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 large devaluations? Following the large devaluation episode of South Korea in 1998, using cross-sectional variation in industrial composition, 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. I find that three years after the devaluation, temporary reductions in migration frictions by empirically plausible level can increase the aggregate export intensity and employment shares in the five most export-intensive sectors by 0.3 and 0.6 percentage points.

Keywords: migration, sectoral reallocation, devaluation, trade
JEL Codes: F16, F31, R23

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1 Introduction

When hit by sector-specific shocks, any barriers to sectoral reallocation of labor hinder workers from flexibly reallocating across sectors and decrease the 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 the 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 boosts exports by making prices of domestic goods in foreign markets cheaper. After large devaluations, higher 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 may 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 South 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. Second, these export-intensive sectors were highly concentrated in a few regions. Due to this geographical concentration, there was substantial cross-sectional variation in regional export intensity, defined as the weighted average of sectoral export intensity, where the weights are given by employment shares in the initial period. I refer to regions with higher regional export intensity as more export-oriented regions.

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

[1] Many economists and policymakers have examined barriers to sectoral reallocation of labor to improve labor market flexibility. See, for example, Heckman and Pages (2000), Wacziarg and Wallack (2004), Kambourov (2009), Helpman et al. (2010), Menezes-Filho and Muendler (2011) Petrin and Sivadasan (2013), and Cosar et al. (2016) for labor market institutions.

[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 the event-time dummies. For spatial reallocation, I similarly regress migration inflows on the regional export intensity of destination regions interacted with the 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 and migration inflows of one region increased by 3.6 and 4.8% higher relative to another with a one standard deviation lower regional export intensity. 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.

Second, guided by the two empirical findings, 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. South Korea is a small open economy and 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). These decisions determine sectoral labor supply within regions conditional on population. The migration decisions are 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 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 decisions characterize region-sector employment shares, governed by the elasticity of region-sector employment shares to region-sector specific wages. Workers' migration decisions characterize population distribution across regions, governed by the elasticity of migration outflow shares to the discounted lifetime utilities net

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

of migration frictions.

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

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 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. The identifying assumption of these IV strategies is that the demand shocks due to the devaluation's expansionary effects on exports are uncorrelated with shocks to labor productivity and migration frictions conditional on controls.

I calibrate the four devaluation shocks 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.

For the quantitative analysis, I evaluate the effects of policies that temporarily reduce migration frictions after the devaluation. To do so, I compare the transition paths of the baseline economy with the migration frictions corresponding to the observed migration flows in the data and the counterfactual economies in which migration frictions temporarily differ from those of the baseline only up to 2002, five years after the devaluation, and move back to the baseline level in 2003, while feeding the same devaluation shocks. By focusing on temporary reductions in frictions, I consider a set of more realistic policy options after the devaluation because policies with permanent reductions can be more costly to implement. Also, I can focus on the effects of migration frictions on short-run labor adjustment after the devaluation rather than their long-run consequences.

I consider hypothetical changes in migration frictions similar to Bryan and Morten (2019) rather than specific policies. Although I do not examine welfare effects and costs of implementing such policies, these quantitative exercises can be useful for policymakers given that many real-world policies target observed outcomes such as aggregate exports, and these exercises are informative on the benefits of migration policies after large devaluations.

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 four counterfactual scenarios. In the first scenario, migration is temporarily not allowed. In the second and third scenarios, I consider common temporary decreases by the 50th and 75th percentile (p50 and p75) of the empirical distribution for all regions, which are equivalent to an 11 and 28% reduction, respectively. In the last scenario, I consider selective decreases by the p50 only for migration flows to more export-oriented regions. In all scenarios, migration frictions return to the original level in 2003.

If migration were temporarily not allowed, in 2000, the aggregate top 5 employment shares and export intensity would have been 0.3 and 0.3 percentage points lower than those in the baseline, which is equivalent to 1.4 and 1 percentage points lower increases between 1997 and 2000 than those of the baseline. With the common (selective) decreases by the p50 of the empirically observed reductions, in 2000, the two aggregate outcomes would have been 0.1 and 0.2 (0.6 and 0.5) percentage points higher than those of the baseline, equivalent to 0.6 and 0.6 (3.3 and 1.4) percentage points higher increases between 1997 and 2000 than those of the baseline. These aggregate effects are mostly driven by changes in population distribution due to increased workers' migration flows to more export-oriented regions rather than changes in region-sector employment shares.

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; Autor et al., 2013; Kovak, 2013; Adão, 2015; Hakobyan and McLaren, 2016; Dix-Carneiro and Kovak, 2017, 2019; Caliendo et al., 2018; Benguria et al., 2018; Kondo, 2018; Bloom et al., 2019; Caliendo et al., 2019; Greenland et al., 2019; Artuc et al., 2021; 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 the local labor market to the transitory trade shocks due to the devaluation.[5]

Second, I contribute to the literature that quantifies effects of internal migration frictions (see, for example, Morten and Oliveira, 2018; Lagakos et al., 2018; Fan, 2019; Monras, 2015; Schmutz and Sidibé, 2019; Tombe and Zhu, 2019; Hao et al., 2020; Imbert and Papp, 2020; Ma and Tang, 2020; Brinatti and Morales, 2021; 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.

[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 of 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.

Third, I contribute to the literature that studies consequences of large devaluations, surveyed by Burstein and Gopinath (2014) (see, e.g., Burstein et al., 2005; Cravino and Levchenko, 2017, 2018; Blanco et al., 2019; Bonadio et al., 2020; Auer et al., 2022). In particular, related to big trade changes after the devaluation, see Alessandria et al. (2010) for inventory behavior of importers and trade dumpiness; Gopinath and Neiman (2014) for large TFP drops due to decreased imports; Blaum (2018) for joint import and export decisions of big firms; and Alessandria et al. (2020) for export dynamics after large devaluation episodes. Unlike these papers, I examine labor market adjustment margins across sectors and regions after the devaluation. House et al. (2018) study the benefits of increased mobility in the euro area, and 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 two studies, I study the devaluation episode of the emerging market economy.

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 devaluation episode of South Korea. In Section 4, I build a quantitative model to quantify the effects of migration frictions and evaluate policies that temporarily reduce 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 2002. See Online Appendix Section A for more detail on construction of the final data set.

Region-sector level data I construct region-sector employment shares from the Census on Establishment which covers the universe of formal establishments in South 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, the WIOD Socio Economic Accounts (WIOD-SEA), and the IMF

[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.

Table 1: Descriptive Statistics

Variable	Mean	SD	Median
Top 5 mfg. emp. share	0.17	0.14	0.12
Overall mfg. emp. share	0.25	0.15	0.21
Outflow migration rate	0.12	0.03	0.12

Notes. This table reports the descriptive statistics of the data set. There are 15 sectors and 121 regions. The sample period is between 1995 and 2002.

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.

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

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

Descriptive statistics Table 1 reports the descriptive statistics of the final data set. The average top 5 and overall manufacturing sector employment shares were 17 and 25%, respectively. On average, 12% of people moved out to different regions annually. When aggregating 121 regions up to 16 states that are more comparable to the average size of the US counties, the average outflow rate is 7.2%, which is about a one percentage point higher than the annual inter-county migration rates (Molloy et al., 2011).[7]

3 Empirical Evidence on Sectoral and Spatial Reallocation of Labor

In this section, I provide two empirical findings: (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.

[7] The median of the geographical size of the spatial unit is 236mi^2 (612km^2), which is 38% of the median of the geographical size of the US counties calculated based on the 2000 US Census.

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 was 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.[8] I normalize the export intensity by the median between 1995 and 1997 before the devaluation. The top 5 export intensity increased by 4.9 (2.2) percentage points higher than the intensity of the other sectors in 1998 (in 2000) relative to 1997.[9]

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:

$$\text{RegEX}_{nt_0} = \frac{\sum_j \text{Emp}_{njt_0} \times \text{SecEX}_{jt_0}}{\sum_j \text{Emp}_{njt_0}}, \tag{3.1}$$

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 was 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 the ones with the higher top 5 employment shares.

3.2 Sectoral Reallocation of Labor

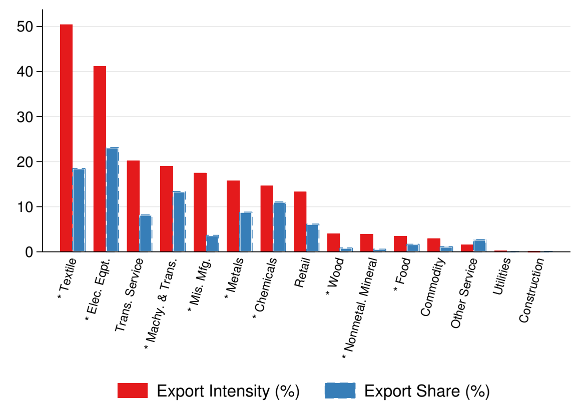
The differential expansionary effects on exports across sectors could have induced workers to reallocate to more export-intensive sectors. For the empirical analysis, I exploit cross-sectional variation in the regional export intensity documented in Panel C of Figure 1. I run the following event-study specification:

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

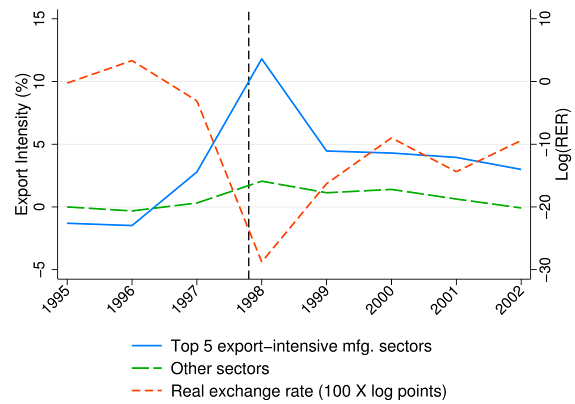
RegEX_{nt_0} is the regional export intensity of the initial period in 1994. I standardize RegEX_{nt_0} for ease of interpretation. D_t^τ are event-time dummies: $D_t^\tau \equiv \mathbb{1}[\tau = t - 1998]$. y_{nt} are the dependent variables: log of employment shares in the top 5 and the overall manufacturing sectors. δ_n and δ_t are region and calendar year fixed effects. $\mathbf{X}_{nt}$ are regional time-varying observables in which I control

[8] 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 the 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.

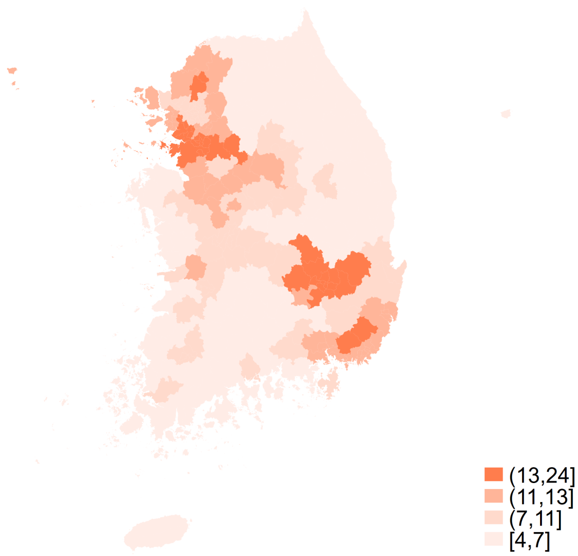
[9] Consistent with the increases in the export intensity, between 1997 and 2000, aggregate employment, GDP, and gross output shares in the top 5 sectors increased from 18.2 to 18.7%, 22.8 to 25.7%, and 35.3 to 39.5%, respectively. See Online Appendix Figure A6.



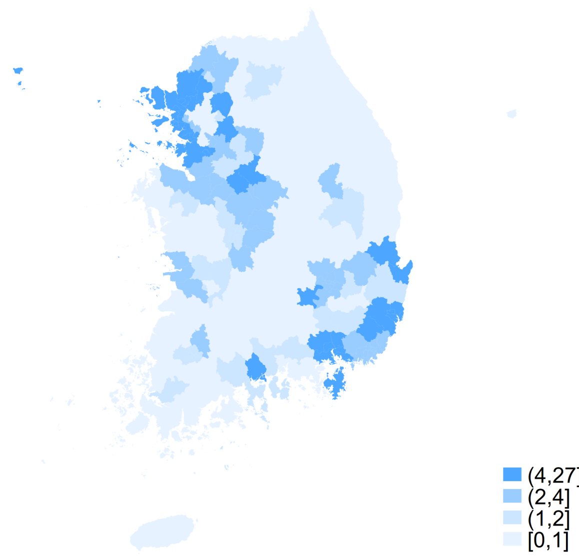
A. Export intensity and export share



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 the 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.

for interacting terms between the log of total employment in 1994 and year fixed effects. ϵ_{nt} is the error term. I normalize β_0 to be zero.

Figure 2 reports the results. In Panels A and B, dependent variables are the 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, workers might move to more export-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:

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

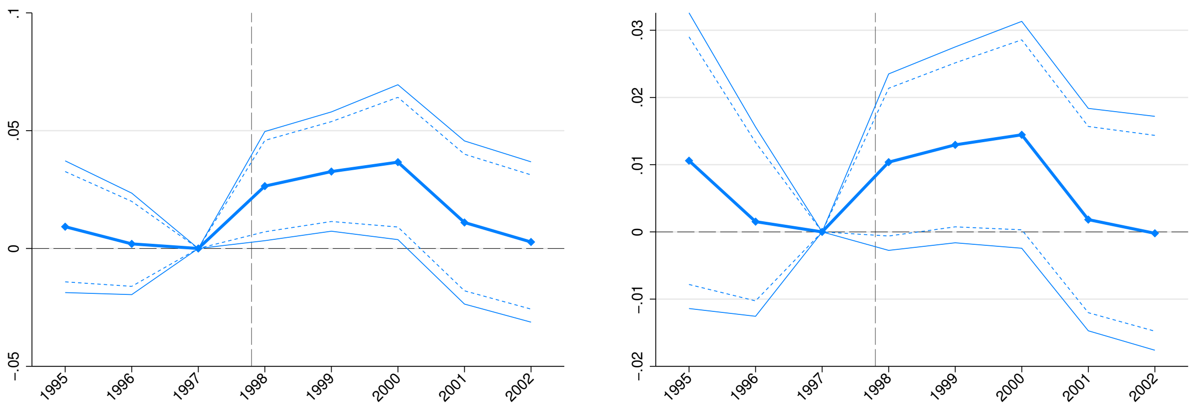
The dependent variables are changes in the log of migration flows μ_{nmt} from region n to m.[10] RegEX_{mt_0} is the standardized regional export intensity of destination region m. δ_{nm} and δ_{nt} are time-invariant pair and origin-year fixed effects. For destination observables $\mathbf{X}_{mt}$, I use the same set of controls with Equation (4.16). ϵ_{nmt} is the error term. I normalize β_τ to be zero. To deal with statistical zeros, I estimate Equation (3.3) using Poisson Pseudo-maximum likelihood (PPML) (Silva and Tenreyro, 2006).

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-time dummies, and I control for destination-year fixed effects. I find migration outflows decreased by 4% of one region compared to another with a one standard deviation lower regional export intensity of origins three years after the devaluation.

3.4 Robustness

Due to the depreciation of the real exchange rate, the devaluation could have negatively affected sectors that imported intermediate inputs more intensively from foreign countries. Based on Campa

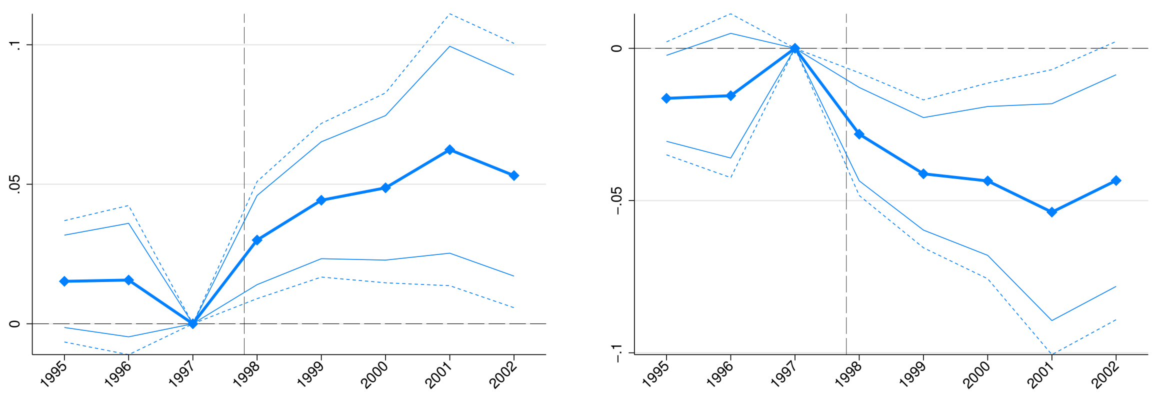
[10] Because the regression model is at the bilateral pair level, the regression model incorporates the bilateral nature of location choices and does not suffer from the critique proposed by Borusyak et al. (2022).



A. Top 5 mfg. B. Overall 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 the log of the 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 the log of migration flows 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.

and Goldberg (1995), I construct an alternative regional exposure measure:

$$\text{RegEXIM}_{nt_0} = \frac{\sum_j \text{Emp}_{njt_0} \times (\text{SecEX}_{jt_0} - \text{SecIM}_{jt_0})}{\sum_j \text{Emp}_{njt_0}}, \tag{3.4}$$

where SecIM_{jt_0} is the share of imported inputs to the total costs of production. The differences between SecIM_{jt_0} and SecEX_{jt_0} capture the sectoral net exposures to the real exchange rate changes. Using this alternative measure, I run the same event study specifications as in Equation (3.2) and (3.3). Online Appendix Figures B7 and B8 report the results. The estimated coefficients are similar to the baseline results except for the overall manufacturing employment shares, of which the estimated coefficients are statistically insignificant.

It is possible that I may include migration that does not entail changing labor markets, for example, through commuting. This bias is likely to underestimate the spatial reallocation results because if the sectoral reallocation results were entirely driven by commuting, workers would have stayed at their original locations, which decreases migration flows to more export-oriented regions. In Online Appendix Figures B9 and B10, I show that the results are robust to excluding regions that are more likely to subject to such bias.[11]

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 the 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, corresponding to South Korea and the rest of the world. Home is a small open economy that 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 is 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 for $n, m \in \mathcal{N} \cup \{F\}$ where F denotes for Foreign, $d^j_{nm} \geq 1$ 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. Workers

[11] For this robustness check, I exclude three regions: Seoul, Busan, and Incheon that are known for large numbers of commuters.

optimally allocate their members across different sectors based on sectoral wages and 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 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 and 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 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

$$\mathrm{EX}_{njt} = (d_{nF}^{j} c_{njt})^{1-\sigma} D_{jt}^{F},$$

where D_{jt}^{F} 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 on 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 $\boldsymbol{\epsilon}_t^i \equiv (\epsilon_{n1t}^i, \ldots, \epsilon_{nJt}^i)$ where ϵ_{njt}^i 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: $F_{nt}(\boldsymbol{\epsilon}_t) = exp(-\sum_{j\in\mathcal{J}} E_{njt}\epsilon_{njt}^{-\theta})$ 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.[12] 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, workers allocate their available members across sectors to maximize the total sum of wages earned by their members. Workers allocate 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 $\Omega_{njt} = \{\boldsymbol{\epsilon}_t | W_{njt}\epsilon_{njt} \geq W_{nkt}\epsilon_{nkt}, \forall k \in \mathcal{J}\}$. Each worker's shares of members allocated to sector j are expressed as:

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

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:[13]

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

Labor supply curves are upward sloping and increase in W_{njt}. The total labor income of each worker in region n is the sum of wages across her members:

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

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.

[12] 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.

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

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.[14] 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.

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

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

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 flows 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: $\iota_t \equiv \frac{\sum_{n \in \mathcal{N}} \sum_{j \in \mathcal{J}} \mathrm{IM}_{njt} - \mathrm{EX}_{njt}}{\sum_{n \in \mathcal{N}} W_{nt} L_{nt}}$ where IM_{njt} is sector j import values of region n. With exogenous trade deficits, workers' income is given as $I_{nt} = (1 + \iota_t) W_{nt}$.

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

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 $R_{nt} \equiv 1 - \delta + r_{nt}/P_{nt}$ is the gross return on capital and ζ_{nt} is recursively defined as

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

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

$$\mathrm{GO}_{njt} = \sum_{m\in\mathcal{N}} \pi_{mnt}^{j}\left[\sum_{k=1}^{J}\gamma_{k}^{j}\mathrm{GO}_{mkt} + \alpha_j((1+\iota_t)W_{mt}L_{mt} + r_{mt}K_{mt})\right] + \mathrm{EX}_{njt}, \tag{4.13}$$

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

$$W_{njt}H_{njt} = \gamma_j^{H}\mathrm{GO}_{njt}. \tag{4.14}$$

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

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

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, $\{\mathbf{\Psi}_t\}_{t=t_0}^{\infty}$, $\{\tau_{nmt}\}_{t=t_0}^{\infty}$, 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 $\{L_{nt},\ \lambda_{njt},\ W_{njt},\ V_{nt},\ r_{nt},\ K_{n,t+1}\}_{t=t_0}^{\infty}$ that satisfies the following condition for each region n, each sector j, and all time periods t: (i) Given W_{njt}, workers optimally allocate their 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 the 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.[15] 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.

[15] 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. Also, see Dix-Carneiro (2014) and Traiberman (2019) for costs of sectoral reallocation under the dynamic setting.

4.3 Counterfactual

I examine how amounts of sectoral reallocation and transition path of the baseline economy would have differed from those of the counterfactual economies with different migration friction levels after the devaluation. To perform counterfactuals and solve for transition paths, I utilize a dynamic hat algebra developed by 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 the sectoral labor supply and migration elasticities; and counterfactual migration friction shocks that are required to construct the transition paths of the counterfactual economies.

For the baseline economy, I assume there are no changes in migration frictions and feed in the exogenous shocks $\hat{\mathbf{\Psi}}_t$ and compute the transition path. I consider policies that temporarily reduce migration frictions for 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 $\hat{m}^c_{nm,03} = 1/\hat{m}^c_{nm,98}$.

4.4 Taking the Model to the Data

This section discusses the calibration procedure for the structural parameters, the initial allocation, 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 2 reports a summary of the calibration procedure. See Online Appendix Section D for detail.

4.4.1 Initial Allocation

I need the initial allocation of $\{\mathrm{GO}_{njt_0}, \lambda_{njt_0}, \mu_{nmt_{-1}}, L_{nt_0}, K_{nt_0}, K_{n,t_0+1}, \mathrm{EX}_{njt_0}, \pi^j_{nmt_0}, \pi^j_{Fnt_0}\}$ to apply the dynamic hat algebra. I obtain region-sector employment shares, gross output, real capital stock, and region-to-region migration flows from the data described in Section 2. However, region-sector exports and imports and region-to-region trade flows are not directly observable. Therefore, I indirectly infer these variables from sectoral exports and imports, region-sector gross output, and the gravity structure of trade.[16]

[16]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.

Table 2: 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 shocks	Gross output, PPI
$\{D^F_{jt}\}$		Foreign demand shocks	Aggregate exports
$\{P^F_{jt}\}$		Import price shocks	Aggregate imports
$\{\iota_t\}$		Trade deficits	Aggregate exports/imports
$\{E_{njt}\}$		Labor productivity shocks	Region-sector emp. shares
Preference			
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	Value-added labor shares	Literature
δ	0.05	Depreciation rate	Literature

Notes. This table summarizes the calibration results.

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}. 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} absorbs the average wage W_{nt} of region n. 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 this endogeneity problem, I estimate the equation using the following IV:

$$\text{RegEX}_{nt_0} \times \text{SecEX}_{jt_0} \times \mathbb{1}[t \geq 1998]. \tag{4.18}$$

The IV exploits positive 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 ($\mathbb{1}[t \geq 1998]$), 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 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.[17]

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

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

δ_{nm} and δ_t are pair and year fixed effects.[18] $\tilde{\epsilon}_{nmt}$ 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, 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.[19] 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 following Moretti (2017), I impute regional CPI data for regions with missing information using housing price data available for all regions.[20]

[17] 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.

[18] The expression captures that current migration flows reflect the future 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 identifies the migration elasticity $1/\nu$.

[19] Specifically, I construction regional workers' income as follows: $I_{nt} = 0.66 \times (1+\iota_t) \times \sum_{j\in\mathcal{J}} \text{VA}_{njt}$ 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.

[20] One concern with using CPI in this regression is that CPI is comparable across times within regions but not

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:

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

The identifying assumption of the IV holds when migration friction 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 the 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.[21]

Trade costs I parametrize internal 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 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). I parametrize international trade costs $d^j_{Fn} = (pdist_n)^{\xi_j}$ 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} capture 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.

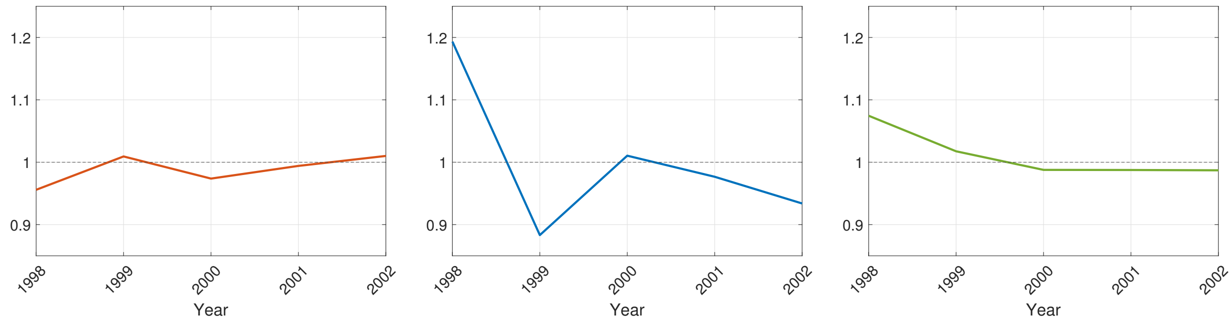
4.4.3 Shocks

I back out five time-varying exogenous shocks $\hat{\mathbf{\Psi}}_t$ by fitting the model to the data between 1997 and 2002 (Allen and Arkolakis, 2014; Eaton et al., 2016; Redding, 2016). 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. 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. Trade deficits are taken directly from the data (Dekle et al., 2008).

Figure 4 presents the weighted average of the three devaluation shocks: productivity, foreign

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, $P_{nt} = (P_{nt}/P_{n,92}) \times P_{n,92}$ 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}.

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



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 Online Appendix Section D.5 for the calibration procedure in more detail.

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. One year after the devaluation in 1998, the average productivity, foreign demands, and import prices decreased by 4.4% and increased by 19.3 and 7.5% relative to the previous year, respectively.

Also, 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 Counterfactual 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. In Online Appendix Section D.6, I show that these backed-out frictions are highly correlated with observed proxies for migration frictions, such as the Euclidean distance and a proxy for regional tension.

Using the inferred frictions, I compute changes in $\mathfrak{m}_{nmt}$ between 1997 and 2017 and find that, on average, there were reductions in migration frictions during these periods. At the 50th and 75th, there were reductions of 11 and 28%, respectively.[22] Following Monte et al. (2018), I use this empirical distribution of these calculated changes between 1997 and 2017 and the estimated value of ν to conduct counterfactuals for empirically-realistic changes in migration frictions.

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

For each region-to-region pair, I compute counterfactual changes in migration frictions in 1998 as follows:

$$\hat{m}^c_{nm,98} \equiv (\hat{\mathfrak{m}}^c_{nm,98})^{\nu} = exp(\tau^c_{nm} - \tau_{nm,98}), \tag{4.22}$$

where τ^c_{nm} is the counterfactual migration frictions. I consider four counterfactual scenarios. In the first scenario, migration is not allowed: $\tau^c_{nm} = \infty$, $\forall n, m \in \mathcal{N}$. For the second and third scenarios, I consider common decreases by the 50th and 75th percentile of the empirical distribution: $\tau^c_{nm} = 0.89 \times \tau_{nm,98}$ and $0.72 \times \tau_{nm,98}$, $\forall n, m \in \mathcal{N}$. 0.89 and 0.72 correspond to the decreases by the p50 and p75. In the fourth scenario, I consider selective decreases by the 50th percentile only for migration flows to more export-oriented regions: $\tau^c_{nm} = 0.89 \times \tau_{nm,98}$ only for origin n and destination m that satisfy $\text{RegEX}_{mt_0} > \text{RegEX}_{nt_0}$. In all the counterfactual scenarios, migration frictions move back to the original level in 2003: $\hat{m}^c_{nm,03} = 1/\hat{m}^c_{nm,98}$.

4.5 Quantitative Results

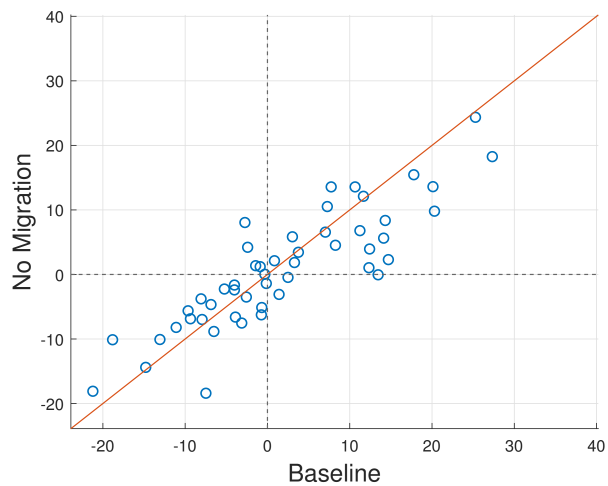
Table 3 reports the changes in the aggregate top 5 employment, top 5 export intensity, and overall export intensity between 1997 and 2000 under the baseline and counterfactual economies. Because I normalize the total population to be one, the aggregate top 5 employment shares are equivalent to the aggregate top 5 employment. In the baseline (column (1)), the aggregate top 5 employment, top 5 export intensity, and overall export intensity increased by 1.8, 7.8, and 14.9% three years after the devaluation. Because the baseline is fitted exactly to the data, these increases are as reported in the data.

In column (2), where migration is temporarily not allowed, these aggregate outcomes are 1.4, 1, and 0.5 percentage points lower than those in the baseline. In columns (3) and (4), with the temporary decreases by the p50 and the p75, more workers are employed in the top 5 sectors, and the export intensities are higher at the aggregate level than the baseline. In column (5), with the selective decreases, the economy achieves even higher employment shares in the top 5 sectors and export intensities. The changes in the aggregate top 5 employment, top 5 export intensity, and overall export intensity are 3.3, 1.4, and 1.9 percentage points higher than those of the baseline. In terms of level in 2000, these three aggregate variables are 0.6, 0.5, and 0.3 percentage points higher than those of the baseline economy.

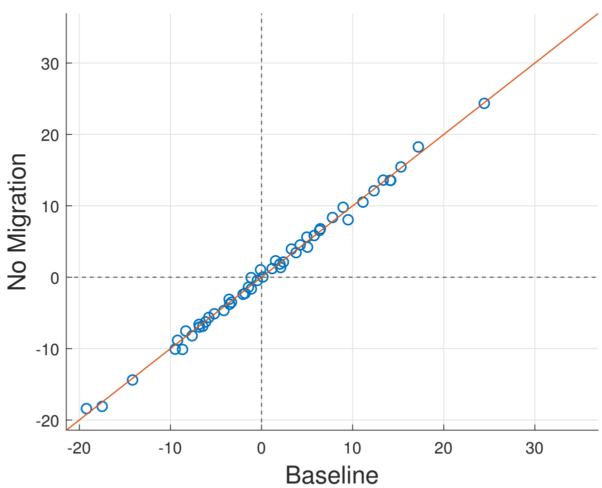
The aggregate results in Table 3 are driven by increased migration flows of workers to more export-oriented regions. Using the variables computed from the model, I regress the growth rate of regional outcomes of interest between 1997 and 2000 on the standardized regional export intensity:

$$\triangle \ln y_{nt} = \beta^{reg} \text{RegEX}_{nt_0} + \epsilon_{nt},$$

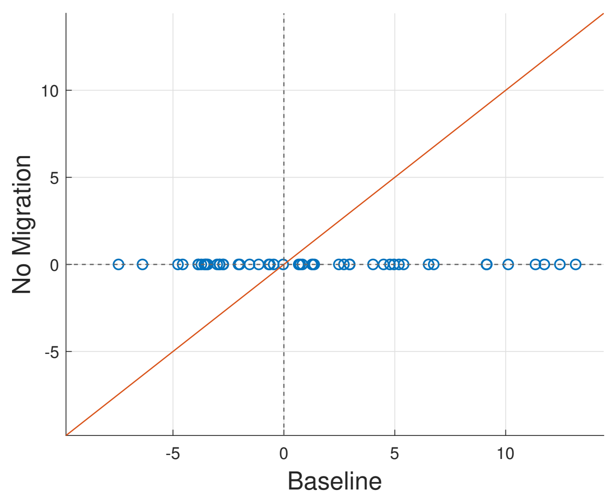
and report the estimated $\hat{\beta}^{reg}$. $\hat{\beta}^{reg}$ can be interpreted as increases in growth rate when the regional



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 regional top 5 employment, top 5 employment shares, and population in 2000. Each dot represents a region. X- and y-axes correspond to the baseline and the no-migration counterfactual economies. The red line is the 45-degree line.

Table 3: Aggregate Effects of Migration Frictions

Changes between 1997-2000	Level in 1997	Baseline (1)	No migration (2)	Decrease p50 (3)	Decrease p75 (4)	Decrease p50 (selective) (5)
Top 5 emp. shares	[0.18]	1.8%	0.4%	2.4%	3.6%	5.1%
Top 5 export intensity	[0.32]	7.8%	6.8%	8.4%	9.9%	9.2%
Overall export intensity	[0.15]	14.9%	13.4%	15.6%	17.3%	16.8%

Notes. Column (1) reports the results for the aggregate-level employment in the top 5 sectors, the aggregate export intensity of the top 5 sectors, and the overall export intensity of the baseline economy. Columns (2), (3), and (4) report the results of the counterfactual economies with no migration and the decreases by the p50 and p75 of the empirical distribution. Column (5) reports the counterfactual results with the decreases by the p50 only for migration flows to more export-oriented regions. These results are based on the calibrated values reported in Table 2.

Table 4: Regional Effects of Migration Frictions

Estimated $\hat{\beta}^{reg}$: $\triangle \ln y_{nt} = \beta^{reg}\text{RegEX}_{nt_0} + \epsilon_{nt}$	Baseline (1)	No migration (2)	Decrease p50 (3)	Decrease p75 (4)	Decrease p50 (selective) (5)
Top 5 emp.	8.7	6.2	9.8	11.9	17.3
Pop.	2.7	0	3.9	6.2	12.3
Top 5 emp. shares	6.0	6.2	5.9	5.7	5.1

Notes. The table reports the estimated coefficients of β^{reg} from the regression model $\triangle \ln y_{nt} = \beta^{reg}\text{RegEX}_{nt_0} + \epsilon_{nt}$ where RegEX_{nt_0} is the standardized regional export intensity defined in Equation (3.1). Column (1) reports the results for the total employment in the top 5 sectors, total population, and employment shares in the top 5 sectors of the baseline economy. Columns (2), (3), and (4) report the counterfactual results with no migration and the decreases by the p50 and p75 of the empirical distribution. Column (5) reports the counterfactual results with the decreases by the p50 only for migration flows to more export-oriented regions. These results are based on the calibrated values reported in Table 2.

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 4 reports the results. In all economies, more export-oriented regions tend to experience higher growth of these three outcomes, implied by the positively estimated coefficients. However, the magnitude of the estimated coefficients differs across the economies depending on the level of migration frictions. With lower frictions, there are larger increases in population and the top 5 employment in more export-oriented regions due to increased migration, reflected by higher $\hat{\beta}^{reg}$.

However, at the same time, due to the upward-sloping labor supply curve, the increased migration inflows decrease the top 5 sector wages and, therefore, the top 5 employment shares, reflected by lower $\hat{\beta}^{reg}$.

Figure 5 illustrates the regional top 5 employment, population, and top 5 employment shares under the baseline and the no migration counterfactual in 2000. Because $L_{njt} = \lambda_{njt} L_{nt}$, the variation in the top 5 employment (L_{njt}) between the two economies can come from the variation in the top 5 employment shares (λ_{njt}) or population (L_{nt}). The variation in population explains most of the variation in the top 5 employment, of which only 1.1% can be explained by the top 5 employment shares. These results highlight the importance of changes in population distribution through migration for the adjustment to the devaluation shocks.

I conduct robustness analysis with different values of elasticity of substitution, sectoral labor supply elasticity, and migration elasticity. For each set of different values of the parameters, the model is re-calibrated. I also conduct robustness analysis that feeds permanent migration friction shocks instead of temporary ones. Online Appendix Tables D8 and D9 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 effects of internal migration and its frictions on sectoral reallocation of labor after the large devaluation episode of South Korea in 1998. Exploiting cross-sectional variation in industrial composition, I provide empirical evidence on reallocation of labor to 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 aggregate effects of migration frictions on short-run labor adjustment and evaluate policies that temporarily reduce migration frictions. 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. 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 the Korean Sector Industry Code (KSIC) to the 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 the 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:

$$\mathrm{GO}_{njt} = \tilde{\omega}_{n(s)jt} \times \tilde{\omega}_{s(n)jt} \times \mathrm{GO}_{jt}^{WIOD}.$$

GO_{jt}^{WIOD} 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:

$$\tilde{\omega}_{s(n)jt} = \frac{\mathrm{GO}_{s(n)jt}}{\sum\limits_{s' \in \mathcal{S}} \mathrm{GO}_{s'jt}},$$

where GO_{sjt} is sector j gross output of state s and $\mathcal{S}$ 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 $s(n)$ in which region n is located:

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

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, the WIOD Socio Economic Accounts (WIOD-SEA), and the 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:

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

where K_t is the aggregate real capital stock from the IMF-ICSD and $\tilde{\omega}^K_{jt}$ is a share of sector j nominal capital stock to the total nominal capital stock across sectors from the WIOD-SEA.

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

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

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: $K_{njt} = \tilde{\omega}^K_{njt} \times K_{jt}$. For the non-manufacturing sectors, I do not have information on region-sector level fixed assets, so I use region-sector employment shares to allocate region-sector real capital stock of these sectors.

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.

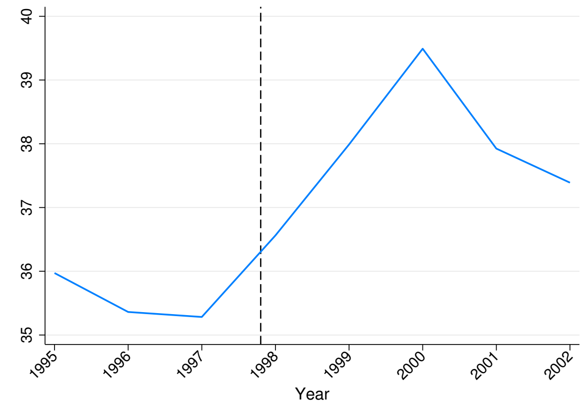
Sectoral imports and exports Sectoral imports and exports are obtained from the WIOD.

Sector classification I categorize sectors into 15 sectors. This grouping is reported in Table A5.

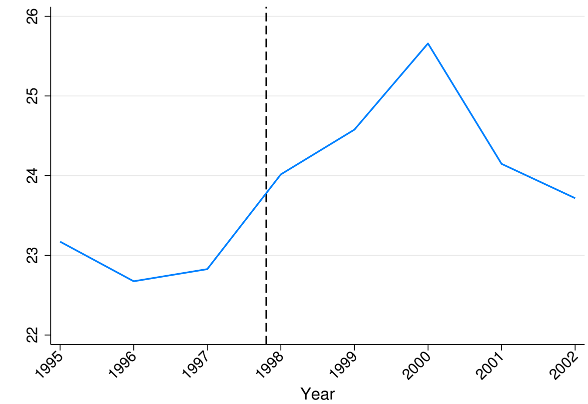
Table A5: Sector Classification

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)

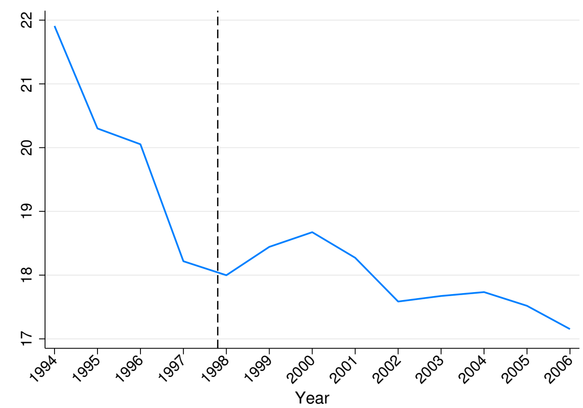
Note. The codes inside the parenthesis denote the ISIC rev 3.1. industry codes.



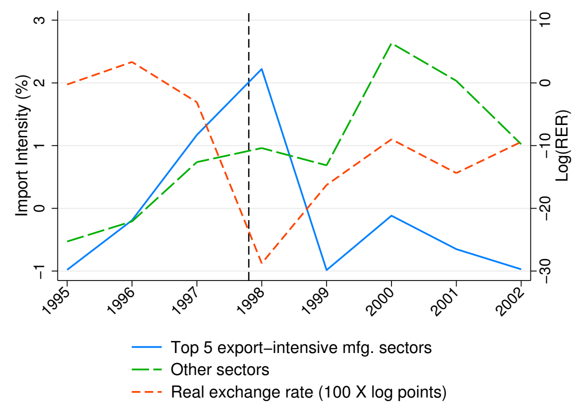
A. Top 5 gross output shares (%)



B. Top 5 value-added shares (%)



C. Top 5 emp. shares (%)

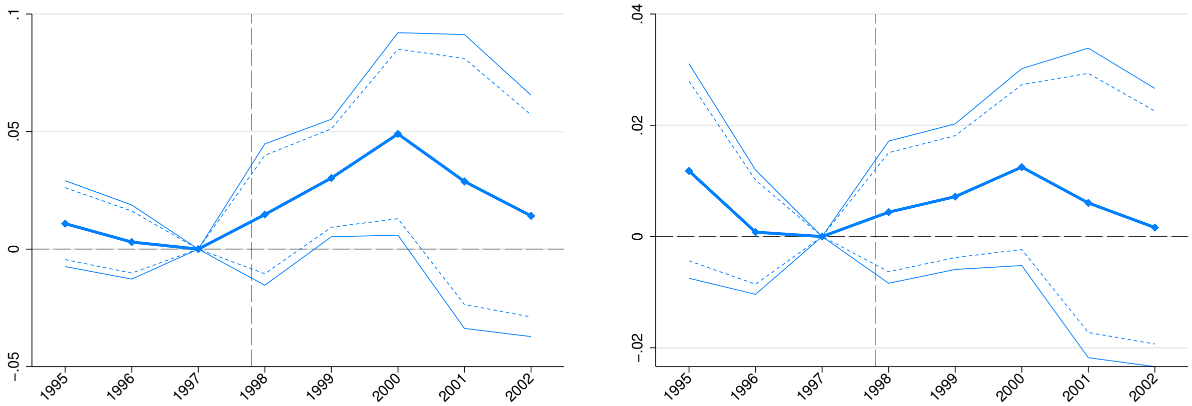


D. Import intensity (%)

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.

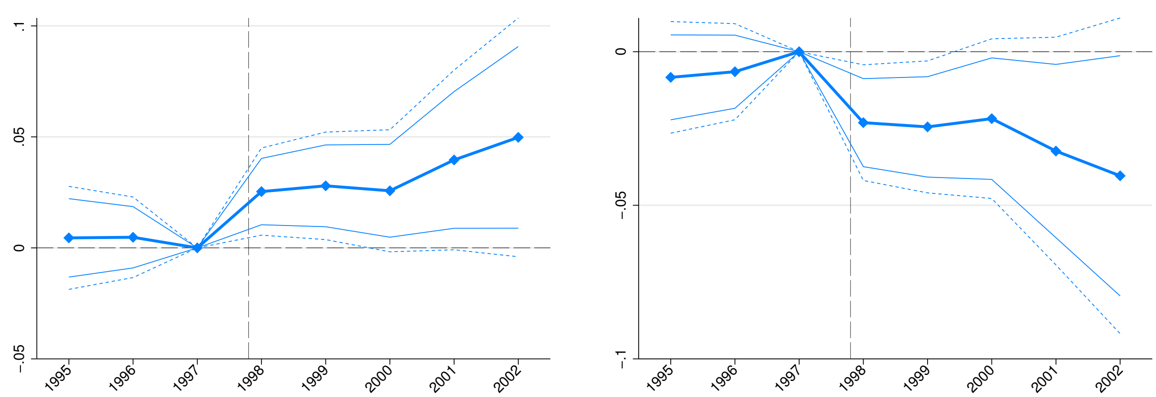
B Appendix: Empirics



A. Top 5 mfg. B. Overall mfg.

Figure B7. Robustness. Alternative Regional Exposure Measure. Event Study. Sectoral Reallocation of Labor. Workers Reallocated to More Export-Intensive Sectors within Regions

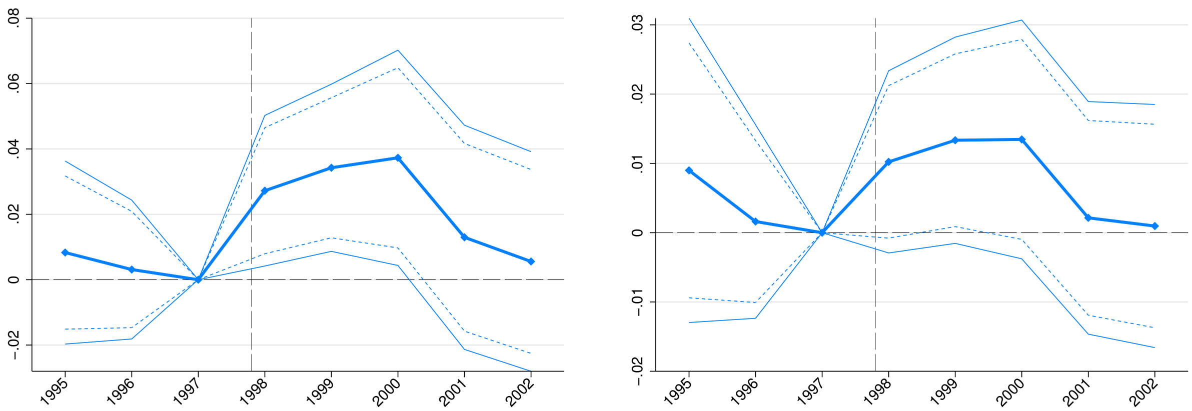
Note. This figure illustrates the estimated β_τ in Equation (3.2). In Panels A and B, the dependent variables are the log of employment shares in the top 5 and all manufacturing sectors, respectively. The black dashed line indicates the start of the devaluation. The figure reports 90 and 95 percent confidence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



A. Destination RegEXIM$_{mt_0}$ B. Origin RegEXIM$_{nt_0}$

Figure B8. Robustness. Alternative Regional Exposure Measure.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 the log of migration shares between origin and destination regions. In Panels A and B, the estimated coefficients of destination's RegEXIM$_{mt_0}$ and origin's RegEXIM$_{nt_0}$ 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.

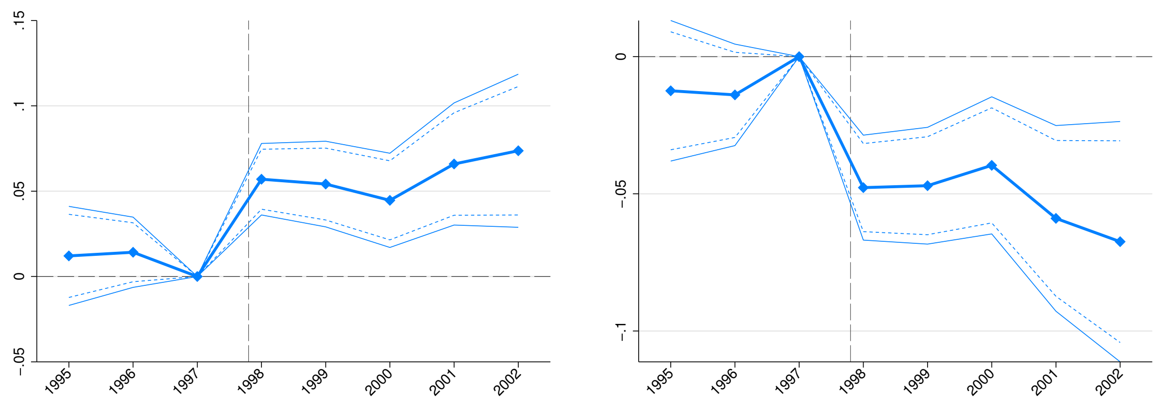


A. Top 5 mfg.

B. Overall mfg.

Figure B9. Robustness. Excluding Regions that are More Likely to be Subject to Commuting Bias. 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 the log of employment shares in the top 5 and all manufacturing sectors, respectively. I exclude three regions: Seoul, Busan, and Incheon, which are known for large numbers of commuters. 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 B10. Robustness. Excluding Regions that are More Likely to be Subject to Commuting Bias. 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 the 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). I exclude three regions: Seoul, Busan, and Incheon, which are known for large numbers of commuters. 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.

C Appendix: Theory

C.1 Landlords' Intertemporal Utility Maximization Problem

Landlords' utility maximization problem can be written as:

$$\max_{C^k_{ns}, K_{n,s+1}} \sum_{s=t}^{\infty} \beta^{t+s} U(C^k_{ns}),$$

subject to the budget constraint:

$$P_{nt} C^k_{nt} + P_{nt}(K_{n,t+1} - (1-\delta) K_{nt}) = r_{nt} K_{nt}.$$

I can rewrite this problem as the following Lagrangian:

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

The first-order conditions are

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

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

D Appendix: Quantification

D.1 Regression Model of Sectoral Labor Supply Elasticity

In this section, I describe derivation and estimation procedure of Equation (4.17). By taking the 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 the 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 D6 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 D6: 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, ∞)	
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. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

D.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 the above equation for pairs nn and nm 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), the above expression can be written as

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

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

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

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:

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

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:

$$gCPI_{n,t+1} = \pi \times gHP_{n,t+1} + \delta_t + \epsilon_{nt},$$

where $gCPI_{n,t+1}$ and $gHP_{n,t+1}$ are growth of CPI and housing price in region n between t and $t+1$. Using the estimated coefficients $\hat{\pi}$ and $\hat{\delta}_t$ and housing prices, I impute the growth of CPI for missing

Table D7: 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. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

regions and compute CPI after normalizing the 1992 level to one.

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 D7 reports the results. The estimated coefficient is 0.69 and is statistically significant at the 1% level with the strong first-stage results.

D.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

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

The 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

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

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

$$
\begin{aligned}
\mathrm{GO}_{nj,t+1} = & \sum_{m \in \mathcal{N}} \pi^{j}_{mn,t+1} \\
& \times \left[\sum_{k \in \mathcal{J}} \gamma^{j}_{k} \mathrm{GO}_{mk,t+1} + \alpha_j ((1+\iota_{t+1}) \hat{W}_{n,t+1} \hat{L}_{n,t+1} W_{nt} L_{nt} + \sum_{k' \in \mathcal{J}} \gamma^{K}_{j} \mathrm{GO}_{mk',t+1}) \right] + \mathrm{EX}_{nj,t+1}.
\end{aligned}
$$

Labor market clearing implies that

$$W_{nj,t+1} H_{nj,t+1} = \gamma^{H}_{j} \mathrm{GO}_{nj,t+1}.$$

Capital market clearing implies that

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

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, $\{\hat{\Theta}\}_{t=1}^{\infty}$ 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

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

The population evolves according to

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

Value functions are given by

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

Derivation I derive expressions in Equations (D.1) and (D.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 (D.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 (D.2):

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

D.4 Algorithm

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

- Step 1. Guess the path of $\{\hat{u}_{nt}^{(0)}\}_{t=t_0+1}^{T+1}$ and $\{\zeta_{nt}^{(0)}\}_{t=t_0+1}^{T+1}$ 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 $\{K_{nt_0}\}$ and $\{K_{n,t_0+1}\}$, set the gross return of capital at time t_0 as follows:

$$R_{nt_0} = \frac{K_{n,t_0+1}}{K_{nt_0}}(1-\zeta_{nt_0}^{(0)}).$$

- Step 3. Given the initial allocation of migration shares $\{\mu_{nmt_0}\}$, using the guessed $\{\hat{u}_{nt}^{(0)}\}_{t=t_0+1}^{T+1}$, compute path of migration shares $\{\mu_{nmt}\}_{t=t_0+1}^{T+1}$:

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

  Using the computed migration shares $\{\mu_{nmt}\}_{t=1}^{T+1}$, compute population for periods $t \geq t_0+1$:

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

  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 the static equilibrium in Section D.3 for each t.

- Step 4. Compute the next period gross return on capital $R_{n,t+1}$[23]:

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

  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 $t+2$:

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

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

- Step 6. For each t, solve backward for $\{\hat{u}_{nt}^{(1)}\}_{t=t_0+1}^{T+1}$:

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

- Step 7. 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.

- Step 8. Take $\{(1-\omega)\hat{u}_{nt}^{(0)} + \omega\hat{u}_{nt}^{(1)}\}_{t=t_0+1}^{T+1}$ and $\{(1-\omega)\zeta_{nt}^{(0)} + \omega\zeta_{nt}^{(1)}\}_{t=t_0+1}^{T+1}$ for some weight $\omega \in (0, 1]$, and return to Step 2.

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

D.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:

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

and

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

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 $\bar{D}^F_{jt} = D^F_{jt}/\tilde{c}^{1-\sigma}_{n_0jt}$, where n_0 denotes the reference region. Then, I solve for $\bar{c}_{njt}$, $\bar{P}^F_{jt}$, and $\bar{D}^F_{jt}$ for each j and t.

- Step 2. Using the backed out $\bar{c}_{njt}$, $\bar{P}^F_{jt}$, and $\bar{D}^F_{jt}$ for each sector and period, I can compute trade shares across regions and countries from Equation (D.3).

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

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

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

$$\hat{P}_{nj,t+1} = \hat{\bar{c}}_{n_0 j,t+1} \times \underbrace{\frac{\left[\sum_{m\in\mathcal{N}}(d^j_{mn}\bar{c}_{mj,t+1})^{1-\sigma} + (d^j_{Fn}\bar{P}^F_{j,t+1})^{1-\sigma}\right]^{\frac{1}{1-\sigma}}}{\left[\sum_{m\in\mathcal{N}}(d^j_{mn}\bar{c}_{mjt})^{1-\sigma} + (d^j_{Fn}\bar{P}^F_{jt})^{1-\sigma}\right]^{\frac{1}{1-\sigma}}}}_{\text{Obtained from the previous step}}.$$

Because I obtained $\bar{c}_{njt}$ and $\bar{P}^F_{jt}$ in level in the previous steps, once I pin down $\hat{\bar{c}}_{n_0 j,t+1}$, $\hat{P}_{nj,t+1}$ is also pinned down.

I construct changes in the sector j's PPI at the aggregate level 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 $\omega_{njt} \equiv \frac{\mathrm{GO}_{njt}}{\sum_{m\in\mathcal{N}}\mathrm{GO}_{mjt}}$. Because $\hat{P}_{njt}$ is a function of $\hat{\bar{c}}_{n_0 j,t+1}$ for all regions, $\hat{P}^{agg}_{jt}$ is pinned down by $\hat{\bar{c}}_{n_0 j,t+1}$.

Then, I choose one reference sector j_0 and pin down $\hat{\bar{c}}_{n_0 jt}/\hat{\bar{c}}_{n_0 j_0 t}$ by fitting the PPI changes relative to the reference sector $\widehat{PPI}_{jt}/\widehat{PPI}_{j_0 t}$.

- Step 4. Because I pin down $\hat{\bar{c}}_{n_0 jt}/\hat{\bar{c}}_{n_0 j_0 t}$ in the previous step, the remaining object is $\hat{\bar{c}}_{n_0 j_0 t}$. I pin down $\hat{\bar{c}}_{n_0 j_0 t}$ by fitting changes in the real value-added of the reference sector. The changes in the reference sector can be written as follows:

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

where $\sum_{n\mathcal{N}}\omega^V_{njt}\hat{VA}_{nj,t+1}$ are 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

$$\hat{c}_{nj,t+1} = \hat{\bar{c}}_{n_0 j,t+1} \times \hat{\bar{c}}_{nj,t+1}, \quad \hat{P}^F_{j,t+1} = \hat{\bar{c}}_{n_0 j,t+1} \times \hat{\bar{P}}^F_{jt}, \quad \text{and} \quad \hat{D}^F_{j,t+1} = \hat{\bar{c}}^{1-\sigma}_{n_0 j,t+1} \times \hat{\bar{D}}^F_{jt}.$$

Note that I obtain $\hat{\bar{c}}_{n_0 j,t+1}$ 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 and labor productivity shocks ($\hat{A}_{nj,t+1}$ and $\hat{E}_{nj,t+1}$). $\hat{\bar{c}}_{njt}$ 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 $\hat{\bar{c}}_{nj,t+1}$. I solve the model and back out $\hat{A}_{nj,t+1}$ by fitting the computed $\hat{\bar{c}}_{nj,t+1}$. Using the model, I can 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 D.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.
   (d) Repeat steps 2-4 until $\{\hat{A}^{(0)}_{nj,t+1}, \hat{E}^{(0)}_{nj,t+1}\}$ converge.

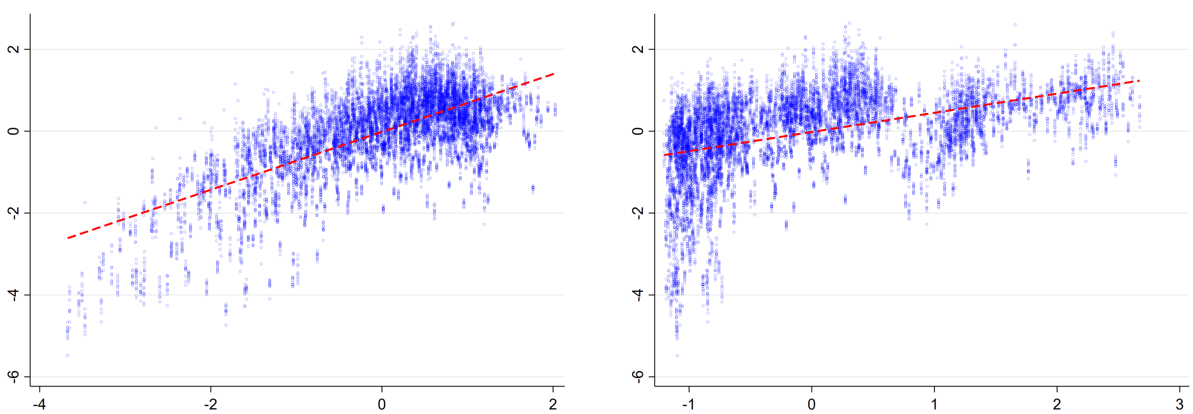
D.6 External Validation of Migration Costs

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

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

where π_n^c is candidate c's share of votes of region n and the denominator is the number of candidates in the election.

Figure D11 plots the 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 tension

Figure D11. Correlates of the Inferred Migration Frictions

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

D.7 Robustness

In this section, I conduct robustness checks for different values of the parameters. I consider $\sigma - 1 = 3$ which is also in range of the trade elasticity estimates (Costinot and Rodríguez-Clare, 2014); $\theta = 2$, the estimate of the Roy model of sector choice from Hsieh et al. (2019); and $1/\nu = 0.5$ based on the migration elasticity estimate from Caliendo et al. (2021). I also conduct a robustness check for permanent decreases in migration frictions.

The results are reported in Table D8 and D9. For each set of parameters, the model is re-calibrated to back out the corresponding shocks by exactly fitting the data. Therefore, the baseline economies for different sets of parameters have the same values as in the data.

Table D8: Robustness. Aggregate Effects of Migration Frictions

	Baseline	No migration	Decrease p50	Decrease p75	Decrease p50 (selective)
	(1)	(2)	(3)	(4)	(5)
Panel A. $\sigma = 4,\ \theta = 1.3,\ 1/\nu = 0.7$					
Top 5 emp. shares (%)	1.8	0.5	2.3	3.4	5
Top 5 export intensity (%)	7.8	7.1	8.3	9.4	8.7
Overall export intensity (%)	14.9	13.8	15.4	16.7	16.1
Panel B. $\sigma = 6,\ \theta = 2,\ 1/\nu = 0.7$					
Top 5 emp. shares (%)	1.8	0.5	2.4	3.5	5
Top 5 export intensity (%)	7.8	6.8	8.4	9.8	9.1
Overall export intensity (%)	14.9	13.5	15.6	17.1	16.6
Panel C. $\sigma = 6,\ \theta = 1.3,\ 1/\nu = 0.5$					
Top 5 emp. shares (%)	1.8	0.4	2.3	3.5	5.2
Top 5 export intensity (%)	7.8	6.8	8.4	9.9	9.3
Overall export intensity (%)	14.9	13.5	15.6	17.3	16.9
Panel D. $\sigma = 6,\ \theta = 1.3,\ 1/\nu = 0.7$, *permanent migration friction shocks*					
Top 5 emp. shares (%)	1.8	0.4	2.4	3.5	4.8
Top 5 export intensity (%)	7.8	6.8	8.4	9.9	9.1
Overall export intensity (%)	14.9	13.4	15.6	17.3	16.7

Notes. Column (1) reports the results for the aggregate-level employment shares in the top 5 sectors, the aggregate export intensity of the top 5 sectors, and the overall export intensity of the baseline economy. Columns (2), (3), and (4) report the results of the counterfactual economies with no migration and the decreases by the p50 and p75 of the empirical distribution, respectively. Column (5) reports the counterfactual results with the decreases by the p50 only for migration flows to more export-oriented regions.

Table D9: Robustness. Regional Effects of Migration Frictions

Estimated $\hat{\beta}^{reg}$: $\triangle \ln y_{nt} = \beta^{reg}\text{RegEX}_{nt_0} + \epsilon_{nt}$	Baseline	No migration	Decrease p50	Decrease p75	Decrease p50 (selective)
	(1)	(2)	(3)	(4)	(5)
Panel A. $\sigma = 4$, $\theta = 1.3$, $1/\nu = 0.7$					
Growth top 5 emp.	8.7	6.3	9.8	11.8	17.2
Growth pop.	2.7	0	3.9	6.2	12.2
Growth top 5 emp. shares	6	6.3	5.9	5.7	5
Panel B. $\sigma = 6$, $\theta = 2$, $1/\nu = 0.7$					
Growth top 5 emp.	8.7	6.3	9.7	11.8	17.1
Growth pop.	2.7	0	3.9	6.1	12.2
Growth top 5 emp. shares	6	6.3	5.9	5.6	4.9
Panel C. $\sigma = 6$, $\theta = 1.3$, $1/\nu = 0.5$					
Growth top 5 emp.	8.7	6.2	9.5	11.5	17.4
Growth pop.	2.7	0	3.6	5.8	12.4
Growth top 5 emp. shares	6	6.2	5.9	5.7	5
Panel D. $\sigma = 6$, $\theta = 1.3$, $1/\nu = 0.7$, *permanent migration friction shocks*					
Growth top 5 emp.	8.7	6.2	9.8	11.9	16.3
Growth pop.	2.7	0	3.9	6.2	11.1
Growth top 5 emp. shares	6	6.2	5.9	5.7	5.2

Notes. The table reports the estimated coefficients of β^{reg} from the regression model $\triangle \ln y_{nt} = \beta^{reg}\text{RegEX}_{nt_0} + \epsilon_{nt}$ where RegEX_{nt_0} is the standardized regional export intensity defined in Equation (3.1). Column (1) reports the results for the total employment in the top 5 sectors, total population, and employment shares in the top 5 sectors of the baseline economy. Columns (2), (3), and (4) report the counterfactual results with no migration and the decreases by the p50 and p75 of the empirical distribution, respectively. Column (5) reports the counterfactual results with the decreases by the p50 only for migration flows to more export-oriented regions.