{mnt}^{j}(\hat{c}_{nj,t+1})^{1-\sigma} + \pi_{Fnt}^{j}(\hat{P}_{j,t+1}^{F})^{1-\sigma}.$$

Domestic trade shares are

$$\hat{\pi}_{mn,t+1}^{j} = \left(\frac{\hat{c}_{mj,t+1}}{\hat{P}_{nj,t+1}}\right)^{1-\sigma}.$$

Import trade shares are

$$\hat{\pi}_{Fn,t+1}^{j} = \left(\frac{\hat{P}_{j,t+1}^{F}}{\hat{P}_{nj,t+1}}\right)^{1-\sigma}.$$

Exports are

$$EX_{nj,t+1} = \hat{c}_{nj,t+1}^{1-\sigma}\hat{D}_{j,t+1}^{F}EX_{njt}.$$

Average wages of each region are

$$\hat{W}_{n,t+1} = \left(\sum_{j\in\mathcal{J}}\lambda_{njt}\hat{W}_{nj,t+1}^{\theta}\right)^{\frac{1}{\theta}}.$$

Workers' income is

$$\hat{I}_{n,t+1} = \frac{(1+\iota_{t+1})}{(1+\iota_t)}\hat{W}_{nt}.$$

Regional employment shares are

$$\hat{\lambda}_{nj,t+1} = \hat{E}_{nj,t+1}\left(\frac{\hat{W}_{nj,t+1}}{\hat{W}_{n,t+1}}\right)^{\theta}.$$

Sectoral labor supply is given by

$$\hat{H}_{nj,t+1} = (\hat{\lambda}_{nj,t+1})^{\frac{\theta-1}{\theta}}\hat{L}_{n,t+1}.$$

Goods market clearing implies that

$$GO_{nj,t+1} = \sum_{m \in \mathcal{N}} \pi^{j}_{mn,t+1}$$
$$\times \Big[\sum_{k \in \mathcal{J}} \gamma^{j}_{k} GO_{mk,t+1} + \alpha_j ((1+\iota_{t+1}) \hat{W}_{n,t+1} \hat{L}_{n,t+1} W_{nt} L_{nt} + \sum_{k' \in \mathcal{J}} \gamma^{K}_{j} GO_{mk',t+1}) \Big] + EX_{nj,t+1}.$$

Labor market clearing implies that

$$W_{nj,t+1} H_{nj,t+1} = \gamma^{L}_{j} GO_{nj,t+1}.$$

Capital market clearing implies that

$$K_{nj,t+1} = \left(\frac{(\gamma^{K}_{j}/\gamma^{L}_{j}) \hat{W}_{nj,t+1} \hat{H}_{nj,t+1} W_{njt} H_{njt}}{\sum_{k \in \mathcal{J}} (\gamma^{K}_{k}/\gamma^{L}_{k}) \hat{W}_{nk,t+1} \hat{H}_{nk,t+1} W_{nkt} H_{nkt}} \right) K_{n,t+1}$$

Dynamic equilibrium Define $u_{nt} = exp(V_{nt})$ and $m_{nmt} = exp(\tau_{nmt})$. Then, $\hat{u}_{n,t+1} = exp(V_{n,t+1} - V_{nt})$ and $\hat{m}_{nm,t+1} = exp(\tau_{nm,t+1} - \tau_{nmt})$. Given initial allocation and an anticipated convergence sequence of changes in shocks, $\{\hat{\Theta}\}^{\infty}_{t=1}$ satisfies the following system of nonlinear equations. Gross return on capital is given by

$$R_{n,t+1} = \frac{\hat{W}_{nj,t+1} \hat{H}_{nj,t+1}}{\hat{P}_{nj,t+1} \hat{K}_{nj,t+1}} \Big(R_{nt} - (1-\delta) \Big) + (1-\delta).$$

Capital stock evolves according to

$$K_{n,t+2} = (1 - \zeta_{n,t+1}) R_{n,t+1} K_{n,t+1}.$$

Landlords' consumption shares evolve according to

$$\zeta_{n,t+1} = \left(\frac{\zeta_{nt}}{1-\zeta_{nt}} \right) \beta^{\psi} R^{\psi-1}_{n,t+1}.$$

Migration shares are expressed as

$$\mu_{nm,t+1} = \frac{\mu_{nmt} (\hat{u}_{m,t+2})^{\frac{\beta}{\nu}} (\hat{m}_{nm,t+1})^{-\frac{1}{\nu}}}{\sum_{m' \in \mathcal{N}} \mu_{nm't} (\hat{u}_{m',t+2})^{\frac{\beta}{\nu}} (\hat{m}_{nm,t+1})^{-\frac{1}{\nu}}}. \tag{C.1}$$

Population evolves according to

$$L_{n,t+1} = \sum_{m \in \mathcal{N}} \mu_{mnt} L_{mt}$$

Value functions are given by

$$\hat{u}_{n,t+1} = \left(\frac{\hat{I}_{nt}}{\hat{P}_{nt}}\right)\left(\sum_{m'\in\mathcal{N}} \mu_{nm't}(\hat{u}_{m',t+2})^{\frac{\beta}{\nu}}(\hat{m}_{nm',t+1})^{-\frac{1}{\nu}}\right)^{\nu}. \tag{C.2}$$

Derivation I derive expressions in Equations (C.1) and (C.2). Migration shares can be expressed as

$$\mu_{nm,t+1} = \frac{exp(\beta V_{m,t+2} - \tau_{nm,t+1})^{\frac{1}{\nu}}}{\sum\limits_{m'\in\mathcal{N}} exp(\beta V_{m',t+2} - \tau_{nm',t+1})^{\frac{1}{\nu}}} = \frac{(\hat{u}_{m,t+1})^{\frac{\beta}{\nu}}(\hat{m}_{mn,t+1})^{-\frac{1}{\nu}} exp(\beta V_{m,t+1} - \tau_{nmt})^{\frac{1}{\nu}}}{\sum\limits_{m'\in\mathcal{N}} (\hat{u}_{m',t+1})^{\frac{\beta}{\nu}}(\hat{m}_{nm',t+1})^{-\frac{1}{\nu}} exp(\beta V_{m',t+1} - \tau_{nm't})^{\frac{1}{\nu}}}.$$

After dividing both the denominator and numerator of the above equation by $\sum\limits_{m'\in\mathcal{N}} exp(\beta V_{m',t+1} - \tau_{nm't})^{\frac{1}{\nu}}$, I can obtain the expression in Equation (C.1).

After taking Equation (4.8) in time differences, I obtain that

$$V_{n,t+1} - V_{n,t} = \ln\frac{I_{n,t+1}}{P_{n,t+1}} - \ln\frac{I_{nt}}{P_{nt}} + \nu\ln\frac{\sum\limits_{m\in\mathcal{N}} exp(\beta V_{m,t+2} - \tau_{nm,t+1})^{\frac{1}{\nu}}}{\sum\limits_{m\in\mathcal{N}} exp(\beta V_{m,t+1} - \tau_{nmt})^{\frac{1}{\nu}}}.$$

Taking exponential from both sides and using the expressions of $\hat{u}_{n,t+1}$ and $\mu_{nm,t+1}$, I can obtain the expression in Equation (C.2):

$$\hat{u}_{n,t+1} = \left(\frac{\hat{I}_{n,t+1}}{\hat{P}_{n,t+1}}\right)\left(\sum_{m\in\mathcal{N}} \mu_{nmt}(\hat{u}_{m,t+2})^{\frac{\beta}{\nu}}(\hat{m}_{nm,t+1})^{-\frac{1}{\nu}}\right)^{\nu}.$$

C.4 Algorithm

In this section, I describe the solution algorithm used to solve the model.

- Step 1. Guess the path of $\{\hat{u}_{nt}^{(0)}\}_{t=1}^{T+1}$ and $\{\zeta_{nt}^{(0)}\}_{t=1}^{T+1}$ for a sufficiently large T. The path converges at $T+1$, so set $\hat{u}_{n,T+1}^{(0)}=1$.

- Step 2. Based on the guessed consumption rates and the observed allocation of capital $\{K_{n0}\}$ and $\{K_{n1}\}$, set the gross return of capital at time t_0 as follows:

$$R_{it_0}=\frac{K_{n1}}{K_{nt_0}}(1-\zeta_{nt_0}^{(0)}).$$

- Step 3. Given the initial allocation of migration shares $\{\mu_{nmt_0}\}$, using the guessed $\{\hat{u}_{nt}\}_{t=1}^{T+1}$, compute path of migration shares $\{\mu_{nmt}\}_{t=1}^{T+1}$:

$$\mu_{nm,t+1}=\frac{\mu_{nmt}(\hat{u}_{m,t+2})^{\frac{\beta}{\nu}}(\hat{m}_{nm,t+1})^{\frac{1}{\nu}}}{\sum_{m'\in\mathcal{N}}\mu_{nm't}(\hat{u}_{m',t+2})^{\frac{\beta}{\nu}}(\hat{m}_{nm',t+1})^{\frac{1}{\nu}}}.$$

  Using the computed migration shares $\{\mu_{nmt}\}_{t=1}^{T+1}$, compute population for periods $t\geq 1$:

$$L_{n,t+1}=\sum_{m\in\mathcal{N}}\mu_{mnt}L_{mt}.$$

  Conditional on implied $\hat{L}_{n,t+1}$, $\hat{K}_{n,t+1}$, and allocation in period t, solve for $\{\hat{W}_{njt}\}$ that satisfy the system of equations of static equilibrium in Section C.3 for each t.

- Step 4. Compute the next period gross return on capital $R_{n,t+1}$[25]:

$$R_{n,t+1}=(1-\delta)+\frac{\hat{W}_{nj,t+1}\hat{H}_{nj,t+1}}{\hat{P}_{n,t+1}\hat{K}_{nj,t+1}}(R_{nt}-(1-\delta)).$$

  Because of cost minimization, the above expression holds for any $j\in\mathcal{J}$.

- Step 5. Using the next period gross return on capital $R_{n,t+1}$ and guessed $\zeta_{n,t+1}^{(0)}$, compute capital $K_{n,t+2}$ in period $t+2$:

$$K_{n,t+2}=(1-\zeta_{n,t+1}^{(0)})R_{n,t+1}K_{n,t+1}.$$

[25] Because $R_{n,t+1}\equiv(1-\delta)+\frac{r_{n,t+1}}{P_{n,t+1}}$, $\frac{R_{n,t+1}-(1-\delta)}{R_{nt}-(1-\delta)}=\frac{\hat{r}_{n,t+1}}{\hat{P}_{n,t+1}}$ holds. The cost minimization implies that $\frac{\hat{W}_{nj,t+1}\hat{H}_{nj,t+1}}{\hat{r}_{n,t+1}\hat{K}_{nj,t+1}}=1$, $\forall j\in\mathcal{J}$. Substituting $\hat{r}_{n,t+1}$ by $\hat{W}_{nj,t+1}\hat{H}_{nj,t+1}/\hat{K}_{nj,t+1}$ in $\frac{R_{n,t+1}-(1-\delta)}{R_{nt}-(1-\delta)}=\frac{\hat{r}_{n,t+1}}{\hat{P}_{n,t+1}}$, we can obtain that $R_{n,t+1}=(1-\delta)+\frac{\hat{W}_{nj,t+1}\hat{H}_{nj,t+1}}{\hat{P}_{n,t+1}\hat{K}_{nj,t+1}}(R_{nt}-(1-\delta))$.

- <u>Step 6.</u> For each t, solve backward for $\{\hat{u}_{nt}^{(1)}\}_{t=1}^{T+1}$:

$$\hat{u}_{n,t+1}^{(1)} = \left(\frac{\hat{I}_{n,t+1}}{\hat{P}_{n,t+1}}\right)\left(\sum_{m\in\mathcal{N}} \mu_{nmt}(\hat{u}_{m,t+2}^{(0)})^{\frac{\beta}{\nu}}(\hat{m}_{nm,t+1})^{-\frac{1}{\nu}}\right)^{\nu}.$$

- <u>Step 7.</u> For each t, solve backward for $\{\zeta_{nt}^{(1)}\}_{t=1}^{T+1}$:

$$\zeta_{nt}^{(1)} = \frac{\zeta_{n,t+1}^{(0)}}{\zeta_{n,t+1}^{(0)} + \beta^{\psi} R_{n,t+1}^{\psi-1}},$$

  where $R_{n,T+1} = 1/\beta$ is imposed.

- <u>Step 8.</u> Take $\{(1-\omega)\hat{u}_{nt}^{(0)} + \omega\hat{u}_{nt}^{(1)}\}_{t=1}^{T+1}$ and $\{(1-\omega)\zeta_{nt}^{(0)} + \omega\zeta_{nt}^{(1)}\}_{t=1}^{T+1}$ for some weight $\omega \in (0,1]$, and return to Step 2.

- <u>Step 9.</u> Continue until $\{\hat{u}_{nt}^{(1)}\}$ and $\{\zeta_{nt}^{(1)}\}$ converge.

C.5 Calibration of Shocks and Trade Shares

In this section, I describe the calibration procedure of the shocks, region-sector exports and import shares, and region-to-region trade shares.

- Step 1. Let $\tilde{c}_{njt}$ denote for the unit cost of sector j in region n: $\tilde{c}_{njt} \equiv c_{njt}/A_{njt}$. The static trade equilibrium of each period can be expressed as follows:

$$
\begin{aligned}
GO_{njt} &= (d^j_{nF}\tilde{c}_{njt})^{1-\sigma} D^F_{jt} \\
&\quad + \sum_{m\in N} \pi^j_{nmt}\Big[\sum_{k\in\mathcal{J}} \gamma^j_k GO_{mkt} + \alpha_j\Big(\sum_{k'\in\mathcal{J}} (1+\iota_t)\gamma^H_{k'} GO_{mk't} + \gamma^K_{k'} GO_{mk't}\Big)\Big], \\
IM_{jt} &= \sum_{n\in\mathcal{N}} \Bigg[\pi^j_{Fnt}\Big[\sum_{k\in\mathcal{J}} \gamma^j_k GO_{mkt} + \alpha_j\Big(\sum_{k'\in\mathcal{J}} (1+\iota_t)\gamma^L_{k'} GO_{mk't} + \gamma^K_{k'} GO_{mk't}\Big)\Big]\Bigg], \\
EX_{jt} &= \sum_{n\in\mathcal{N}} \Big[(d^j_{nF}\tilde{c}_{njt})^{1-\sigma} D^F_{jt}\Big],
\end{aligned}
$$

  and

$$
\pi^j_{mnt} = \frac{(d^j_{mn}\tilde{c}_{mjt})^{1-\sigma}}{\sum_k (d^j_{m'n}\tilde{c}_{m'jt})^{1-\sigma} + (d^j_{nF}P^F_{jt})^{1-\sigma}} \qquad \text{and} \qquad \pi^j_{Fnt} = \frac{(d^j_{Fn}P^F_{jt})^{1-\sigma}}{\sum_k (d^j_{m'n}\tilde{c}_{m'jt})^{1-\sigma} + (d^j_{nF}P^F_{jt})^{1-\sigma}} \tag{C.3}
$$

  hold.

  Given the data on region-sector gross output GO_{njt}, sectoral exports EX_{jt}, sectoral imports IM_{jt} and the parametrized trade costs (d^j_{mn} and d^j_{Fn}), the above system of equations holds for each j and t. The above system of equation has $N+2$ number of equations with the same number of unknowns ($\{\tilde{c}_{njt}, P^F_{jt}, D^F_{jt}\}_{n\in\mathcal{N}}$) and the system of equation is exactly identified up to scale. Without loss of generality, I re-express P^F_{jt}. D^F_{jt}, and $\tilde{c}_{njt}$ relative to the unit cost of the reference region for each j and t: $\bar{c}_{njt} = \tilde{c}_{njt}/\tilde{c}_{n_0jt}$, $\bar{P}^F_{jt} = P^F_{jt}/\tilde{c}_{n_0jt}$, and $\bar{D}^F_{jt} = D^F_{jt}/\tilde{c}^{1-\sigma}_{n_0jt}$. n_0 denotes the reference region.

- Step 2. Using the backed out relative unit costs, import prices, and foreign demands, for each sector and period, I can compute trade shares across regions and countries from Equation (C.3).

- Step 3. Region-sector price indices can be written as follows:

$$
P_{njt} = \Big[\sum_{m\in\mathcal{N}} (d^j_{mn}\tilde{c}_{mjt})^{1-\sigma} + (d^j_{Fn}P^F_{jt})^{1-\sigma}\Big]^{\frac{1}{1-\sigma}} = \tilde{c}_{n_0jt} \times \Big[\sum_{m\in\mathcal{N}} (d^j_{mn}\bar{c}_{mjt})^{1-\sigma} + (d^j_{Fn}\bar{P}^F_{jt})^{1-\sigma}\Big]^{\frac{1}{1-\sigma}}.
$$

Using the above expression, changes in region-sector price indices can be expressed as:

$$\hat{P}_{nj,t+1} = \hat{\hat{c}}_{n_0j,t+1} \times \underbrace{\frac{\left[\sum_{m\in\mathcal{N}}(d^j_{mn}\bar{c}_{mj,t+1})^{1-\sigma} + (d^j_{Fn}\bar{P}^F_{j,t+1})^{1-\sigma}\right]^{\frac{1}{1-\sigma}}}{\left[\sum_{m\in\mathcal{N}}(d^j_{mn}\bar{c}_{mjt})^{1-\sigma} + (d^j_{Fn}\bar{P}^F_{jt})^{1-\sigma}\right]^{\frac{1}{1-\sigma}}}}_{\text{Obtained from the previous step}}.$$

Because I obtained $\bar{c}_{njt}$ and $\bar{P}^F_{jt}$ in level in the previous step, the remaining object to be pinned down is $\hat{\hat{c}}_{n_0j,t+1}$.

I construct changes in the aggregate PPI of sector j as follows:

$$\hat{P}^{agg}_{j,t+1} = \left[\sum_{n\in\mathcal{N}} \omega_{njt}\hat{P}^{1-\sigma}_{nj,t+1}\right]^{\frac{1}{1-\sigma}},$$

where $\omega_{njt} \equiv \frac{GO_{njt}}{\sum_{m\in\mathcal{N}} GO_{mjt}}$. Because $\hat{P}_{njt}$ is a function of $\hat{\hat{c}}_{n_0j,t+1}$, $\hat{P}^{ag}_{jt}$ is pinned down by $\hat{\hat{c}}_{n_0j,t+1}$. Then, I choose one reference sector j_0 and pin down $\hat{\hat{c}}_{n_0jt}/\hat{\hat{c}}_{n_0j_0t}$ by fitting the PPI changes relative to the reference sector $\widehat{PPI}_{jt}/\widehat{PPI}_{j_0t}$.

- Step 4. Because I pin down $\hat{\hat{c}}_{n_0jt}/\hat{\hat{c}}_{n_0j_0t}$ in the previous step, the remaining object is $\hat{\hat{c}}_{n_0j_0t}$. I pin down $\hat{\hat{c}}_{n_0j_0t}$ by fitting changes in the real value-added of the reference sector. The changes in the reference sector can be written as:

$$\frac{\sum_{n\in\mathcal{N}} \omega^V_{njt}\hat{VA}_{nj,t+1}}{\hat{P}^{agg}_{j,t+1}}.$$

where $\sum_{n\mathcal{N}} \omega^V_{njt}\hat{VA}_{nj,t+1}$ is changes in sector j's aggregate value-added and ω^V_{njt} is region n's sector j value-added weight.

- Step 5. I compute changes in region-sector level unit costs, import prices, and foreign demands

$$\hat{c}_{nj,t+1} = \hat{\hat{c}}_{n_0j,t+1} \times \hat{\bar{c}}_{nj,t+1}, \quad \hat{P}^F_{j,t+1} = \hat{\hat{c}}_{n_0j,t+1} \times \hat{\bar{P}}^F_{jt}, \quad \text{and} \quad \hat{D}^F_{j,t+1} = \hat{\hat{c}}^{1-\sigma}_{n_0j,t+1} \times \hat{\bar{D}}^F_{jt}.$$

Note that I obtain $\hat{\hat{c}}_{n_0j,t+1}$ from Steps 3 and 4, and $\hat{\bar{c}}_{nj,t+1}$, $\hat{\bar{P}}^F_{jt}$ and $\hat{\bar{D}}^F_{jt}$ from Step 1.

- Step 6. In this step, I calibrate productivity shocks $\hat{A}_{nj,t+1}$ and labor productivity shocks $\hat{E}_{nj,t+1}$. $\hat{\tilde{c}}_{njt}$ is composed of changes in price of input bundles $\hat{c}_{njt}$ and productivity $\hat{A}_{njt}$. In order to back out $\hat{A}_{nj,t+1}$, I have to separately identify $\hat{c}_{nj,t+1}$ and $\hat{A}_{nj,t+1}$ from $\hat{\tilde{c}}_{nj,t+1}$. I solve the model and back out $\hat{A}_{nj,t+1}$ by fitting the computed $\hat{\tilde{c}}_{nj,t+1}$. The model allows me to separately identify changes in the unit cost and the productivity shock.

I identify $\hat{E}_{nj,t+1}$ from region-sector employment shares using Equation (4.6). Conditional on other variables, $\hat{E}_{nj,t+1}$ is identified up to normalization within each region, so I set $\hat{E}_{nj_0,t+1} = 1$ for one reference sector j_0 across regions and periods.

I use the following algorithm to identify $\hat{A}_{nj,t+1}$ and $\hat{E}_{nj,t+1}$:

1. Guess $\{\hat{A}^{(0)}_{nj,t+1}, \hat{E}^{(0)}_{nj,t+1}\}$
2. Solve the model using the algorithm described in Section C.4.
3. Update a guess of $\hat{A}^{(0)}_{nj,t+1}$
   (a) Compare changes in $\hat{c}^{0}_{nj,t+1}$ computed from the model to $\hat{c}_{nj,t+1}$ obtained in the Step 5.
   (b) If $\hat{c}^{0}_{nj,t+1} > \hat{c}_{nj,t+1}$, compute a new guess of $\hat{A}^{(1)}_{nj,t+1}$ by decreasing $\hat{A}^{(0)}_{nj,t+1}$ and vice versa.
   (c) Use $\hat{A}^{(1)}_{nj,t+1}$ as a new guess and iterate steps 2 and 3(a, b, c) until $|\hat{c}^{(0)}_{nj,t+1} - \hat{c}_{nj,t+1}| < \epsilon$ holds for some threshold ϵ
4. Update a guess of $\hat{E}^{(0)}_{nj,t+1}$
   (a) Compare changes in $\hat{\lambda}^{(0)}_{nj,t+1}$ computed from the model to $\hat{\lambda}_{nj,t+1}$ obtained from the data.
   (b) If $\hat{\lambda}^{(0)}_{nj,t+1} > \hat{\lambda}_{nj,t+1}$, compute a new guess of $\hat{E}^{(1)}_{nj,t+1}$ by decreasing $\hat{E}_{nj,t+1}$ and vice versa.
   (c) Use $\hat{E}^{(1)}_{nj,t+1}$ as a new guess and iterate steps 2, 3(a, b, c), and 4(a, b, c) until $|\hat{\lambda}^{(0)}_{nj,t+1} - \hat{\lambda}_{nj,t+1}| < \epsilon$ holds for some threshold ϵ

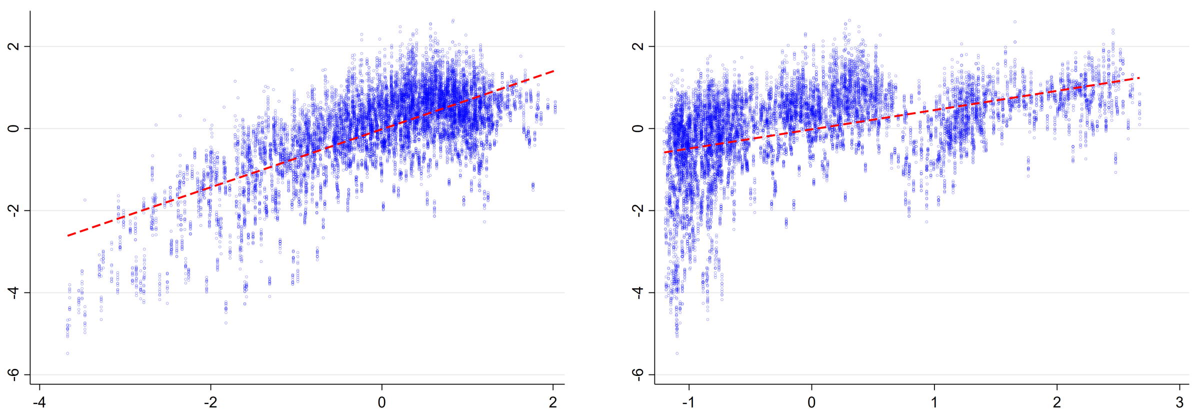
C.6 External Validation of Migration Costs

In this section, I show that the inferred migration frictions correlate with the Euclidean distance and a proxy for regional conflicts between regions, which externally validates the inferred migration frictions. I measure the proxy using each candidate's share of the vote in the 1992 14th presidential election in each region six years before the 1998 large devaluation. In the historical and political setting of South Korea, this is a good proxy for regional conflicts (Park, 2003). I compute the proxy between regions m and n as

$$\text{Proxy}_{nm} = \sqrt{\frac{\sum_c (\pi_n^c - \pi_m^c)}{\text{The Number of Candidates}}} \tag{C.4}$$

where π_n^c is candidate c's share of votes in region n.

Figure C7 plots log of the estimated migration frictions against the log of the Euclidean distance and the proxy for regional conflicts. A one standard deviation increase in the log of the Euclidean distance and the proxy is correlated with a 0.70 and 0.38 standard deviation increase in the log of the measured migration frictions, respectively.



A. Log of the Euclidean distance

B. Proxy for regional conflicts

Figure C7. Correlates of the Inferred Migration Frictions

Notes. Panels A and B are the scatter plots between log of the inferred migration frictions and log of the Euclidean distance and the proxy for regional conflicts defined in Equation (C.4). Log of the migration frictions, the Euclidean distance, and the proxy for regional conflicts are standardized. Migration frictions are inferred from Equation (4.21) and demeaned by year.

C.7 Robustness. Different Parameter Values

Table C7: Robustness. Aggregate Effects of Migration Frictions

	Baseline	No migration	Decrease by p50	Decrease by p75
	(1)	(2)	(3)	(4)
Panel A. $\sigma = 4,\ \theta = 1.3,\ 1/\nu = 0.7$				
Top 5 emp. shares (%)	18.4	18.2	18.5	18.7
Top 5 export intensity (%)	34.9	34.6	35.1	35.5
Overall export intensity (%)	17.2	17.1	17.3	17.6
Panel B. $\sigma = 6,\ \theta = 2,\ 1/\nu = 0.7$				
Top 5 emp. shares (%)	18.4	18.2	18.6	18.8
Top 5 export intensity (%)	34.9	34.5	35.1	35.6
Overall export intensity (%)	17.2	17.0	17.4	17.6
Panel C. $\sigma = 6,\ \theta = 1.3,\ 1/\nu = 0.5$				
Top 5 emp. shares (%)	18.4	18.2	18.6	18.8
Top 5 export intensity (%)	34.9	34.5	35.1	35.6
Overall export intensity (%)	17.2	17.0	17.3	17.6
Panel D. $\sigma = 6,\ \theta = 1.3,\ 1/\nu = 0.7$, *permanent frictions*				
Top 5 emp. shares (%)	18.4	18.2	18.6	18.8
Top 5 export intensity (%)	34.9	34.5	35.1	35.6
Overall export intensity (%)	17.2	17.0	17.3	17.6

Notes. Column (1) reports the results of the baseline economy. Column (2) reports the counterfactual economy in which migration is not allowed. Columns (3) and (4) report the results of the counterfactual economies where migration frictions decrease by the p50 and p75 of the empirical distribution, respectively. The first, second, and third rows report the aggregate-level employment shares in the top 5 sectors, the aggregate export intensity of the top 5 sectors, and the overall export intensity, respectively. These results are based on the calibrated values reported in Table 1.

Table C8: Robustness. Regional Effects of Migration Frictions

	Baseline	No migration	Decrease by p50	Decrease by p75
$\triangle \ln y_{nt} = \beta^{reg} RegEX_{nt_0} + \epsilon_{nt}$	(1)	(2)	(3)	(4)
Panel A. $\sigma = 4$, $\theta = 1.3$, $1/\nu = 0.7$				
Growth top 5 emp.	8.8	6.3	9.8	11.8
Growth pop.	2.8	0	4	6.2
Growth top 5 emp. shares	6	6.3	5.9	5.7
Panel B. $\sigma = 6$, $\theta = 2$, $1/\nu = 0.7$				
Growth top 5 emp.	8.7	6.3	9.8	11.8
Growth pop.	2.7	0	4	6.2
Growth top 5 emp. shares	6	6.3	5.9	5.6
Panel C. $\sigma = 6$, $\theta = 1.3$, $1/\nu = 0.5$				
Growth top 5 emp.	8.6	6.2	9.6	11.6
Growth pop.	2.6	0	3.7	5.9
Growth top 5 emp. shares	6	6.2	5.9	5.7
Panel D. $\sigma = 6$, $\theta = 1.3$, $1/\nu = 0.7$, *permanent frictions*				
Growth top 5 emp.	8.7	6.3	9.8	11.9
Growth pop.	2.7	0	4	6.2
Growth top 5 emp. shares	6	6.3	5.9	5.7

Notes. The table reports the estimated coefficients of β^{reg} from the regression model $\triangle \ln y_{nt} = \beta^{reg} RegEX_{nt_0} + \epsilon_{nt}$ where $RegEX_{nt_0}$ is the standardized regional export intensity defined in Equation (3.1). Column (1) reports the results of the baseline economy. Column (2) reports the counterfactual economy in which migration is not allowed. Columns (3) and (4) report the results of the counterfactual economies where migration frictions decrease by the p50 and p75 of the empirical distribution, respectively. In the first, second, and third rows, the results for total employment in the top 5 sectors, total population, and employment shares in the top 5 sectors are reported, respectively. These results are based on the calibrated values reported in Table 1.