Internal Migration, Sectoral Reallocation, and Large Devaluation*

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Abstract

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

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

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1 Introduction

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

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

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

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

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

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

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

evidence suggest that sectoral and spatial reallocation of labor could have been interlinked through migration after the devaluation.

For sectoral reallocation, I regress region-sector employment shares in the top five most export-intensive manufacturing sectors (the top 5 sectors) on the regional export intensity interacted with event time dummies. I find that the employment share in the top 5 sectors of one region increased 3.6% higher relative to another with one standard deviation lower regional export intensity three years after the devaluation. For spatial reallocation, I similarly regress migration inflows between origin and destination regions on the regional export intensity of destinations interacted with event time dummies while controlling for origin-year fixed effects. I find that migration inflows of one region increased by 4.8% when compared to another whose regional export intensity of its destination were a one standard deviation lower three years after the devaluation. 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 evidence, I build a dynamic spatial general equilibrium model with trade and forward-looking migration and investment. I use this model to quantify the effects of migration frictions on amounts of sectoral reallocation of labor after the devaluation. The devaluation is modeled in a reduced-form fashion as four exogenous time-varying shocks: productivity, foreign demand, import price, and trade deficit shocks. These four shocks rationalize big drops in total factor productivity (TFP), expansion of exports, collapse in imports, and rapid decreases in trade deficits that are common features of emerging market economies after large devaluation episodes.[4]

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

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

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

sector employment shares to region-sector specific wages. Workers' migration decision determines population distribution across regions. The migration decision is governed by the elasticity of migration inflows to the average real incomes across destination regions.

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

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

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

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

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

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

If migration were temporarily not allowed after the devaluation, aggregate employment shares and export intensity of the top 5 sectors would have been 1.1 and 1.2% lower than those of the baseline economy with the observed migration flows. With the 50th percentile decrease of the empirically observed reductions, these aggregate outcomes would have increased by 1.2 and 0.6% higher relative to the baseline. These aggregate effects are mostly driven by workers' migration to more export-oriented regions.

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

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

Third, I contribute to the literature that studies the effects of large devaluations, surveyed by Burstein and Gopinath (2014) (see, e.g., Burstein et al., 2005; Cravino and Levchenko, 2017; Blanco et al., 2019; Bonadio et al., 2020; Auer et al., 2022). Alessandria et al. (2010) study inventory behavior of importers and trade dumpiness, Gopinath and Neiman (2014) large TFP drops due to decreased imports, and Blaum (2018) joint import and export decisions of big firms after 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 to the commodity price shocks in Brazil. Topalova (2010) and Dix-Carneiro and Kovak (2017) also find limited evidence after the trade liberalization episodes in India and Brazil, respectively. On the other hand, Greenland et al. (2019) find increased migration flows among young or less-educated workers into regions that were less exposed to the China shock in the US. Hakobyan and McLaren (2016) find that migration outflows of high school dropouts increased from regions negatively affected by NAFTA.

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

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

2 Data

The final data set has information on employment, gross output, and real capital stock of each region-sector, region-to-region migration shares, and sectoral trade. I aggregate data to 121 regions and 15 sectors. The sample period is between 1994 and 2004. See Appendix A for more detail on construction of the final data set.

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

I construct region-sector gross output by combining the Census of Establishment, the state-sector gross output obtained from Statistics Korea, and the IO tables from the World Input-Output Database (WIOD) 2013 release (Timmer et al., 2015). I allocate the aggregate gross output of each sector 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 calculated from the Census of Establishment.

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

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

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

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

3 Empirical Evidence on Sectoral and Spatial Reallocation of Labor

In this section, I provide two empirical evidence: (i) increases in sectoral reallocation of labor to relatively more export-intensive sectors within relatively more export-oriented regions and (ii) increases in spatial reallocation of labor to relatively more export-oriented regions after the devaluation occurred.

3.1 Sectoral and Regional Heterogeneity

I first graphically illustrate sectoral heterogeneity in expansionary effects on exports of the devaluation and regional heterogeneity in industrial composition in Figure 1. This sectoral and regional heterogeneity implies that each region would have been differentially affected by the devaluation.

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

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

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

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

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

regions tended to be ones with the higher top 5 employment shares.

3.2 Sectoral Reallocation of Labor

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

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

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

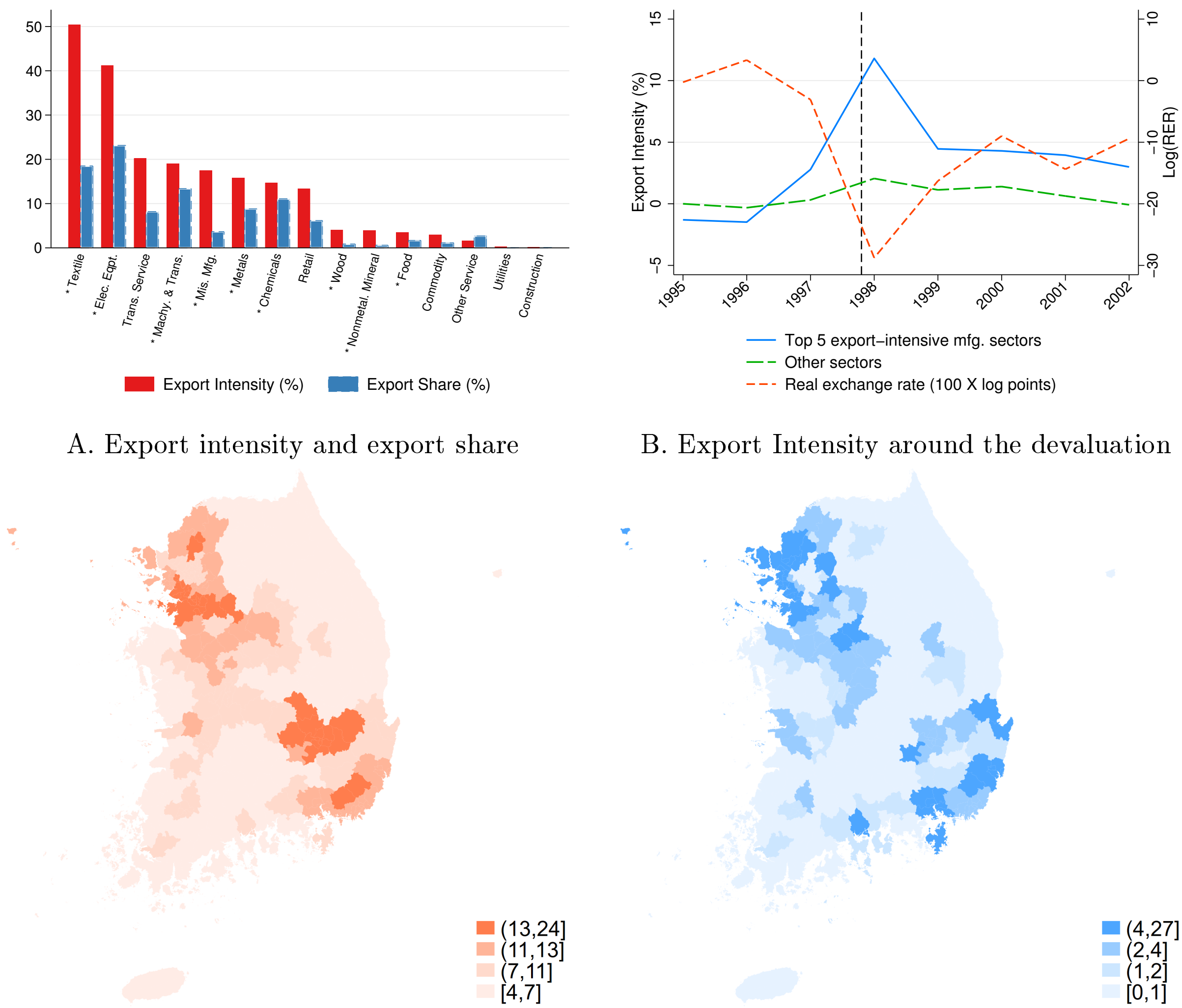
Figure 2 reports the results. In Panels A and B, dependent variables are the log of employment shares in the top 5 and the manufacturing sectors, respectively. A region experienced 3.6 and 1.4% higher increases in the top 5 and overall manufacturing employment shares than a region whose regional export intensity is 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 are geographically concentrated (Panels C and D of Figure 1), workers could have to move to relatively more expor-oriented regions to work in these more export-intensive sectors. To examine this spatial reallocation of labor, I consider the following event-study specification:

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

The dependent variables are changes in the log of migration shares μ_{nmt} between 1997 and 2000, which are defined as shares of total migrants from region n to m to lagged population of region n. $RegEX_{mt_0}$ is the standardized regional export intensity of destination region m. δ_{nm} are time-invariant pair fixed effects. δ_{nt} are origin-year fixed effects. I normalize β_τ and $\boldsymbol{\gamma}_0$ to be zero. $\mathbf{X}_{mt_0}$ are observables of destination region m in the initial period, in which I control for a log of total employment in 1994. To deal with statistical zeros, I estimate Equation (3.3) using Poisson Pseudo-



A. Export intensity and export share

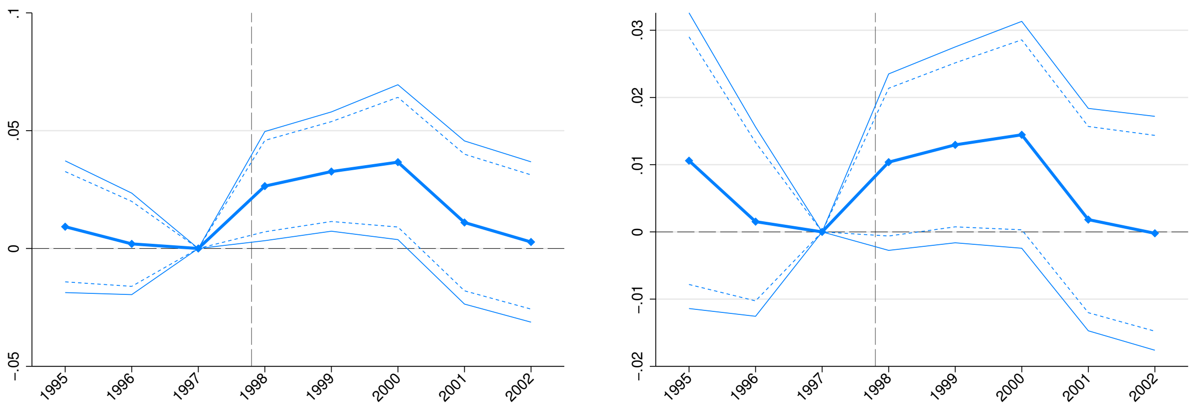
B. Export Intensity around the devaluation

C. Regional export intensity

D. Top 5 mfg. emp share

Figure 1. Sectoral and Regional Heterogeneity in Export Intensity

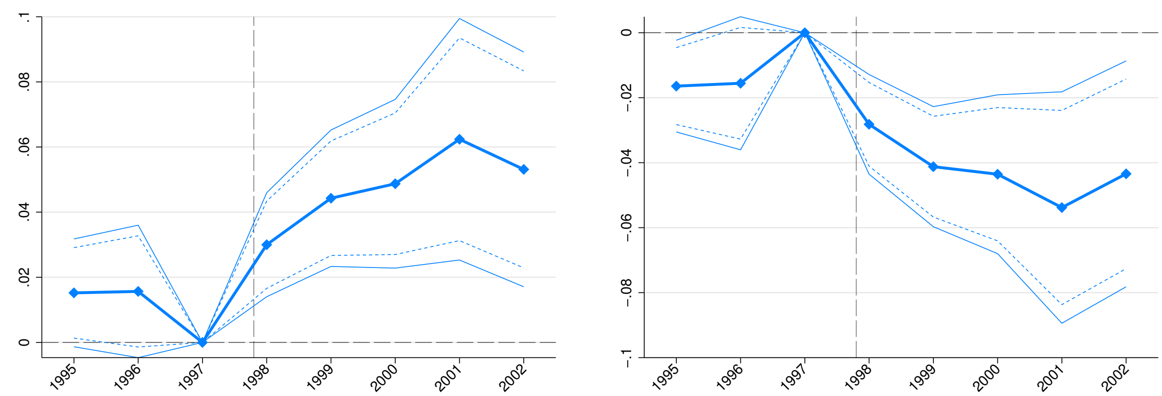
Note. Panel A plots the sectoral export intensity and export shares in 1993 that are defined as export value divided by gross output and shares of exports to the total exports, respectively. An asterisk * denotes manufacturing sectors. Plot B plots changes in the sectoral export intensity around the 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 a log of the real exchange rate. Panels C and D plot the regional export intensity defined in Equation (3.1) and the employment share in the top 5 sectors, respectively. Regions are colored based on the quartiles and colored darker with higher values.



A. Top 5 mfg. B. All mfg.

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

Note. This figure illustrates the estimated β_τ in Equation (3.2). In Panels A and B, the dependent variables are 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 $RegEX_{mt_0}$ 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 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. 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.

maximum likelihood (PPML) (Silva and Tenreyro, 2006).

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

4 Quantitative Framework

4.1 Model

Motivated by empirical evidence on sectoral and spatial reallocation of labor during the devaluation, I develop a dynamic spatial general equilibrium model to quantify the effects of migration frictions on sectoral reallocation after the 1998 large devaluation episode in Korea. Given that the devaluation was a transitory shock, transitional dynamics are important in this setup.

4.1.1 Environment

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

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

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

4.1.2 Production

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

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

where A_{njt} is region-sector level productivity, H_{njt} and K_{njt} are labor and capital inputs, M_{njt}^k is the 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 the 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 specific wages, R_{nt} is a rental rate of local capital, and P_{njt} is the price of intermediate inputs.

Final goods producer 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. Final goods are used as material inputs as well as final consumption goods and are non-tradable. The associated price index is

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

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

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

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

Sector j total export values of region n are

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

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

4.1.3 Workers

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

$$U(C_{nt}) = \ln(C_{nt}), \qquad C_{nt} = \prod_k (C_{nkt})^{\alpha_j}$$

where C_{nt} is region n workers' consumption at time t. The ideal price index is $P_{nt} = \prod_{k=1}^{J} (P_{nkt}/\alpha_k)^{\alpha_k}$. 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 incomes for consumption each period.

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

I assume that skills of each member in region n are independently and identically drawn from a multivariate Frechét distribution across regions and time: $F_{nt}(\boldsymbol{\epsilon}_t) = exp(-\sum_{j\in\mathcal{J}} E_{njt}\epsilon^{-\theta}_{njt})$ with $\theta > 1$ (Eaton and Kortum, 2002; Lagakos and Waugh, 2016; Hsieh et al., 2019). θ is the shape parameter of the Frechét distribution that governs the dispersion of skills across members, with the higher value of θ corresponding to smaller dispersion. E_{njt} is the region-sector level location parameter that can be interpreted as region-sector labor productivity. I introduce this labor productivity to account for rapid decreases in manufacturing employment shares but relatively constant manufacturing GDP shares during the sample period.[8] This pattern can be rationalized by decreases in E_{njt} and increases in overall productivity A_{njt}.

Given sectoral wages, a worker allocates its available members across sectors to maximize the total sum of wages earned by her members. A worker allocates member i to sector j only if it generates the highest wage over other sectors, that is, $\epsilon^i_{njt} \in \Omega_{njt}$, where $\Omega_{njt} = \{\boldsymbol{\epsilon}_t | W_{njt}\epsilon_{njt} \geq W_{nkt}\epsilon_{nkt}, \forall k \in \mathcal{J}\}$. Shares of members allocated to sector j are expressed as:

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

[8] During the sample period, manufacturing employment shares decreased from 21.4 to 19.1% but manufacturing value-added shares remained constant at 23%. Similar results also hold for the top 5 most export-intensive sectors.

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:[9]

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

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

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

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

The dynamic problem of workers is

$$\mathrm{v}_{nt} = \ln(C_{nt}) + \max_{m\in\mathcal{N}} \{\beta V_{mt+1} - \tau_{nmt} + \eta_{mt}\}.$$

I assume that η_{mt} is distributed Type-1 Extreme Value with zero mean with the parameter ν.[10] The life time expected utility is defined as $V_{nt} = \mathbb{E}[\mathrm{v}_{nt}]$, where the expectation is taken over the idiosyncratic 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:

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

The above expression indicates that all things equal, workers migrate more into regions with higher

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

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

expected lifetime utility net of migration frictions, with the migration elasticity $1/\nu$. The migration elasticity governs how migration shares are sensitive to changes in expected lifetime utilities and migration frictions. The lower migration elasticity implies that location choices are more persistent. With the distribution of population, L_{nt} across regions in t, the population of the next period evolves as

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

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

4.1.4 Capital Accumulation

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

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

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

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

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

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

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

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

4.1.5 General Equilibrium

Market clearing Goods market clearing of final goods requires that

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

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

$$W_{njt}H_{njt} = \gamma_j^H GO_{njt}. \tag{4.14}$$

Capital market clearing requires that landlords' capital incomes 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

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

Equilibrium Let $\mathbf{\Psi}_t = \{A_{njt},\ P_{jt}^F,\ D_{jt}^F,\ \iota_t, E_{njt}\}$. 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, capital returns, and capital stock $\{L_{nt},\ \lambda_{njt},\ W_{njt},\ V_{nt},\ \lambda_{njt},\ K_{n,t+1}\}_{t=t_0}^{\infty}$ that satisfies the following condition for each region n, each sector j, and all time periods t: (i) Given W_{njt}, a worker optimally allocates her members across different sectors (Equation (4.6)); (ii) $\{V_{nt}\}$ satisfies Equation (4.8); (iii) L_{nt} evolves according to Equation (4.10); (iv) $\{K_{n,t+1}\}$ evolves according to Equation (4.12); (v) goods, labor, and capital market clearing conditions are satisfied (Equations (4.13), (4.14), and (4.15)).*

4.2 Devaluation and Sectoral Reallocation

Devaluation I model the devaluation as four time-varying exogenous shocks in a reduced-form fashion:

$$\mathbf{\Psi}_t^d = \{A_{njt}, P_{jt}^F, D_{jt}^F, \iota_t\} \subset \mathbf{\Psi}_t.$$

These four shocks capture common features of emerging market economies after devaluation episodes. Decreases in A_{njt} rationalize large TFP drops; increases in D_{jt}^F (P_{jt}^F) large increases (decreases) in exports (imports) due to depreciated real exchange rates; and ι_t rapid decreases in trade deficits.

Sectoral reallocation The total amounts of members working in sector j (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.[11] θ affects changes in sectoral employment shares within regions conditional regional population in time t, related to the first empirical finding. $1/\nu$ affects the evolution of regional population through migration flows, related to the second empirical finding.

4.3 Counterfactual

I examine how amounts of sectoral reallocation and transition path of the baseline economy would have differed from the counterfactual economies with different migration friction levels after the devaluation. Our counterfactuals do not consider specific migration policies but hypothetical reductions in migration frictions in Korea.

To perform counterfactuals and solve for transition paths, I utilize a dynamic hat algebra developed by Caliendo et al. (2019). The dynamic hat algebra allows us to solve the model in time differences without knowing information about fundamentals in level. For any variable x, I denote time differences as $\hat{x}_{t+1} = x_{t+1}/x_t$. To perform counterfactuals, I require (i) the initial allocation in 1997; (ii) the exogenous shocks; (iii) structural parameters including sectoral labor supply and migration elasticities (θ and $1/\nu$); and (iv) migration friction shocks ($\hat{m}_{nmt} \equiv \exp(\tau_{nm,t+1} - \tau_{nmt})$).

For the baseline, I assume there are no changes in migration frictions and feed in the exogenous shocks $\hat{\boldsymbol{\Psi}}_t$ and compute the transition path of the economy. Given that my focus is the transitory effects of migration frictions on transition paths after the devaluation, I assume that migration frictions of the counterfactuals temporarily differ from those of the baseline only up to five years and move back to the original level six years after the devaluation. To do so, I feed in transitory migration friction shocks jointly with $\hat{\boldsymbol{\Psi}}_t$ 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 shocks 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 in 1997, 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 each region has positive employment shares for 15 sectors, and migration flows between regions are positive. Table 1 reports a summary of the calibration procedure. See Appendix Section C for detail.

[11] 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, which are not available in my data set. However, unlike the model of Caliendo et al. (2019) where workers' decisions are governed by

Table 1: Summary of Calibration

Parameters	Value	Description	Target
Elasticities			
$1/\nu$	0.65	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			
$\{d^j_{mn}\}$		Migration friction	Equation (4.21)
$\{\xi_j\}$	0.26, 0.4	Trade cost	Monte et al. (2018), Eckert (2019)
Shocks			
$\{A_{njt}\}$		Productivity shock	Gross output, PPI
$\{D^F_{jt}\}$		Foreign demand shock	Aggregate exports
$\{P^F_{jt}\}$		Import price shock	Aggregate imports
Preferences			
β	0.96	Discount factor	Literature
$\{\alpha_j\}$		Final consumption shares	IO table
Production			
$\{\gamma^k_j\}$		IO coefficients	IO table
$\{\gamma^V_j\}$		Value-added shares	IO table
$\{\gamma^H_j/\gamma^V_j\}$	0.66	Labor share	Literature
δ	0.05	Depreciation rate	Literature

Notes. This table summarizes the calibration results.

4.4.1 Initial Allocation

I need the initial allocation of $\{GO_{njt_0},\ \lambda_{njt_0},\ \mu_{nmt_{-1}},\ L_{nt_0},\ K_{nt_0},\ K_{n,t_0+1},\ EX_{njt_0},\ \pi^j_{nmt_0},\ \pi^j_{Fnt_0}\}$ to apply the dynamic hat algebra. I obtain region-sector employment shares, gross output, and real capital stock, and region-to-region migration shares from the data described in Section 2. Exports and import shares of region-sectors and region-to-region trade flows are not directly observable from the data. Therefore, I indirectly infer these variables from sectoral exports and import shares, region-sector gross output, and the gravity structure of trade.[12]

a single elasticity, workers' decisions in my model are governed by two elasticities.

[12] Gervais and Jensen (2019), and Eckert (2019) similarly infer trade flows using region-sector gross output and gravity structure of trade.

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 E_{njt}.[13] I obtain data on region-sector nominal wages W_{njt} from the Mining and Manufacturing Survey. Because the survey only covers establishments of the mining and manufacturing sectors, I run the above regression only for the mining and manufacturing sectors. δ_{nj}, δ_{nt}, and δ_{nj} are region-sector, region-year, and sector-year fixed effects. δ_{nt} absorb region n's average wage W_{nt}. I cluster standard errors at the region-sector level.

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

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

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

To use the data more efficiently, I estimate Equation (4.17) using overlapping 3-year long-differences: 1996-1999 and 1997-2000. The estimated coefficient is 1.34 and statistically significant at 5%. The first stage F-statistics is 9.4, which is below the rule of thumb value of 10. Therefore, I conduct inference based on the Anderson-Rubin (AR) statistic that is robust to weak instruments following the recommendation of Andrews et al. (2019). The AR statistic also rejects the null at 1%. The estimated value of 1.34 is in line with the previous estimates in the literature.[14]

Migration elasticity Following Artuc et al. (2010), I can derive the following regression model[15]:

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

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

[14] 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.

[15] The expression implies that current migration flows reflect the futures values of expected real wage and the option values, where the future migration flows are the sufficient statistics for the option values. Conditioning on the option values, the variation of wage differences across regions identify the migration elasticity $1/\nu$. $\tilde{\epsilon}_{nmt}$ has a structural interpretation of migration friction shocks.

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

To run the above regression, I need information on I_{nt} and P_{nt}. After assuming that labor shares of value-added are 0.66 constant across regions and sectors as standard in the literature, I calculate I_{nt} by dividing the labor share of the total sum of the value-added across sectors in region n by the total number of the employed multiplied by observed $(1 + \iota_t)$ that rationalizes trade deficits.[16] Regional price levels P_{nt} are obtained from the regional Consumer Price Index (CPI) data. The Korean statistical agency only reports CPI data of the selected regions, so I impute regional CPI data for regions with missing information using housing price data available for all regions following Moretti (2017).[17]

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

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

The identifying assumption of the IV holds when migration frictions shocks are uncorrelated with the differences in regional demand shocks due to increases in exports. I estimate Equation (4.19) in first differences for the sample period between 1997 and 2000. The estimated coefficient is 0.69 and is statistically significant at 1% level. This estimate is also in line with the estimates from the previous papers.[18]

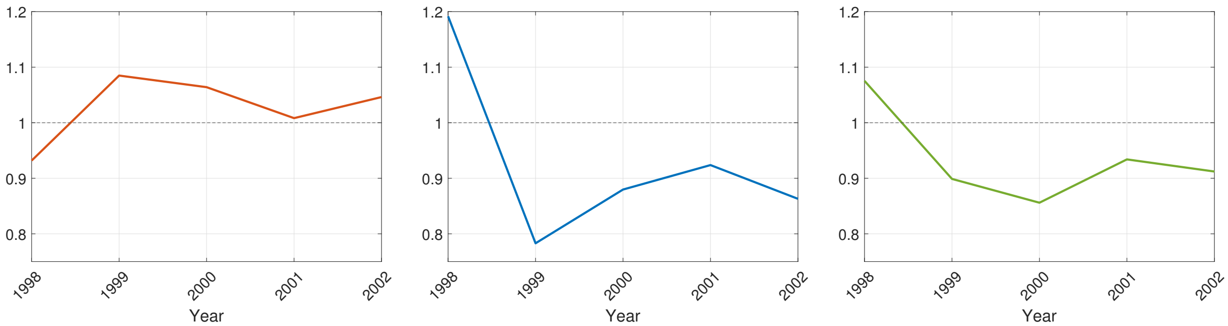
Trade costs I parametrize domestic bilateral trade costs as a function of physical distance: $d^j_{nm} = dist^{\xi_j}_{nm}$ where $dist_{nm}$ is distance between regions and ξ_j are parameters that potentially vary across sectors. I set $(\sigma - 1)\xi_j$ to be 1.29 for commodity and manufacturing sectors and 2 for service sectors based on the estimates from Monte et al. (2018) and Eckert (2019), respectively. I parametrize international trade cost $d^j_{Fn} = (pdist_n)^{\xi_j}$ where $pdist_n$ is the minimum distance to port of region n.[19]

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

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

[18] Among many previous papers that estimated migration elasticity, the closest set up is Caliendo et al. (2021) whose estimate is around 0.5.

[19] Any sector j import and export trade costs that are common across regions are not separately identifiable from P^F_{jt} and D^F_{jt}, so d^j_{Fn} are interpreted as the costs relative to those of regions with ports.



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 exports of the previous period for productivity, import price, and foreign demand shocks, respectively. See Appendix Section C.5 for the calibration procedure in more detail.

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 $\hat{\boldsymbol{\Psi}}_t$ by fitting the model to the data between 1997 and 2002 following the inversion logic (Allen and Arkolakis, 2014). Productivity shocks are identified from gross outputs and sectoral producer price indices (PPI); foreign demand shocks from aggregate exports; foreign import price shocks from aggregate import shares; and labor productivity shocks from region-sector level employment shares.[20] Trade deficits are taken directly from the data.

Figure 4 presents the weighted average of these shocks, where the weights are given by region-sector level gross output, sectoral imports, and sectoral exports of the previous period for productivity, import price, and foreign demand shocks, respectively. After the large devaluation occurred in 1998, the average productivity, foreign demands, and import prices decreased by 2.1%, increased by 18.9%, and increased by 7.3%, relative to 1997. There were decreasing trends in labor productivity of the manufacturing sectors that account for decreasing trends in manufacturing employment shares of the data. If I do not account for such trends, the quantitative results may overstate the effects of migration frictions on labor reallocation toward export-intensive manufacturing sectors after the devaluation.

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

4.4.4 Migration Frictions

Following Head and Ries (2001), I infer migration frictions from the observed migration flows under the symmetry.[21]:

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

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

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

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

where τ^{c}_{nmt} is the counterfactual migration friction. I consider three counterfactual scenarios. First, I consider a case where migration is now allowed. In the remaining two, I use the distribution of the inferred $\hat{\mathfrak{m}}_{nmt}$ to conduct counterfactuals for empirically realistic changes in migration frictions following Monte et al. (2018). I consider a common decrease by the 50th and 75th percentile of the observed changes between 1997 and 2017 across all regions (11 and 28% reduction). In all the counterfactual scenarios, migration frictions move back to the original level in 2003.

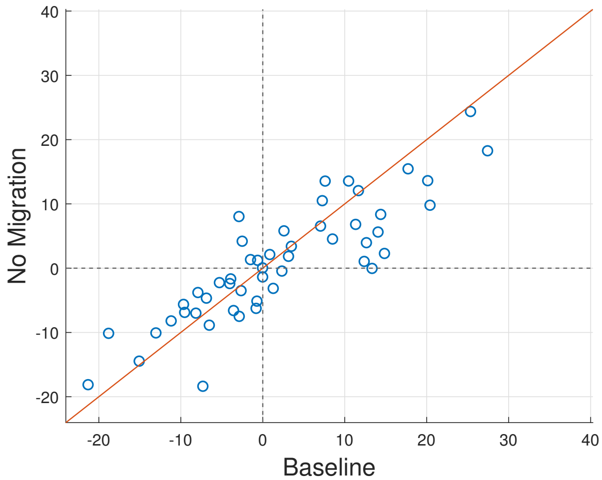
4.5 Quantitative Results

Table 2 reports aggregate top 5 employment shares, top 5 export intensity, and overall export intensity three years after the devaluation. Column (1) reports the results of the baseline economy. In the baseline with no changes in migration frictions, aggregate top 5 employment shares, top 5 export intensity, and overall export intensity are 18.47, 34.85, and 17.19%, respectively. In column (2), where migration is temporarily not allowed, these aggregate outcomes are 1.3, 1, and 1.4% lower than those in the baseline. In columns (3) and (4), I consider temporary decreases in migration frictions based on the empirically observed reductions. With the decrease by the 50th in column (3), these aggregate outcomes are 1.2, 0.6, and 1.1% higher than those in the baseline.

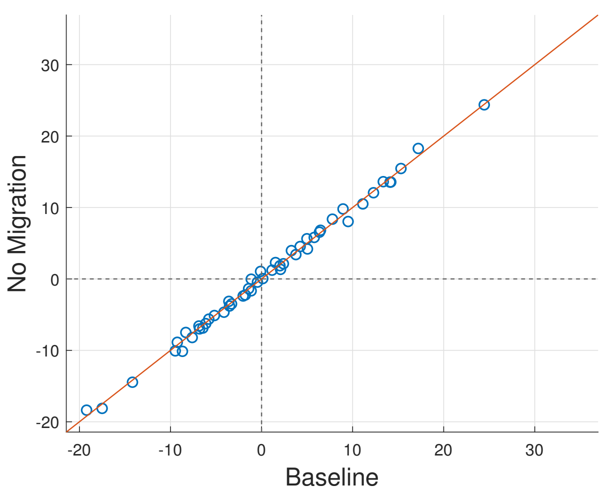
The aggregate effects of the migration frictions of Table 2 are driven by the migration of workers to more export-oriented regions. In Table 3, I regress the growth rate of regional outcomes of interest

[21] Either real wage differentials or migration frictions explain observed differences in migration shares. However, higher migration frictions decrease bilateral movements of migrants between m and n relative to own migration shares, whereas higher real wages increase both bilateral inflow and own shares. By dividing bilateral flows by their own shares, real wage differentials are exactly canceled out, capturing the symmetric bilateral cost components.

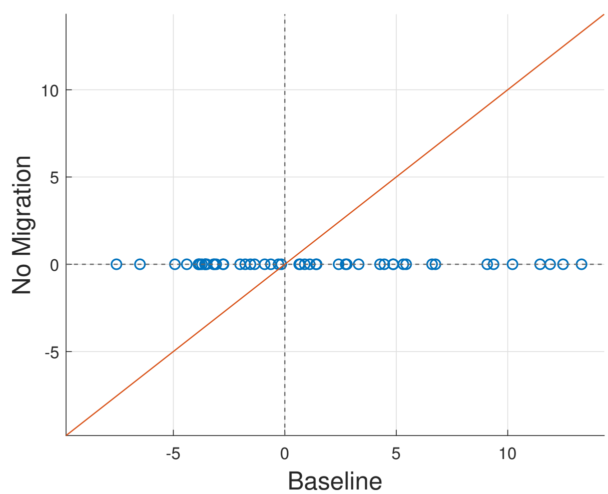
[22] The magnitude of 11 and 28% is consistent with Monte et al. (2018) who find that there were 12 and 21% reduction at the 50 and 75th of the empirical distribution of commuting cost changes in the US between 1990 and 2010.



A. Growth of the top 5 employment



B. Growth of the top 5 employment shares



C. Growth of population

Figure 5. Migration Frictions and Sectoral Reallocation of Labor: Baseline vs. No Migration Counterfactual

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

Table 2: Aggregate Effects of Migration Frictions

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

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

Table 3: Regional Effects of Migration Frictions

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

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

between 1997 and 2000 on the standardized regional export intensity:

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

and report the estimated $\hat{\beta}^{reg}$. Because $RegEX_{nt_0}$ is standardized, β^{reg} can be interpreted as changes in growth rate when the regional export intensity increases by a one standard deviation.

The first, second, and third rows report the growth of the top 5 employment, population, and the top 5 employment shares, respectively. In all baseline and counterfactual economies, regions with higher $RegEX_{nt_0}$ tend to experience relatively higher growth in these three outcomes, as shown by the positive estimates. However, the magnitude of $\hat{\beta}^{reg}$ differs across the economies depending on levels of migration frictions. When migration frictions become lower, there are larger increases in population and employment in the top 5 sectors in regions with higher $RegEX_{nt_0}$ due to increased migration. However, at the same time, this increased labor supply decreases wages and, therefore, the top 5 employment shares. These results are reflected by higher (lower) $\hat{\beta}^{reg}$ with lower migration frictions for the top 5 employment and the population (the top 5 employment shares).

Figure 5 illustrates the growth of the top 5 employment, population, and the top 5 employment shares under the baseline economy and the counterfactual economy where migration is not allowed. There are large variation in the growth of the top 5 employment between these two economies (Panel A). Because $L_{njt} = \lambda_{njt} L_{nt}$, the variation in the growth of the top 5 employment can come from the variation in the top 5 employment shares within regions (λ_{njt}) or population (L_{nt}). The figure shows that most of these variation in the top 5 employment come from the variation in population rather than those in the top 5 employment shares (Panels B and C). The variation in the top 5 employment shares explain about 1.1% of the total variation in the top 5 employment growth.[23]

Appendix Tables C7 and C8 reports the results under different values of substitution elasticity σ, sectoral labor supply elasticity θ, and migration elasticity $1/\nu$. The quantitative results are robust to different values of the parameters.

5 Conclusion

This paper studies the role of internal migration and its frictions on sectoral reallocation of labor after the 1998 Korean devaluation. Using cross-sectional variation in industrial composition and event-study specifications, I provide empirical evidence that workers reallocated to more export-intensive sectors within regions and to more export-oriented regions. These findings motivate that sectoral and spatial reallocation of labor could have been interlinked.

Motivated by these empirical findings, I build the dynamic spatial general equilibrium model to quantify the effects of migration frictions on short-run adjustment of labor. I use observed migration flows between regions to infer the empirical distribution of changes in migration frictions between 1997 and 2017. When migration is not allowed, aggregate employment shares and export intensity of the top five most export-intensive sectors would have decreased by 1.1 and 1.2%. 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 imply that spatial linkages across factor markets can play an important role in shaping the aggregate adjustment of an economy to large sector-specific shocks.

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

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ONLINE APPENDIX

(NOT FOR PUBLICATION)

A Appendix: Data

A.1 Data Construction

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

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

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

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

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

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

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

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

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

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

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

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

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

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

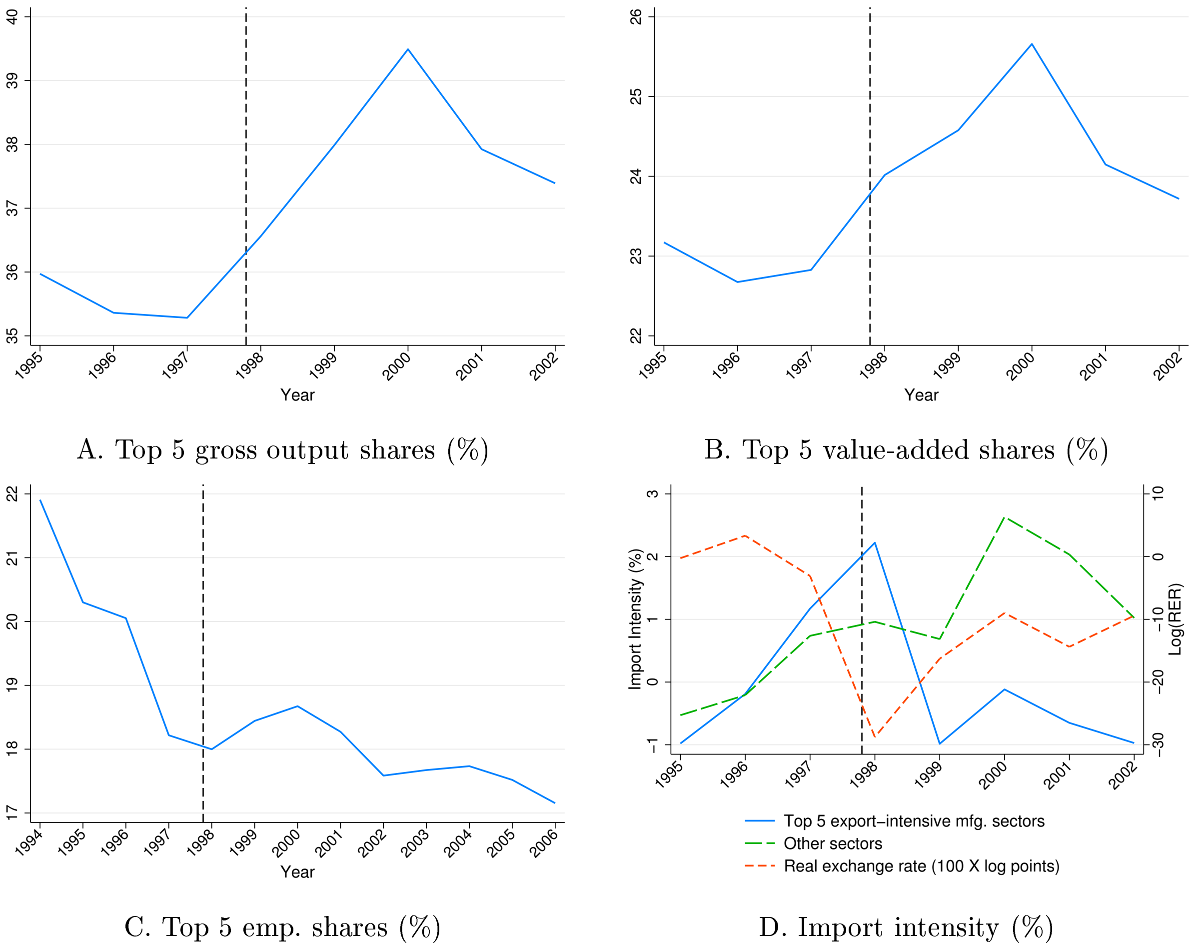
Sectoral imports and exports Sectoral imports and exports are obtained from the World Input-Output Database (WIOD).

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

Table A4: Sector Classification

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

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



A. Top 5 gross output shares (%)

B. Top 5 value-added shares (%)

C. Top 5 emp. shares (%)

D. Import intensity (%)

Figure A6. Aggregate Patterns after the Devaluation

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

B Appendix: Theory

B.1 Landlords' Intertemporal Utility Maximization Problem

Landlords' utility maximization problem can be written as:

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

I can rewrite this problem as the following Lagrangian:

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

The first order conditions are

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

and

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

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

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

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

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

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

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

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

B.2 Derivation of Workers' Welfare Equations

I denote V_{nt} bet the present discounted value of utility at period t in region n under the counterfactual changes in shocks $\{A'_{nt}, FMA'_{nt}, CMA'_{nt}\}$ and let V_{nt} be the same object under the sequence of shocks $\{A_{nt}, FMA_{nt}, CMA_{nt}\}$. I can write the expected lifetime utility of living in region n at period t as

$$V_{nt} = \ln C_{nt} + \beta V_{n,t+1} + \nu \ln\left(\sum_m exp(\beta(V_{m,t+1} - V_{n,t+1}) - \tau_{nm,t} + B_{n,t})^{\frac{1}{\nu}}\right) \tag{B.1}$$

where the second term on the RHS of the above equation is the option value of beginning at region n at period t. This option value can be expressed as its own migration share, that is,

$$\nu \ln \left(\sum_m exp(\beta(V_{m,t+1} - V_{n,t+1}) - \tau_{nm,t} + B_{n,t})^{\frac{1}{\nu}} \right) = -\nu \ln \mu_{nnt}. \tag{B.2}$$

Plugging this into the value function, I get

$$V_{nt} = \ln C_{nt} + \beta V_{n,t+1} - \nu \ln \mu_{nnt}. \tag{B.3}$$

Iterating the above equation, I obtain

$$V_{nt} = \sum_{s=0}^{\infty} \beta^{s-t} \ln C_{ns} - \nu \sum_{s=t}^{\infty} \beta^{s-t} \ln \mu_{nn,s}. \tag{B.4}$$

Using the above expression, I can express the lifetime utilities in the baseline and the counterfactual economy as follows:

$$V_{nt} = \sum_{s=t}^{\infty} \beta^{s-t} \ln \left(\frac{C_{ns}}{(\mu_{nn,s})^{\nu}} \right), \qquad V'_{nt} = \sum_{s=t}^{\infty} \beta^{s-t} \ln \left(\frac{C'_{ns}}{(\mu'_{nn,s})^{\nu}} \right) \tag{B.5}$$

The changes in welfare between the baseline and counterfactual are measured in terms of compensating variation, defined as the scalar δ_n^{wel} that satisfies

$$\sum_{s=t}^{\infty} \beta^{s-t} \ln \left(\frac{\delta_n^{wel} C_{ns}}{(\mu_{nn,s})^{\nu}} \right) = V'_{nt}. \tag{B.6}$$

Rearranging the equation,

$$\ln \delta_n^{wel} = (1 - \beta) \sum_{s=t}^{\infty} \beta^{s-t} \ln \left(\frac{(W'_{ns}/W_{ns})}{(P'_{ns}/P_{ns})(\mu'_{nn,s}/\mu_{nn,s})^{\nu})} \right).$$

C Appendix: Quantification

C.1 Regression Model of Sectoral Labor Supply Elasticity

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

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

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 shocks, $\tilde{e}_{nj}$ is time-invariant region-sector fixed effects, and $\tilde{e}_{njt}$ is region-sector-year specific shocks. Then, the above regression model can be re-expressed as in Equation (4.17):

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

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

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

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

Table C5: Estimation of Sectoral Labor Supply Elasticity θ

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

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

C.2 Regression Model of Migration Elasticity

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

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

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

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

Using Equation (4.8), this can be written as

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

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

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

I assume that migration costs consist of time-invariant and time-varying components: $\tau_{nmt} = \tau_{nm} + \tilde{\tau}_{nmt}$. This gives me the following estimable regression model:

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

where $\delta_{nm} = (1-\beta)/\nu\tau_{nm}$ and $\tilde{\epsilon}_{nmt} = 1/\nu \times (\tilde{\tau}_{nmt} - \tilde{\tau}_{nm,t+1})$.

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 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 the missing information. For the subset of regions with non-missing CPI, I run the following regression:

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

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

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

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

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

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

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

C.3 Shock Formulation of the Model

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

Static equilibrium Unit costs are expressed as:

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

Price indices are expressed as:

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

Domestic trade shares are

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

Import trade shares are

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

Exports are

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

Average wages of each region are

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

Workers' incomes are

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

Regional employment shares are

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

Sectoral labor supply is given by

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

Goods market clearing implies that

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

Labor market clearing implies that

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

Capital market clearing implies that

$$K_{nj,t+1} = \left(\frac{(\gamma^K_j/\gamma^L_j)\hat{W}_{nj,t+1}\hat{H}_{nj,t+1}W_{njt}H_{njt}}{\sum\limits_{k\in\mathcal{J}}(\gamma^K_k/\gamma^L_k)\hat{W}_{nk,t+1}\hat{H}_{nk,t+1}W_{nkt}H_{nkt}}\right)K_{n,t+1}$$

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

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

Capital stock evolves according to

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

Landlords' consumption shares evolve according to

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

Migration shares are expressed as

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

Population evolves according to

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

Value functions are given by

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

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

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

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

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

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

Taking exponential from both sides and using the expressions of $\hat{u}_{n,t+1}$ and $\mu_{nm,t+1}$,

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

C.4 Algorithm

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

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

- Step 2. Based on the guessed consumption rates and the observed allocation of capital $\{K_{n0}\}$ and $\{K_{n1}\}$, set the gross return of capital at time 0 as follows:

$$R_{i0} = \frac{K_{n1}}{K_{n0}}(1 - \zeta_{n0}^{(0)}).$$

- Step 3. Given the initial allocation of migration shares $\{\mu_{nm0}\}$, using the guessed $\{\hat{u}_{nt}\}_{t=1}^{T} + 1$, compute path of migration shares $\{\mu_{nmt}\}_{t=1}^{T+1}$:

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

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

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

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

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

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

- Step 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 $t+2$:

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

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

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

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

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

C.5 Calibration of Shocks and Trade Shares

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

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

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

  where

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

  hold.

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

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

- Step 3. In the second step, I pin down the unit costs of the reference region for each sector using sectoral PPI data. For each region-sector level, price indices can be written as follows:

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

  Because I obtained $\bar{c}_{njt}$ and $\bar{P}^F_{jt}$ in the previous step, changes in prices is pinned down by $\hat{\tilde{c}}_{n_0jt}$

for each region:

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

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

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

where $\omega_{njt} \equiv \frac{GO_{njt}}{\sum_{m\in\mathcal{N}} GO_{mjt}}$ is the gross output weight of region n in sector j total gross output in $t-1$. Because $\hat{P}_{njt}$ is a function of $\hat{\bar{c}}_{n_0j,t+1}$, $\hat{P}^{ag}_{jt}$ is pinned down by $\hat{\bar{c}}_{n_0j,t+1}$.

Then, I choose one reference sector j_0 and pin down $\hat{\bar{c}}_{n_0jt}/\hat{\bar{c}}_{n_0j_0t}$ by fitting the PPI changes relative to the reference sector $\widehat{PPI}_{jt}/\widehat{PPI}_{j_0t}$.

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

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

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

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

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

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

- Step 6. The remaining object is productivity shocks $\hat{A}_{nj,t+1}$. $\hat{\bar{c}}_{njt}$ 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 $\hat{\bar{c}}_{nj,t+1}$. To do so, I solve the model and back out $\hat{A}_{nj,t+1}$ by fitting the computed $\hat{\bar{c}}_{nj,t+1}$. I use the following algorithm:

  1. Guess $\{\hat{A}^{(0)}_{nj,t+1}\}$
  2. Solve the model using the algorithm described in Section C.4.

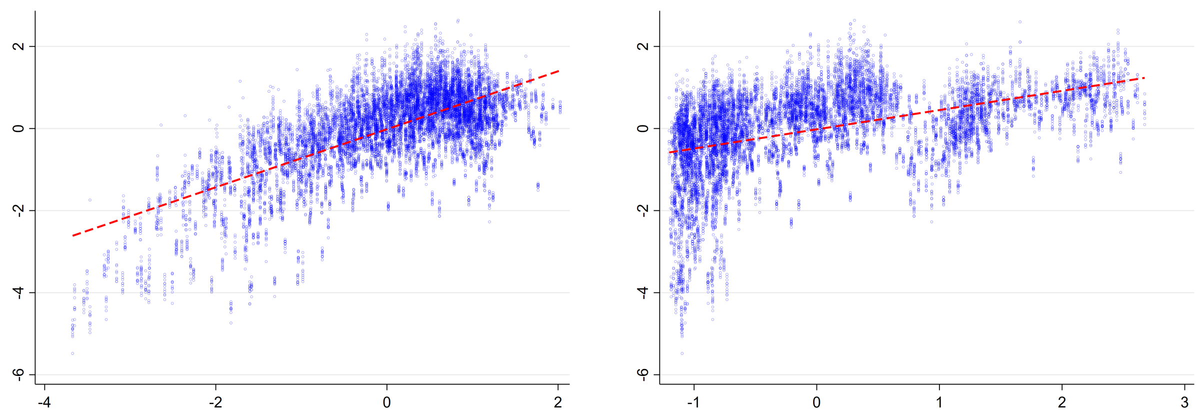
3. Compare changes in $\hat{c}^0_{nj,t+1}$ computed from the model to $\hat{c}_{nj,t+1}$ obtained in the Step 5.
4. If $\hat{c}^0_{nj,t+1} > \hat{c}_{nj,t+1}$, decreases $\hat{A}^{(0)}_{nj,t+1}$ and vice versa.
5. Make a new guess based on the adjusted $\hat{A}^{(0)}_{nj,t+1}$ in the previous step.
6. Iterate steps 2-5 until $|\hat{c}^0_{nj,t+1} - \hat{c}_{nj,t+1}| < \epsilon$ holds for some threshold ϵ

C.6 External Validation of Migration Costs

In this section, I show that migration costs correlate with euclidean distance and political distance between regions, which externally validates the estimated migration costs. Figure C7 plots log of the estimated migration frictions against the log of distance and political distance. I measure the political distance using each candidate's share of the vote in the 1992 14th presidential election in each region, which happened six years before the Asian Financial Crisis. I compute the political distance between two regions m and n as

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

where π_n^c is the candidate c's share of votes in the region n. One standard deviation increase in the log of Euclidean cost and political distance is correlated with 0.70 and 0.38 standard deviation increase in the log of the measured migration costs.



A. Log Euclidean Distance
$\beta = 0.70$; t-stat = 194.05

B. Political Distance
$\beta = 0.38$; t-stat = 158.51

Figure C7. Correlates of Migration Costs in Korea

Notes. Panels A and B are the scatter plots between the log of migration costs and the log of Euclidean distance and the political distance defined in Equation (C.4). Log of migration costs, log of Euclidean distance, and political distance are standardized. Migration costs are backed out from Equation (4.21) and demeaned by year.

C.7 Robustness. Different Parameter Values

Table C7: Robustness. Aggregate Effects of Migration Frictions

	Baseline	No migration	Decrease by p50	Decrease by p75
	(1)	(2)	(3)	(4)
		Panel A. $\sigma = 4$, $\theta = 1.3$, $1/\nu = 0.66$		
Top 5 emp. shares (%)	18.4	18.2	18.5	18.7
Top 5 export intensity (%)	34.9	34.6	35.1	35.5
Overall export intensity (%)	17.2	17.1	17.3	17.6
		Panel B. $\sigma = 6$, $\theta = 2$, $1/\nu = 0.66$		
Top 5 emp. shares (%)	18.4	18.2	18.6	18.8
Top 5 export intensity (%)	34.9	34.5	35.1	35.6
Overall export intensity (%)	17.2	17.0	17.4	17.6
		Panel C. $\sigma = 6$, $\theta = 1.3$, $1/\nu = 0.5$		
Top 5 emp. shares (%)	18.4	18.2	18.6	18.8
Top 5 export intensity (%)	34.9	34.5	35.1	35.6
Overall export intensity (%)	17.2	17.0	17.3	17.6

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

Table C8: Robustness. Regional Effects of Migration Frictions

	Baseline	No migration	Decrease by p50	Decrease by p75
$\triangle \ln y_{nt} = \beta^{reg} RegEX_{nt_0} + \epsilon_{nt}$	(1)	(2)	(3)	(4)
		Panel A. $\sigma = 4,\ \theta = 1.3,\ 1/\nu = 0.66$		
Growth top 5 emp.	8.8	6.3	9.8	11.8
Growth pop.	2.8	0	4	6.2
Growth top 5 emp. shares	6	6.3	5.9	5.7
		Panel B. $\sigma = 6,\ \theta = 2,\ 1/\nu = 0.66$		
Growth top 5 emp.	8.7	6.3	9.8	11.8
Growth pop.	2.7	0	4	6.2
Growth top 5 emp. shares	6	6.3	5.9	5.6
		Panel C. $\sigma = 6,\ \theta = 1.3,\ 1/\nu = 0.5$		
Growth top 5 emp.	8.6	6.2	9.6	11.6
Growth pop.	2.6	0	3.7	5.9
Growth top 5 emp. shares	6	6.2	5.9	5.7

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