Internal Migration, Geography, and Large Devaluation*

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Abstract

How internal migration and its frictions affect amount of sectoral reallocation and welfare changes in the aftermath of a large devaluation? Because of asymmetric expansionary effects of a devaluation on exports across sectors and differences in industrial composition across regions, regions are heterogeneously affected by a devaluation. Using regional employment and internal migration data following the 1998 Korean devaluation, I provide causal evidence on a sizable increase in internal migration into regions whose industry composition is more export-oriented. To quantify these effects of internal migration and its frictions, I build a quantitative dynamic spatial general equilibrium model of trade and internal migration. The model is calibrated to region-sector level data. Had there been no internal migration after the devaluation, aggregate welfare would have decreased 9% more, and there would have been 4% less amount of sectoral reallocation when compared to the economy with the amounts of internal migration observed in the data. Because of the local heterogeneous exposure to the devaluation, the devaluation had large distributional effects across regions. However, internal migration mitigated these distributional effects.

JEL Codes: F16, F31, F41, O24, J61, R12, R15, R23

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1 Introduction

A large devaluation is associated with a large depreciation in the real exchange rate and dramatic changes in exports and imports of tradable sectors. When a real exchange rate gets depreciated, foreign demand for domestic goods rises, increasing exports to foreign markets. However, a real exchange rate depreciation also makes foreign imports to be more expensive, decreasing imports from foreign countries. Depending on export and import intensities, each sector is differentially affected by a devaluation. Given these asymmetric effects of a devaluation on sectoral trade, if labor can be flexibly reallocated across sectors after a devaluation, the recessionary effects of a devaluation can be mitigated. However, if the costs of adjusting sectoral labor reallocation are high, the amount of sectoral reallocation will be limited, decreasing the overall efficiency of an economy after a devaluation occurs.

Sectoral reallocation is spatial by nature. Because each region has its own unique industrial composition and comparative advantage, the asymmetric effects of a devaluation on exports and imports affect each region heterogeneously. For example, regions whose industrial composition is more export-oriented (or that have a larger comparative advantage in export-intensive sectors) may be relatively better off after a devaluation when compared to other regions. If these regional differences become sufficiently large after a large devaluation, workers may migrate into these more export-oriented regions to work in export-intensive sectors. However, if the cost of migration across regions is high, the amount of sectoral reallocation accompanied by migration will decrease. This suggests that sectoral reallocation may depend on the level of migration frictions.

The importance of spatial labor mobility in response to large exchange rate shocks has been conceptually well-described in the literature (Mundell, 1968; Blanchard and Katz, 1992).[1] However, empirical evidence and quantitative implications of geographic aspects of sectoral reallocation have been less studied beyond its conceptual level, which give rises to some important questions. Do migration flow respond to asymmetric shocks of a devaluation? If so, to what extent would sectoral reallocation and welfare be quantitatively affected by a devaluation given a certain amount of internal migration? Understanding the implications of internal geography and migration frictions after a devaluation is particularly important in emerging market economies because they frequently suffer from a large currency crisis, and they are known to have higher internal migration frictions.[2]

This paper studies the consequences of internal migration and its frictions after the 1998 Korean

[1] Mundell (1968) studies the role of spatial labor mobility on the desirability of common currency areas. Blanchard and Katz (1992) studies the importance of spatial labor mobility on the adjustment to the macroeconomic shocks in the US and the Euro Zone.

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

devaluation. This paper makes two contributions to the literature. First, this paper provides empirical evidence of increased internal migration flows into more exporting regions after the devaluation. Second, based on this empirical evidence, I build a dynamic spatial general equilibrium model to quantify the effect of internal migration and its frictions on amounts of sectoral reallocation and welfare changes after the devaluation.

This paper documents three motivating facts on internal migration in South Korea after the devaluation. First, after the devaluation, there were sharp asymmetric increases in exports across sectors. There were larger increases in exports for sectors that were more export-intensive. Second, there was large regional heterogeneity in industrial composition across regions, and employment of export-intensive sectors was geographically concentrated in a few regions. Combined with the asymmetric sectoral trade shocks induced by the devaluation, this regional heterogeneity implies that each region is differentially affected by the devaluation. Finally, I provide reduced-form evidence of increases in internal migration flows into regions whose industrial composition was more export-oriented. Because of these increased migration flows, more exporting regions experienced higher population growth. In terms of the regional exposure to the devaluation measured by the average sectoral exposure to the trade shocks weighted by employment shares within region, after the devaluation, the population of the upper quartile region increased by 3.21%. In contrast, the population of the lower quartile region decreased by 2.1%.

Guided by these three motivating facts, this paper quantitatively examines the aggregate and regional impacts of internal migration and its frictions. To do so, this paper builds a dynamic spatial general equilibrium model that incorporates rich internal geography, an input-output structure, internal and international trade, and costly internal migration. The devaluation is modeled in a reduced-form fashion as four time-varying shocks: 1) sector-region productivity shocks, 2) higher foreign demand shocks, 3) higher import cost shocks, and 4) labor supply shocks. These four shocks capture many common features of an emerging market economy after a devaluation.[3] Productivity shock rationalizes a big drop in total factor productivity (TFP) and gross outputs. Sudden increases in foreign demand and import costs explain dramatic export increases and import decreases. Finally, labor supply shocks account for a big rise in unemployment after a devaluation. The rich geographical heterogeneity of the model captures the heterogeneous regional exposure to the devaluation.

In the model, households are forward-looking and choose a location to work each period. The location choice of households is modeled as a dynamic discrete choice building on Artuc et al. (2010) and Caliendo et al. (2019). When households make location decisions, they consider both current real

[3]A big drop in TFP, increases in unemployment, collapses in imports, and expansion of exports are common features of many devaluation episodes. For example, for TFP drops, see Kim (2014) and Queralto (2020) for Korea; Gopinath and Neiman (2018) for Argentina; and Pratap and Urrutia (2012) for Mexico. For unemployment, see Drenik (2016); Blanco et al. (2019) for Argentina and Schmitt-Grohé and Uribe (2016) for the euro zone. For big changes of imports and exports, see Kehoe and Ruhl (2009) for Mexico and Gopinath and Neiman (2018); Blaum (2018) for Argentina.

wages and their option value of being in a current location. The heterogeneous regional exposure resulting from the four time-varying shocks, incentivizes households to migrate into more exporting regions after the devaluation. However, although real wages are higher in more exporting regions, if migration frictions are large, workers opt to stay in their initial locations. Because the effect of devaluation is transitory, considering the dynamics of migration decisions is particularly important in this setting. The four time-varying shocks affect the economy only temporarily, so when making location decisions, households have to consider not only temporarily increased real wages in more exporting regions, but also the fact that the economy will return to the normal phase, which is captured by the option value.

The model is calibrated to region-sector level data. The four shocks are extracted by fitting the model to the observed gross output, exports, imports, and unemployment changes. I estimate the migration elasticity using the instrumental variable (IV) approach. The IV is constructed based on the regional heterogeneous exposure to the real exchange rate changes.

I evaluate the welfare effects of South Korea's 1998 large devaluation. I compare the baseline economy where the actual devaluation occurred to the counterfactual economy where the devaluation did not occur. On average, the devaluation decreased aggregate welfare by 17%. However, the aggregate masks big heterogeneity of welfare effects across regions, ranging from -30% to 5%. Because of the differences in industrial composition and asymmetric sectoral trade shocks, regions with a comparative advantage in export-intensive sectors experienced relatively smaller welfare decreases when compared to regions with a comparative advantage in less export-intensive sectors. This indicates that regional heterogeneity is important for understanding the welfare effects of the devaluation.

I also examine how the economy would respond differently to different levels of migration frictions. For each different level of migration frictions, I evaluate 1) the welfare changes between the baseline and counterfactual economies, 2) the distributional effects of welfare changes, and 3) the amount of sectoral reallocation. Following the approach in the international trade literature, I infer migration frictions from the observed migration flows between regions. Migration frictions affect the welfare changes, the distributional consequences, and the amount of sectoral reallocation by considerable size. When migration is restricted, the aggregate welfare would have decreased by an additional 9%, and there would have been 4% less sectoral reallocation relative to the baseline scenario with the observed level of migration in 1997. Also, internal migration has distributional consequences. Because workers in less exporting migrate to more exporting regions, internal migration equilibrates heterogeneous local exposures to the devaluation across regions. If migration is restricted, then the standard deviation of the welfare changes across regions would increase by 5%.

Related literature. This paper is related to the literature that quantitatively studies the joint implications of international trade and internal geography.[4] I use a dynamic spatial model pioneered by Artuc et al. (2010) and Caliendo et al. (2019) to study dynamic labor market adjustments to large devaluations.[5] I quantitatively show that migration and its frictions play a sizable role in welfare effects and dynamic sectoral reallocation during the large devaluation. Unlike previous studies on internal migration (Morten and Oliveira, 2016; Bryan and Morten, 2019; Fan, 2019; Tombe and Zhu, 2019; Pellegrina and Sotelo, 2021), I study how internal migration frictions affect the responses of an economy to temporary trade shocks caused by the devaluation.[6]

This paper also contributes to the literature that studies labor market adjustment to trade shocks (Kambourov, 2009; Topalova, 2010; Menezes Filho and Muendler, 2011; Dix-Carneiro, 2014; Kovak, 2013; Dix-Carneiro and Kovak, 2017, 2019; Traiberman, 2019). Unlike previous studies which examine trade liberalization episodes, I study the role of internal migration when the economy is hit by temporary trade shocks. I provide the novel empirical finding of increased migration flows into more exporting regions after the 1998 Korean large devaluation.[7] More broadly, this paper is related to the literature that studies geographic labor mobility to local shocks pioneered by Blanchard and Katz (1992).[8] Different from previous studies, the model presented in this paper incorporates rich regional heterogeneity, migration frictions, and an input-output structure. This paper, also, studies the consequences of geographic labor mobility associated with the devaluation in the emerging market economy.

Finally, this paper is related to the literature that studies the economic consequences of a large devaluation.[9] For instance, Gourinchas (1999), Haltiwanger et al. (2004) and Kehoe and Ruhl (2009) study the sectoral reallocation of labor resulting from big exchange rate shocks. I add to this literature

[4] For example, see Adão (2015), Adao et al. (2019), Allen and Costas (2014), Atkin and Donaldson (2015), Coşar and Fajgelbaum (2016), Ramondo et al. (2016), Redding (2016), Caliendo et al. (2018), Fajgelbaum and Redding (2018), Sotelo (2019) and Pellegrina and Sotelo (2021).

[5] Balboni (2018), Caliendo et al. (2017) and Caliendo and Parro (2020) also use a similar methodology to study large infrastructure investments, EU integration, and trade policy.

[6] Previous studies have examined the long-term effects of internal migration and its frictions. Bryan and Morten (2019); Tombe and Zhu (2019) study the effect of internal migration on TFP; Morten and Oliveira (2016) and Fan (2019) study the distributional consequences of migration in Brazil and China; and Pellegrina and Sotelo (2021) studies the effects of internal migration on comparative advantage.

[7] There is mixed empirical evidence on responses for how internal migration responds to trade shocks. Autor et al. (2013) finds limited evidence of internal migration in the US to the China shock. Adão (2015) and Benguria et al. (2018) find that there were no internal migration responses to the commodity shocks in Brazil. Topalova (2010) and Dix-Carneiro and Kovak (2017) also find that internal migration did not respond to the trade liberalization episodes in India and Brazil. On the other hand, Greenland et al. (2019) finds that there was increased migration into regions that are less exposed to the China shock in the US among young or less-educated workers.

[8] For example, see Bound and Holzer (2000); Cadena and Kovak (2016) for local demand shocks in the US; Monras (2015) and Fogli et al. (2012) for Great Recession; and House et al. (2019) for exchange rate shocks in the US.

[9] For example, see Burstein et al. (2005) and Burstein et al. (2019) for price changes; Drenik (2016) for labor market dynamics; Gopinath and Neiman (2018) and Blaum (2018) for firm-level importing or exporting behavior during large devaluation; Aguiar (2005), Bleakley and Cowan (2008), Kim et al. (2015) and Verner and Gyöngyösi (2020) for foreign currency debt.

by examining the role of migration frictions as a barrier to sectoral reallocation after a devaluation. This paper also has relevance for the literature that studies distributional consequences of large devaluations (Cravino and Levchenko, 2017, 2018; Drenik et al., 2018; Blanco et al., 2019; Hausman et al., 2019). I shows that depending on regional comparative advantage and industrial composition, devaluation can have regional distributional consequences, and internal migration mitigates these distributional consequences.

The structure of this paper is as follows. Section 3 describes the data and presents the three empirical facts motivating the model. In Section 4, I build the quantitative model that is consistent with the empirical facts. Section 5 discusses the counterfactual and the calibration procedure of the model. In Section 6, the counterfactual results are reported. Section 7 concludes.

2 Data

I construct the data by merging three main data sets. The data sets allow me to measure sectoral employment, gross output, and trade at the regional-level.

The data on regional population, unemployment, and internal migration comes from Statistics Korea. Unemployment data is available up to the state level. So, I assume that the unemployment rate within state is common across regions. The total employment of each region is computed as population multiplied by employment rate.

I use Census on Establishment to compute each sector's employment and gross outputs shares within region, which contains the employment data of the universe of formal establishments in Korea at a finely disaggregated geographic level for both manufacturing and service sectors. Mining and Manufacturing Survey contains richer information including value-added, gross output, and exports of each plant for mining and manufacturing establishments. Based on these firm-level data, I aggregate employment and gross output of each establishment up to region for each sector. I then compute each region's employment shares and gross output shares of each sector. Then, these shares are combined with national level input-output (IO) tables which comes from WIOD. Each sector's employment shares are obtained as

$$\lambda_{nj,t} = \frac{\text{Emp. Share}^{j}_{nt} \times Emp^{WIOD}_{jt}}{\sum_{j'} \text{Emp. Share}^{j'}_{nt} \times Emp^{WIOD}_{j't}},$$

where Emp. Share$^{j}_{nt}$ is region n's share in national sector j employment calculated from the establishment data and Emp^{WIOD}_{jt} is sector j's employment obtained from WIOD.[10]

Data of sectoral imports and exports of each region is obtained from Korea Customs Service.[11] The

[10]Specifically, Emp. Share$^{j}_{nt} = \frac{Emp^{j}_{nt}}{\sum_{n'} Emp^{j}_{n't}}$, where Emp^{j}_{nt} is sector j employment aggregated up each region.

[11]The data started in 2000. For the periods before 2000, I impute regional trade data based on the gravity structure

region-sector level imports and exports data are re-scaled to fit the national-level imports and exports from WIOD IO data. Specifically, region-sector level exports are calculated as

$$Exports_{nj,t} = \frac{Exports^{customs}_{nj,t}}{\sum_{n' \in \mathcal{N}} Exports^{customs}_{n'j,t}} \times Exports^{WIOD}_{jt},$$

where $Exports^{customs}_{nj,t}$ is exports obtained from Korea Customs Service and $Exports^{WIOD}_{j,t}$ is the total exports of sector j obtained from WIOD. Region-sector level imports are similarly obtained.

3 Three Motivating Facts

In this section, I provide three motivating facts. First, there are sharp increases in exports among export-intensive sectors after the devaluation. Second, sectors with larger export intensities are highly concentrated, indicative of heterogeneous effects of the devaluation across regions depending on regional industrial composition. Third, there was an increase in internal migration into regions composed of more export-intensive sectors. Fourth, there was a larger magnitude of sectoral reallocation in regions with a larger share of export-oriented sectors.

Fact 1. (Sectoral heterogeneity) After the large devaluation, there were sharp increases in exports in export-intensive sectors.

I define the sectoral exposure to exchange rate as the difference between share of exports to gross output and imported input share to total costs:

$$\text{SecEX}_{jt_0} = 100 \times \left(\frac{\text{Export Revenue}_{jt_0}}{\text{Gross Output}_{jt_0}} - \frac{\text{Import Input Costs}_{jt_0}}{\text{Total Costs}_{jt_0}} \right), \tag{3.1}$$

where t_0 is 1995, 3 years before the large devaluation episode.[12] Total Costs_{jt_0} are computed as the sum of value-added and the total expenditures spent on intermediate inputs of sector j. As the real exchange rate gets depreciated, foreign price of domestic goods becomes relatively cheaper in foreign markets, which increases gross output through export expansion. However, the real exchange rate depreciation also makes prices of imported inputs higher in the domestic market, increasing overall cost of production.[13] Therefore, how each sector get affected by the real exchange rate depreciation is determined by their net-export intensities defined as export intensities minus net of intensities of total costs.

Panel A of Figure 1 displays the sectoral exposure for each sector. There is a large heterogeneity

and validate it with establishment-level export data, which comes from the Mining and Manufacturing Survey.

[12] WIOD is used to construct the sectoral exposure.

[13] Campa and Goldberg (1995) used the same measure to examine the effects of the real exchange rate shocks on sectoral investment of the US.

across different sectors. Manufacturing sectors tend to be net-exporting sectors in South Korea. Panel B of Figure 1 compares export intensities, exports relative to gross output, between the top 5 net-exporting manufacturing sectors based on the sectoral exposure and non-top 5 manufacturing sectors.[14] I normalize export intensities to be zero at 1997 so that changes of export intensities between the two groups are comparable after the devaluation. The export intensity of the top 5 manufacturing sectors increased 10% larger than the non-top 5 manufacturing sectors after the devaluation.

Fact 2. (Regional heterogeneity in industrial composition and comparative advantage) Each region has different industrial composition, and employment of export-intensive sectors is geographically concentrated.

Each region has different industrial composition. Given the sectoral heterogeneity of exchange rate exposure, regions with different industrial compositions will be affected differentially by the real exchange rate shock. Another fact is that export-intensive sectors are geographically concentrated in a few regions in Korea. The more export-intensive sectors are geographically concentrated, the more important the role of spatial reallocation plays. Suppose export-intensive sectors are uniformly distributed across regions. Then, workers will not migrate to other regions. Instead, they will change sectors within the region.

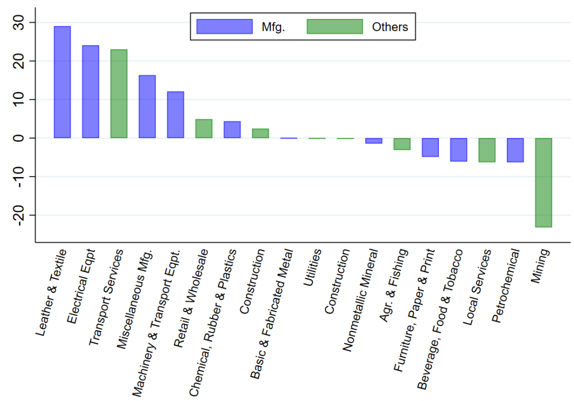
I define region n's exposure to exchange rate as the weighted mean of the sectoral exposure defined in Equation 3.1, weighted by employment share in region n at the baseline period:

$$RegEX_{nt_0} = \frac{\sum_j Emp_{nj,t_0} \times \text{SecEX}_{j,t_0}}{\sum_j Emp_{nj,t_0}} \tag{3.2}$$

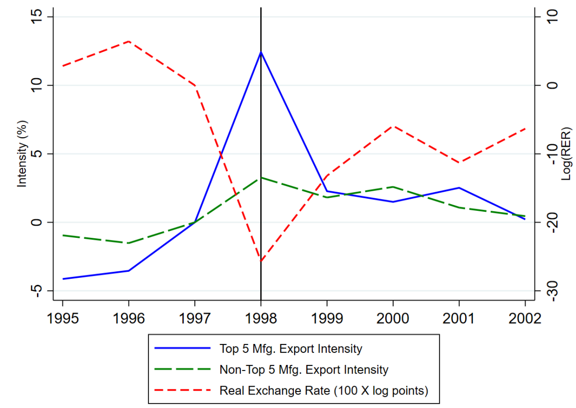
where Emp_{nj,t_0} is employment of sector j in region n at period t_0. For the empiical analysis, I pick t_0 to be 1994, which is four years before the Korean large devaluation. A region have overall higher value of $RegEX$ if it is composed of more net-exporting sectors. Regions with higher value of $RegEX$ are regions that are more composed of export-intensive sectors and more likely to get better off from the devaluation. Throughout this paper, I will call regions with larger $RegEX$ as more exporting regions.

Panel C of Figure 1 depicts geographical distribution of the regional exposure. Regions are categorized based on the quartiles of the distribution of the exposure. The darker-colored regions are more exporting regions. The figure shows that variations of the regional exposure are large, and more exporting regions are geographically concentrated in the northwestern and southeastern parts

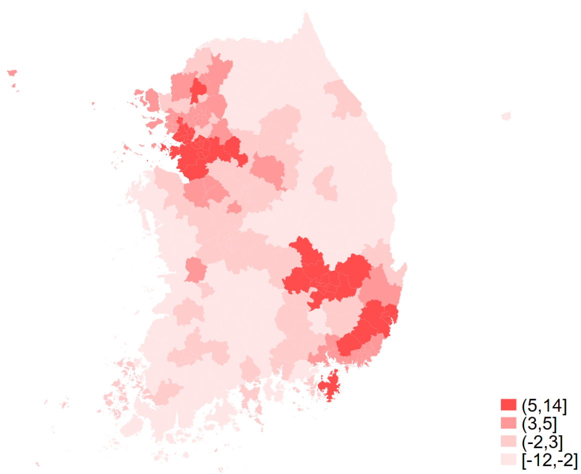
[14] As in Panel A of Figure 1, The top 5 net-exporting manufacturing sectors are leathers and textile, electrical equipment, miscellaneous manufacturing, machinery, and transport equipment, and chemical products.



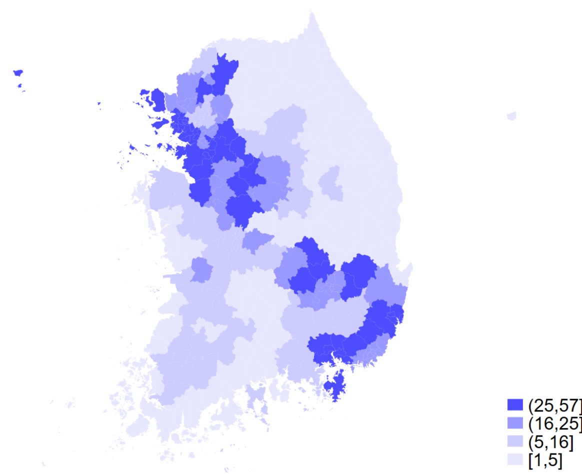
A. Sectoral Exposure to Exchange Rate



B. Export Intensity around Large Devaluation



C. Regional Exposure to Exchange Rate



D. Regional Top 5 Mfg. Emp Share

FIGURE 1: The First and Second Motivating Facts. Sectoral and Regional Heterogeneity to Exchange Rate Exposure

Note. This figure illustrates the first and second motivating facts. Panel A plots sectoral net exposure to exchange rate defined in Equation 3.1. Manufacturing sectors are colored blue and other industries are colored green. Plot B plots export intensities, defined as the ratio of total exports to total sales. The blue real line and green dashed line are export intensity of the top 5 manufacturing sectors and the other sectors. Export intensity is normalized to be zero in 1997 for both groups. The red dotted line is log of the real exchange rate. Panel C and D plot the regional exposure defined in Equation 3.2 and each region's employment share of the top 5 manufacturing sectors out to total employment. Regions are colored based on the quartiles of the distribution. Regions with large values are colored darker.

of Korea. Panel D of Figure 1 confirms this. Panel D shows regional employment shares of the top 5 exporting manufacturing sectors. The share ranges from 1 to 57 percents.[15] The regions with the higher regional exposure are the regions with more exporting manufacturing sectors.

Fact 3. (Spatial reallocation of labor) After the devaluation, there were increases in internal migration flows into more exporting regions.

I provide the reduced-form evidence of sudden increases in internal migration flows into regions whose industrial composition is more export-oriented.

Empirical Strategy. My empirical strategy uses the variation that sudden depreciation of exchange rate makes more exporting areas better off through expansion of exports, increasing overall wage and in turn attracting more migration flows from other regions. The unit of analysis is migration flows between two regions. I use variation in the extent to which the regional exposure to exchange rate of origin and destination work as pull and push factors for migration. If the origin is characterized by a high level of the regional exposure, after the devaluation, fewer people will leave the location. A similar argument holds for destination in the opposite direction.

I use the difference-in-difference (DID) estimator to examine the effect of devaluation on migration flows in the following regression model:

$$\ln \mu_{nm,t_1} - \ln \mu_{mn,t_0} = \beta_o \text{ORegEX}_{n,t_0} + \beta_d \text{DRegEX}_{m,t_0} + \mathbf{X}'_{nm,t_0}\gamma + \epsilon_{nm}, \tag{3.3}$$

where $\mu_{nm,t}$ is migration share from region n to m in year t, defined as share of total migrants from region n to m to lagged total population. ORegEX and DRegEX are the origin and destination exposure defined in Equation 3.2. ORegEX and DRegEX are standardized. This is the DID estimator with two treatments, the origin and destination exchange rate exposure, and with continuous treatment intensity. The parameter β_o and β_d are identified by comparison between pairs whose origin and destination are more and less exposed to the exchange rate shock. I set t_1 and t_0 to be 2002 and 1997 to allow for lagged response of migration. The model removes time-unvarying characteristics of each pair, by taking the difference of outcome.

The identifying assumption is the parallel trend of pairs with different values of $RegEX$ before the devaluation. I conduct the event-analysis to test parallel trend assumption. Using the dyadic structure of migration flows, I can conduct the event study at origin and destination levels. I run

[15] This is not a coincidence. Main exporting ports are located in the northwestern and southeastern parts of the country, which decreases the trade costs of exporting.

Table 1: Migration Flows and Regional Exposure to Exchange Rate

Dep.	Migration Flows				
	(1)	(2)	(3)	(4)	(5)
Panel A: RegEX, 1997-2002					
$ORegEX$	-0.07***		-0.07***	-0.06***	-0.03*
	(0.01)		(0.02)	(0.01)	(.01)
$DRegEX$	0.05***	0.05***		0.06***	0.05***
	(0.01)	(0.01)		(0.01)	(0.01)
N	14647	14647	14647	14647	14647
Panel B: Log Distance to Port, 1997-2002					
O. ln(Dist. Port)	-0.05***		-0.05***	-0.03***	-0.01**
	(0.01)		(0.01)	(0.01)	(0.01)
D. ln(Dist. Port)	0.02**	0.01*		0.00	-0.01
	(0.01)	(0.01)		(0.01)	(0.01)
N	14647	14647	14647	14647	14647
Panel C: Pair-Specific Trend, 1996-1997 & 1999-2000					
$ORegEX$	-0.02**		-0.02**	-0.01	-0.01
	(0.01)		(0.01)	(0.01)	(0.01)
$DRegEX$	0.04***	0.04***		0.04**	0.04**
	(0.01)	(0.01)		(0.02)	(0.02)
N	27558	27558	27558	27558	27558
Panel D: Poisson Pseudo-Maximum-Likelihood, 1999-2002					
$ORegEX$	-0.04***		-0.04***	-0.04***	-0.04***
	(0.01)		(0.01)	(0.01)	(0.01)
$DRegEX$	0.04***	0.04***		0.05***	0.04***
	(0.01)	(0.01)		(0.01)	(0.01)
N	32856	32856	32856	32856	32856
Origin × year FE	N	Y	N	N	N
Destination × year FE	N	N	Y	N	N
Controls	N	N	N	Y	Y
Balance Sheet	N	N	N	N	Y

Notes. Panel A reports the OLS estimates based on Equation 3.3. $ORegEX$ and $DRegEX$ are the regional exposure to exchange rate of origin and destination, defined in Equation 3.2. In Panel B, log of the inverse of the origin and destination's minimum distance to port are used as alternative proxy for $ORegEX$ and $DregEX$. Panel C reports the regression results based on Equation 3.5 which controls pair-specific random trend. Panel D reports the PPML estimates of Equation 3.6. Standard errors two-way are reported in parentheses, clustered at origin and destination CZ. $p < 0.1; **p < 0.05; ***p < 0.01$.

the following event study regression separately for both origin and destination exposure:

$$\ln \mu_{mn,t} = OregEX_{mt} + \delta_{nt} + \delta_{mn} + \epsilon_{mn,t}, \qquad \ln \mu_{mn,t} = DregEX_{mt} + \delta_{mt} + \delta_{mn} + \epsilon_{mn,t}. \quad (3.4)$$

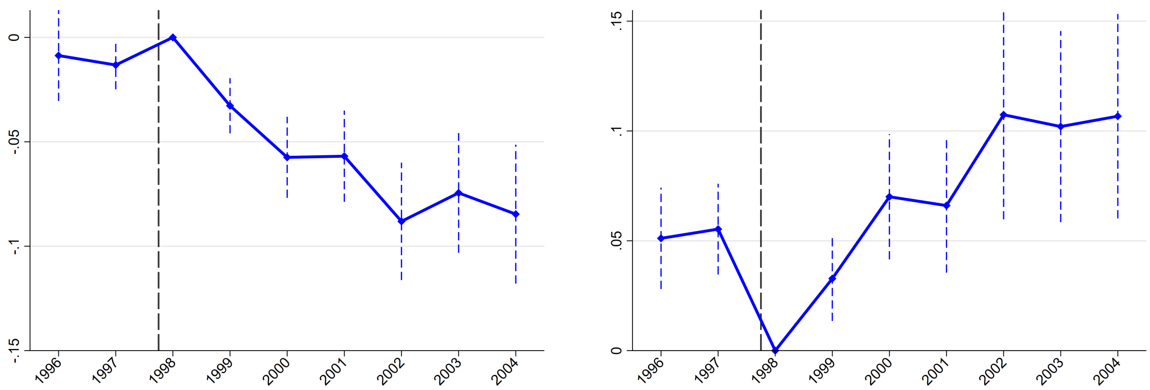
Destination-year and origin-year fixed effects are controlled in the first and second models to absorb any destination-specific and origin-specific time-varying shocks. In the first model, the specification uses variations of origin's regional exposure within pairs with the same destination. Similarly, in the second regression model, the variation comes from the differential destination exposure across migration flows. Standard errors are two-way clustered at origin and destination commuting zone (CZ) levels to allow for spatial correlation across pairs within the same origin or destination commuting zone, where the CZ level is at the higher aggregated level than the unit of analysis in the regression models.[16]

Baseline Results. Panel A of Table 1 reports the results. The baseline result in Column (1) implies that one standard deviation increase of the origin's regional exposure decreases the out-migration flow by 7%, holding destination exposure constant. Similarly, one standard deviation increase of destination exposure increases bilateral inflows by 5%, holding origin exposure constant. In Columns (2) and (3), I control the origin and destination-specific fixed effects to absorb any origin or destination-specific unobservables common across pairs. In Column (4), I also control the log of the population of both origin and destination at 1997 and the log of migration share to allow for differential trends depending on these variables. The results are consistent with the baseline estimates.

The event study results in Figure 2 confirm the baseline results. In Panel A, destination-time fixed effects are controlled, and in Panel B, origin-time fixed effects are controlled. The figures show no pre-trends of migration flows. The direction of flows changed after the devaluation, less out-migration flows from more exporting regions, and more in-migration flows into more exporting regions. In Panel B, there is an initial drop of the flows into more exporting regions at the time of the shock in 1998, resulting from the uncertain economic situation at the beginning of the crisis. However, it sharply starts to increase. Four years after the event, one standard deviation increase of destination's regional exposure is associated with a 5% increase in in-migration flows compared with the observed level in 1997. The event study results when using the distance to port instead of the regional exposure are reported in Online Appendix Figure A1.

Robustness. One concern is that there might be other regional shocks correlated with the regional exposure to the real exchange rate. During the devaluation, there was also financial shocks that

[16] I applied a hierarchical cluster algorithm to the 1995 commuting data across regions and constructed the commuting zone following Tolbert and Sizer (1996).



A. Origin Regional Exposure

B. Destination Regional Exposure

FIGURE 2: Event Study. Spatial Reallocation and Regional Exposure to Exchange Rate

Note. Panel A and B plot the estimated β_k coefficients from regressions in Equation 3.4. β_{-1} is normalized to be zero. Dependent variables are migration flows between regions. All regression models include pair and time fixed effects. Origin and destination specific time fixed effects are controlled in regressions of Panel A and B respectively. Error bars represent 95 percent confidence intervals from standard errors, two-way clustered at the origin and destination commuting zone levels.

heterogeneously affected sector, depending on their balance sheet structure. If exposure to financial shocks and exchange rates are systematically correlated, DID estimators will be biased. To show that financial shocks are not driving the results, I control regional exposure to balance sheet effect in Column (5).[17] The estimated coefficients are similar to the baseline, although the coefficient of $ORegEX$ becomes smaller.

I use the log of the inverse of minimum distance to port as the alternative proxy for regional exposure to the real exchange rate. I take the inverse so that the sign of the coefficients is the same with $RegEX$.[18] Large exporting regions are concentrated near the main ports in Korea.[19] The distance to port captures the natural advantage of exporting due to lower trade costs of exporting.[20] If devaluation lowers the price of domestic goods in foreign markets, regions with lower trade costs of exporting, measured by the distance to the port, will increase their exports relatively more than other inland regions, attracting more migrants. The results are reported in panel B of Table 1, which

[17] I construct industry-level balance sheet exposure from the firm-level data. I calculate the net foreign debt ratio as net foreign debt as a share of net worth at the firm level. Net foreign debt is the foreign currency-denominated debt minus foreign currency denominated assets. The net foreign asset is calculated as total assets minus total liabilities. I define industry level exposure as the median of net foreign debt ratio across firms within industry. Regional exposure is obtained as the weighted mean of the industry level exposure weighted by employment share in 1994, similar to Equation 3.2.

[18] Log of the minimum distance to port is inversely correlated with $RegEX$.

[19] I choose the top seven ports in terms of total amounts of exports, Pusan, Ulsan, and Incheon.

[20] Atkin and Donaldson (2015); Coşar and Fajgelbaum (2016); Fajgelbaum and Redding (2018) examines sizable internal trade costs within country.

are consistent with the baseline specification.

Another concern for the DID estimates is that there could be some unobserved systematic trend in the pair that are more exposed to $ORegEX$ and $DregEX$. To control pair specific trend, I compare the changes of migration flows between 1996 and 1997 to those between 1998 and 1999.[21] I estimate the following fixed effects model:

$$\triangle \ln \mu_{mn,t} = \beta_o(ORegEX \times D_t^{1998}) + \beta_d(DRegEX \times D_t^{1998}) + \boldsymbol{\beta}(\mathbf{X}_{mn,t_0} \times D_t^{1998}) + \mu_{mn} + \epsilon_{mn,t} \quad (3.5)$$

where D_t^{1998} is an indicator of years after the devaluation episode. The interaction term between initial characteristics of pairs $\mathbf{X}_{mn,t_0}$ and $1_{[t\geq 1998]}$ are controlled to absorb possible differential trends. Panel C of Table 1 reports the estimates, which is consistent with the baseline specification.

As final robustness checks, I estimate the following model using Poisson pseudo-maximum likelihood (PPML). PPML allows me to use zero migration flows, and avoid possible bias of the OLS estimates because of heteroskedasticity. The specification is as follows:

$$\mu_{mn,t} = \beta_o(ORegEX \times D_t^{1998}) + \beta_d(DRegEX \times D_t^{1998}) + \boldsymbol{\beta}(\mathbf{X}_{mn,t_0} \times D_t^{1998}) + \mu_{mn} + \epsilon_{mn,t} \quad (3.6)$$

for $t = 1997, 2002$. The results are reported in panel D of Table 1. The estimated elasticity of migration flows to $OregEX$ or $DregEX$ is 4%, which is similar with the baseline estimates.

Aggregation. Based on the reduced-form estimates, I calculate the predicted relative population changes across regions after the devaluation. Using the baseline specification estimates from regression in Equation 3.3, I compute the portion of the exchange rate shock on migration flows as

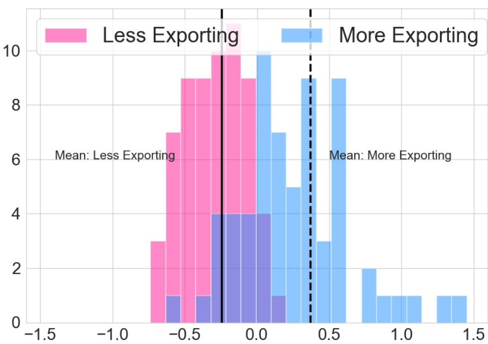
$$\hat{\mu}_{mn,t_1} = exp(\hat{\beta}_o ORegEX_{nt} + \hat{\beta}_d DRegEX_{mt}) \times \mu_{nm,t_0}. \quad (3.7)$$

Using the above predicted migration flows, I calculate

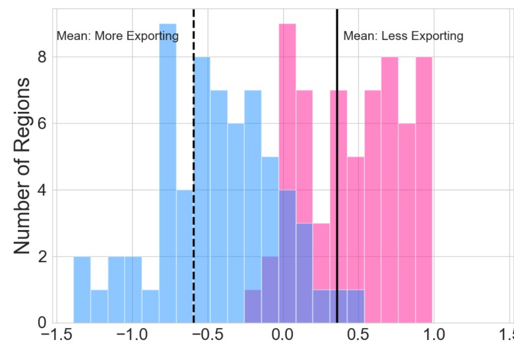
$$\begin{gathered} \widehat{\text{In-Rate}}_{n,t_1} = 100\frac{\sum_m \hat{\mu}_{mn,t_1} Pop_{m,t_0}}{Pop_{n,t_0}}, \quad \widehat{\text{Out Rate}}_{n,t_1} = 100\frac{\sum_n \hat{\mu}_{nm,t_1} Pop_{m,t_0}}{Pop_{n,t_0}} \\ \widehat{\text{Net-Rate}}_{n,t_1} = \widehat{\text{In Rate}}_{n,t_1} - \widehat{\text{Out Rate}}_{n,t_1} \end{gathered} \quad (3.8)$$

where $\widehat{\text{In-Rate}}$, $\widehat{\text{Out Rate}}$, and $\widehat{\text{Net Rate}}$ are the predicted in-migration, out-migration, and net migration rates between 1997 and 2002. The predicted migration rates are normalized to have zero mean, because only relative changes between migration flows are identfied from the DID estimator.

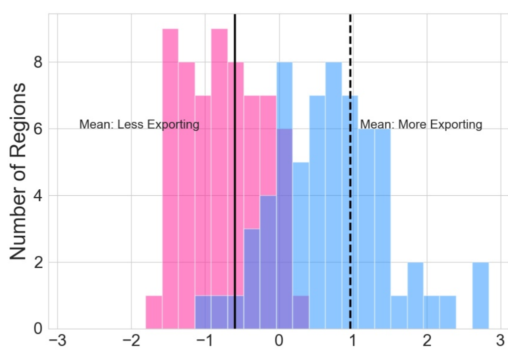
[21] The start year of the data is 1996, so only available pre-devaluation changes are between 1996 and 1997. To make the comparison, I use the annual changes between 1998 and 1999, whereas I examine the changes of migration flows between 1997 and 2002 in the baseline specification.



A. In-Migration Rate (%)



B. Out-Migration Rate (%)



C. Net Migration Rate (%)

Figure 3: Predicted Population Changes

Note. The figure plots the histograms of the predicted population changes between 1997 and 2002, based on Equation 3.8. Panel A plots the predicted in-migration rates, panel B plots the predicted out-migration rates, and panel C plots the predicted net migration rates in percentage points. Regions are divided into the two groups based on the median of the regional exposure defined in Equation 3.2. Regions above the median, more exporting regions, are colored blue, and regions below the median, less exporting regions, are colored red. The estimates are from the baseline specification reported in Column (1) of Panel A of Table 3.3. The distribution in each panel is normalized to have zero mean.

Regions are divided into two groups based on the median of the regional exposure. Figure 3 reports histograms of the predicted population changes in Equation 3.8 for each group, the predicted in-migration, out-migration, and net migration rates in Panel A, B, and C. More exporting regions are colored blue, and less exporting regions are colored red. The figures display that there are sizable population changes depending on the exposure. More exporting regions, on average, have a 0.3% larger in-migration rate, 0.6% less out-migration rate, and 1% increase in net migration rate overall. On the other hand, less exporting regions experience a decrease in the population by about 0.7% on average. The distribution of the migration rates also reveals big heterogeneity across regions, ranging from 2% of population loss to 3% of population increase.

4 Theoretical Framework

Based on these facts, I develop a dynamic spatial general equilibrium model to quantify the effects of internal migration and its friction on welfare effects and amounts of sectoral reallocation after the large devaluation episode in Korea.

The devaluation is modeled as four time-varying shocks: 1) region-sector level productivity shocks, 2) region-sector level foreign demands shocks for domestic goods, 3) region-sector level increases import costs shocks, and 4) regional level labor supply shocks. The four shocks capture features of the emerging market economies after devaluations. Productivity shocks rationalize large TFP decreases after devaluations, changes of foreign demands and import costs explain large changes of exports and imports, and labor supply shocks rationalize big rise in unemployment.

The sudden changes in foreign demands and import costs temporarily affect each region's trade patterns and these trade pattern changes are the equilibrium outcome of trade, migration, geography, and the shocks. Existing literature has focused on comparing one steady-state to the other steady state based on the static geography model, but devaluations are transitory shocks. Therefore, understanding transitional dynamics is important.[22]

4.1 Environment

The world is divided into Home, Korea, and Foreign, the rest of the world. Home is a semi-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 $\mathcal{N}$ regions. I index domestic regions by n, m and Foreign by f. I define a set of Home regions $\mathcal{N} = \{1, \ldots, N\}$ and a set of all regions by $\mathcal{W} = \mathcal{N} \cup \{f\}$ There are $j = 1, \ldots, J$ sectors. $\mathcal{J}$ is the set of sectors,

[22] If exchange rate pass-through is perfect, changes in the nominal exchange rate might not affect the real economy and trade patterns. As long as exchange rate pass-through is imperfect, it may affect affect trade patterns. The foreign demand shocks and import costs shocks in the model rationalize these changes. See Gopinath and Neiman (2018) for a review on exchange rate pass-through.

$\mathcal{J} = \{1, \ldots, J\}$.

Each region has different natural productivity across different sectors, and they are spatially linked through internal trade and migration. The labor market is segmented across each region. Within each region, a representative household has continuum of members. Each member has different amounts of labor efficiency units across sectors. A representative household optimally allocates its members across different sectors based on sectoral wages and each member's labor efficiency units. The total labor income earned by each household is the sum of wages earned by her members. In each period, households make location decisions. When making location decisions, households consider both current real wages and option values of staying in each location.

4.2 Households

Preferences. At each period, households earn income and decide how much to consume each local final goods across different sectors. Preference $U(C_t)$ across sectors is Cobb-Douglas with shares γ^k

$$C_{nt} = \prod_k C_{nk,t}^{\gamma^j}, \quad \sum_k \gamma^k = 1, \tag{4.1}$$

where $C_{nk,t}$ is the consumption of sector k good at time t. The associated price index is $P_{nt} = \prod_{k=1}^{J} (P_{nk,t}/\gamma^k)^{\gamma^k}$ where $P_{nk,t}$ is the price index of sector k good for final consumption. The budget constraint is $P_{nt}C_{nt} = W_{nt}H_{nt}$, where $W_{nt}H_{nt}$ is the total amounts of labor income.

Migration. At the end of each period, households can reallocate to another location where they work next period after they earn income and make consumption decisions. However, when changing locations, households have to incur a migration cost measured in terms of utility. The migration costs are origin-destination specific and can be time-varying, represented by the bilateral cost matrix $\mu_{nm,t}$. The migration costs decrease amounts of spatial reallocation of labor after the devaluation and make people's location choices more persistent. Households have idiosyncratic preference shocks η_{nt} for each location choice, which is independently and identically distributed across households, regions, and time.

Households are forward-looking and discount the future with discount factor $\beta \in (0, 1)$. The dynamic problem of households is

$$\mathrm{v}_{nt} = \ln C_{nt} + \max_m \{\beta V_{mt+1} - \tau_{nm,t} + \eta_{mt}\}. \tag{4.2}$$

Household choose region that gives the highest utility net of migration costs. I assume that η_{mt} is distributed Type-1 Extreme Value with zero mean with the parameter ν.[23] The life time expected

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

utility is defined as $V_{nt} = E[\mathrm{v}_{nt}]$, where the expectation is taken over the idiosyncratic preference shocks. Under the distributional assumption, V_{nt} admits the closed form:

$$V_{nt} = \ln C_{nt} + \nu \ln \sum_m exp(\beta V_{m,t+1} - \tau_{nm})^{\frac{1}{\nu}}. \tag{4.3}$$

Equation 4.3 implies that the value of being in region n is the sum of the current utility and the option value to move into other regions.

The distributional assumption yields the closed form for the fraction of households that migrate from region n to m at the end of time t:

$$\mu_{nm,t} = \frac{exp(\beta V_{mt+1} - \tau_{nm})^{\frac{1}{\nu}}}{\sum_{m'} exp(\beta V_{m',t+1} - \tau_{nm',t} + B_{m',t})^{\frac{1}{\nu}}}. \tag{4.4}$$

Migration shares in Equation 4.4 imply that all things equal, people migrate more into regions with higher expected lifetime utility net of migration costs, with the migration elasticity $1/\nu$. The migration elasticity governs how migration shares are sensitive to changes of expected lifetime utilities and migration costs, with the lower migration elasticity implying 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

$$L_{n,t+1} = \sum_m \mu_{mn,t} L_{m,t}, \quad \forall n. \tag{4.5}$$

L_{nt} is the only dynamic variable in the model, derived from the Household's forward looking dynamic choice.

Labor Supply. Each household is made up of a continuum of members with measure one, $i \in [0, 1]$. Sectoral labor supply is determined by the household's allocation of its members across sectors. Each member is ex-ante identical, but ex-post heterogeneous due to different ability draws across sectors. Members receive new draws every period after the household chooses the location. Each member is characterized by ability vector $\boldsymbol{\epsilon}^i \equiv (\epsilon^i_{n1}, \ldots, \epsilon^i_{nJ})$ where ϵ^i_{nj} is amounts of efficiency units of labor of member i that can be supplied to sector j.

A household in region n is subject to exogenous region-specific labor supply shocks u_{nt}. In each region n, only the random fraction of members $1 - u_{nt}$ can supply labor. This rationalizes large increases in unemployment after the devaluation.[24] The total amounts of working members in each

[24]For the simplicity, the model rationalizes unemployment by exogenous shocks. By modeling unemployment with an exogenous labor shock, with the model environments where households choose locations based on the average wages, I can derive the regression model to estimate the migration elasticity that can be connected with the observed data. In the trade literature, many papers have adopted different ways of modeling unemployment (or non-employment). For example, see Caliendo et al. (2019) for home production sectors; see Rodrıguez-Clare et al. (2020) for downward nominal wage rigidity; and Kim and Vogel (2021) for matching frictions.

region n is $H_{nt} = (1 - u_{nt})L_{nt}$.

Given wages and a measure of members $1-u_{nt}$ who are available to supply labor, a household allocates its available members across sectors to maximize the total sum of wages earned by members who are available to work. Let $\Omega_{nj,t} = \{\boldsymbol{\epsilon}_{nt} | W_{nj,t}\epsilon_{nj,t} \geq W_{nk,t}\epsilon_{nk,t}, \forall k \in \mathcal{J}\}$. A household allocates member i to sector j only if it generates the highest wage over other sectors, that is, $\epsilon^i_{nt} \in \Omega_{nj,t}$

I assume that each member's skills are independently and identically drawn from a multivariate Frechét distribution (Eaton and Kortum, 2002) following EK-Roy literature (Lagakos and Waugh, 2016; Hsieh et al., 2019; Galle et al., 2020):

$$F_{nj}(\boldsymbol{\epsilon}) = exp(-\boldsymbol{\epsilon}^{-\theta}), \tag{4.6}$$

where θ is the shape parameter of the Frechét distribution.[25] The parameter θ governs the dispersion of skills across members, with the higher value of θ corresponding to smaller dispersion. The properties of Frechét distribution implies that the share of members allocated toward sector j conditional on working $\lambda_{nj,t}$ is

$$\lambda_{nj,t} = \int_0^1 \int_{\Omega_{nj,t}} dF_{nj}(\boldsymbol{\epsilon}) di = \frac{W^{\theta}_{nj,t}}{\sum_{j'} W^{\theta}_{nj',t}}, \tag{4.7}$$

which is equal to the share of members whose earnings are the highest in sector j if they were available to supply labor, because u_{nt} is random.

Labor supply of sector j in the unit of effective labor in region n is given by

$$E_{nj,t} = L_{nt} \int_0^{1-u_{nt}} \left[\int_{\Omega_{nj,t}} \epsilon_{jt} dF(\boldsymbol{\epsilon}_t) \right] di = \Gamma^1 \lambda_{nj,t}^{\frac{\theta-1}{\theta}} H_{nt}, \tag{4.8}$$

where $H_{nt} = L_{nt}(1 - u_{nt})$ is the total amounts of members that can supply labor. The total labor incomes in region n is the sum of wages across members and households:

$$W_{nt}H_{nt} = L_{nt} \int_0^{1-u_{nt}} \max_j \{W_{nj,t}\epsilon^i_{nj,t}\} di = \Gamma^1 [\sum_j W^{\theta}_{nj,t}]^{\frac{1}{\theta}} H_{nt}, \tag{4.9}$$

where Γ^1 is a constant.[26] The wage per household is $W_{nt}(1 - u_{nt})$. Households earn larger income if average wage W_{nt} is higher or can supply more supply (higher $(1 - u_{nt})$). The following relationship between sectoral wage bill and the total wage bill holds in each region:

$$W_{nj,t}E_{nj,t} = \lambda_{nj,t}W_{nt}H_{nt}. \tag{4.10}$$

[25] I normalize the mean of the distribution to be the same across regions so that the differences in region-sector level productivity only enter through production side.

[26] Γ_1 is the Gamma function evaluated at $1 - \frac{1}{\theta}$

Migration elasticity ν and sectoral labor supply elasticity θ are the two key elasticities of the model. There are two advantages of making sectoral labor supply and migration decisions to be governed by different elasticities. First, migration decisions and within region sectoral labor supply decisions are a conceptually different problem.[27] The second is because of the data structure. The structure of the data that I employ has a lack of information on sector to sector transitions.[28] [29]

4.3 Production

Production embeds multi-sectors with input-output linkages across sectors and regions. Each region n produces a unique intermediate good (Armington, 1969). Intermediate varieties from each region and Foreign are aggregated by local final good producers in each region who produce local non-tradable final goods that can be used for either material inputs of production or final good consumption. Final good is non-tradable, and only intermediate goods are tradable. The production side of the model is static, characterized by the static optimization problem of representative firms which take prices, local wages, and labor supply by households as given.

Intermediate Goods Producer. 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:

$$q_{nj,t} = A_{nj,t} E_{nj,t}^{\alpha_j^E} \prod_{k=1}^{J} (M_{nj,t}^k)^{\alpha_j^k}, \qquad \alpha_j^E + \sum_k \alpha_j^k = 1, \tag{4.11}$$

where $A_{nj,t}$ is region-sector level productivity, $E_{nj,t}$ is labor input in the efficiency unit, $M_{nj,t}^k$ is the material input of sector k used by sector j, α_j^E is the value added share, and α_j^k is the share of sector j goods spent on intermediate input from sector k. Under cost minization, the cost for input bundle is

$$x_{nj,t} = \left(\frac{w_{nj,t}}{\alpha_j^E}\right)^{\alpha_j^E} \prod_{k=1}^{J} \left(\frac{P_{nk,t}}{\alpha_j^k}\right)^{\alpha_j^k}. \tag{4.12}$$

The unit cost of production is be $c_{nj,t} = x_{nj,t}/A_{nj,t}$.

Final Goods Producer. Final goods in region n of sector j which can be used as material inputs and final consumption goods are produced by combining intermediate goods of sector j. Final goods

[27] In Caliendo et al. (2019), sectoral and spatial reallocation is governed by one single elasticity.

[28] Alternatively, I can model the transition of migrations across region-sector to other region-sector similar to Caliendo et al. (2019) who imputed sector to sector transition using the American Community Survey (ACS) and the Current Population Survey (CPS). Obtaining sector-to-sector transition data is not easy as it requires keeping track individual's working history.

[29] Although KLIPS can track an individual's working history, it is not representative of the finely disaggregated industry transitions.

market is perfectly competitive, and free entry ensures zero profits. A representative final good producer combines both domestic and foreign intermediate goods. The production of final goods is

$$Q_{nj,t} = \Bigg(\underbrace{\sum_{n' \in \mathcal{N}} q_{n'j,t}^{1-1/\sigma}}_{\text{Domestic Inputs}} + \underbrace{q_{fj,t}^{1-1/\sigma}}_{\text{Foreign Inputs}} \Bigg)^{\frac{\sigma}{\sigma-1}}, \tag{4.13}$$

where σ is the elasticity of substitution.

4.4 Trade

Trade Costs. Domestic and international trade are subject to iceberg trade costs. For a unit of any variety good shipped from n to m for $n, m \in \mathcal{W}$, $d_{nm,j} \geq 1$ units has to be shipped. I normalize $d_{nn,j} = 1$, $\forall n \in \mathcal{W}$. Perfect competition implies that price paid by region n for region m's intermediate good of sector j is $d_{nm,j} c_{mj,t}$ for all $n, m \in \mathcal{W}$.

Imports and Consumer Foreign Market Access. Under the Armington assumption, the price of the sectoral aggregate good for sector j in region n is

$$P_{nj,t}^{1-\sigma} = \sum_{n' \in \mathcal{N}} (d_{n'n,jt} c_{n'j,t})^{1-\sigma} + \underbrace{(d_{fn,j} e_{nj,t}^{im,f} c_{fj,t})^{1-\sigma}}_{=CMA_{nj,t}}, \tag{4.14}$$

where $c_{fj,t}$ is the exogenous import input costs and $e_{nj,t}^{im,f}$ is a reduced form parameter that captures the exogenous increases in import costs after a devaluation. Increases in $e_{nj,t}^{im,f}$ make sector j's foreign input price more expensive paid by region n (Blaum, 2018; Gopinath and Neiman, 2018). $e_{nj,t}^{im,f}$ is region-sector nj specific. By making it nj specific, the model can be exactly fitted to the region-sector level import data.[30] I define $(d_{fn,j} e_{nj,t}^{im,f} c_{fj,t})^{1-\sigma}$ as *Consumer foreign market access (CMA)* shock, which is exogenous to Home. A devaluation increases the foreign import price and this decreases the market access for consumers.

The trade shares are

$$\pi_{n'n,jt} = \frac{(c_{n'j,t} d_{n'n,jt})^{1-\sigma}}{\sum_{m \in \mathcal{N}} (c_{mj,t} d_{mn,jt})^{1-\sigma} + CMA_{nj,t}^{1-\sigma}}, \quad \pi_{fn,jt} = \frac{CMA_{nj,t}^{1-\sigma}}{\sum_{m \in \mathcal{N}} (c_{mj,t} d_{mn,jt})^{1-\sigma} + CMA_{nj,t}^{1-\sigma}}. \tag{4.15}$$

[30] Another interpretation is that $e_{nj,t}^{im,f}$ is composed of two terms, one region-sector nj specific and the other common across regions within the same sector: $e_{nj,t}^{im,f} = \tilde{e}_{nj,t}^{im,f} \times \bar{e}_{jt}^{im,f}$. A devaluation increases $\bar{e}_{j,t}^{im,f}$ common across regions and $\tilde{e}_{nj,t}^{im,f}$ captures trading technology shock between region n and Foreign during a devaluation. In the model, region-sector nj specific trading technology shocks $\tilde{e}_{nj,t}^{im,f}$ explain the residuals of the regional imports data net of $\bar{e}_{j,t}^{im,f}$ that is common across regions.

Equation 4.15 implies that household in region n purchase more inputs from region m's sector j variety if unit cost or trade costs are lower. Consumers substitute foreign imported variety and increase spending more toward domestically produced varieties if $CMA_{nj,t}$ is high.

Exports and Firm Foreign Market Access. Foreign f demand for region-sector nj is given by

$$(d_{nf,j}p_{nj,t}/e^{ex,f}_{nj,t})^{1-\sigma}X_{fj,t} = c^{1-\sigma}_{nj,t}\underbrace{(d_{nf,j}e^{ex,f}_{nj,t})^{1-\sigma}X_{fj,t}}_{=FMA_{nj,t}} \tag{4.16}$$

$X_{fj,t}$ is the size of foreign market that is common across Home's regions and $e^{ex,f}_{nj,t}$ is a demand shock for goods from nj, which is region-sector nj specific. Again, by making $e^{ex,f}_{nj,t}$ region-sector specific, the model rationalizes the regional export data net of the common factors.[31] A devaluation increases $e^{ex,f}_{nj,t}$ by making price of Home's goods relatively cheaper than goods from Foreign. I define $(d_{nf,j}e^{ex,f}_{nj,t})^{1-\sigma}X_{fj,t}$ as *Firm Foreign Market Access (FMA)*. By increasing $e^{ex,f}_{nj,t}$, a devaluation increases $FMA_{nj,t}$ which in turn increases exports of nj.

4.5 Equilibrium

Market Clearing. Let $X_{nj,t}$ be the total expenditure on sector j good in region n which is expressed as

$$X_{nj,t} = \sum_{k=1}^{J}\alpha^j_k GO_{nk,t} + \beta_j(\sum_{k=1}^{J} w_{nk,t}L_{nk,t}), \tag{4.17}$$

where $GO_{nj,t}$ is gross output of sector j in region n. The first and second terms of the RHS are the expenditure spent on intermediate goods and final consumption goods. Then, regional market clearing in sector j's final goods implies that

$$GO_{nj,t} = \sum_{m\in\mathcal{N}}\pi_{nm,jt}X_{mj,t} + c^{1-\sigma}_{nj,t}\times\underbrace{(e^{ex,f}_{nj,t}d_{fj,t})^{\sigma-1}X^f_{jt}}_{=FMA_{nj,t}} \tag{4.18}$$

where $GO_{nj,t}$ is the gross output of sector j in region n. Labor market clearing condition implies that

$$W_{nj,t}E_{nj,t} = \alpha^E_j GO_{nj,t}. \tag{4.19}$$

Equilibrium. There are four time-varying shocks in the economy,

$$\Psi_{nj,t} = \{A_{nj,t}, u_{nj,t}, CMA_{nj,t}FMA_{nj,t}\}$$

[31] Similar to $e^{im,f}_{nj,t}$, another interpretation is that $e^{ex,f}_{nj,t}$ is composed of the two terms, one region-sector specific $\tilde{e}^{ex,f}_{nj,t}$ and the other common across regions within the same sector $\bar{e}^{ex,f}_{jt}$: $e^{ex,f}_{nj,t} = \tilde{e}^{ex,f}_{nj,t}\times\bar{e}^{ex,f}_{jt}$, where $\bar{e}^{ex,f}_{jt}$ is Foreign's price index and $\tilde{e}^{ex,f}_{nj,t}$ is Foreign's demand shock for goods from nj.

for $n \in \mathcal{N}$ and $j \in \mathcal{J}$. The parameters of the model are three elasticities ν, θ, and σ; production technology $\{\alpha_j^E, \alpha_j^k\}$; preference parameters $\{\gamma^j\}$; migration and trade frictions $\{\tau_{nm}\}$, $\{d_{nm,j}, d_{nf,j}\}$.

Definition 1. *Given the parameters of the model, $\{\Psi_{nj,t}\}_{t=t_0}^{\infty}$, and initial allocations, the competitive equilibrium of the model is the set of population $\{L_{nt}\}$, sectoral allocation of members $\{H_{nj,t}\}$, wages $\{W_{nj,t}\}$, and expected lifetime utilities $\{V_{nt}\}$ that satisfies the following condition for each region $n \in \mathcal{N}$ and all time periods t: (i) Given $W_{nj,t}$, the household optimally allocates its members across different sectors as in Equation 4.7; (ii) $\{W_{nj,t}, \lambda_{nj,t}, H_{nt}\}$ satisfies final goods and labor market clearing conditions in Equation 4.10, 4.18 and 4.19; (iii) Given $\{W_{nj,t}\}$, each household optimally choose location, that is, $\{V_{nt}, \mu_{mn,t}\}$ satisfies Equation 4.3 and 4.4; (iv) regional population evolves according to Equation 4.5.*

The conditions (i) and (ii) are static, derived from the static production and trade structure given population across regions. The conditions (iii) and (iv are dynamic, derived from the household's dynamic forward looking decision. These conditions explain the evolution of population across regions.

Welfare. The expected life time utility in region n at time t is

$$V_{nt} = \sum_{t'=t}^{\infty} \beta^{t'-t} \ln \left(\frac{W_{nt}(1 - u_{nt})}{P_{nt}\mu_{nn,t}^{\nu}} \right) \tag{4.20}$$

Depending on the shocks, the welfare of each region is differentially affected by devaluation, leading to distributional effects. The distributional effects are the equilibrium outcomes of the shocks and the spatial linkages through labor mobility and trade. Because households in regions that are more negatively affected by the devaluation may migrate to other regions, internal migration may dampen distributional consequences of the devaluation. The aggregate welfare is defined as the mean of each region's welfare, weighted by the initial population

$$V_t^{agg} = \sum_{n \in \mathcal{N}} \frac{L_{nt_0}}{\sum_m L_{mt_0}} V_{nt}. \tag{4.21}$$

5 Counterfactual and Taking the Model to the Data

5.1 Counterfactual

How would the Korean economy respond differently to the devaluation in 1998 with different levels of migration frictions? I examine how sectoral reallocation and welfare changes are affected depending on levels of migration frictions.

First, I compute baseline and counterfactual equilibrium allocation when migration costs are held constant. In the baseline economy, the devaluation happens in 1998, whereas in the counterfactual economy, the devaluation does not happens. To solve for both the baseline and the counterfactual economies, I employ dynamic hat-algebra pioneered by Caliendo et al. (2019). The advantages of dynamic hat-algebra is that it solves the model in changes, so it does not require to know the levels of the shocks, simplifying computation. Given the set of parameters Φ, The dynamic hat-algebra only requires initial equilibrium allocation and changes of shocks $\hat{\psi} = \{\hat{A}_{nj,t}, \widehat{FMA}_{nj,t}, \widehat{CMA}_{nj,t}, \hat{u}_{nj,t}\}_{t=0}^{infty}$, where $\hat{x}_t = x_{t+1}/x_t$. Given the set of initial conditions $L_{n,1997}$, $e_{n,1997}$, $\mu_{mn,1996}$, $GO_{nj,1997}$, $EX_{nj,1997}$, and $IM_{nj,1997}$, I feed in baseline and counterfactual changes of shocks and solve out for $\widehat{GO}_{nj,t}$, $\widehat{EX}_{nj,t}$, $\widehat{IM}_{nj,t}$, $\hat{H}_{nj,t}$, $\hat{w}_{nj,t}$, and $\hat{L}_{nt}$. The baseline changes of shocks are the path of changes of shocks that rationalizes the path of the regional gross output, exports, imports, and employment observed in the actual data during the devaluation between 1998 and 2002. The counterfactual shocks $\hat{\Psi}^c_{nj,t} = \{\hat{A}^c_{nj,t}, \widehat{FMA}^c_{nj,t}, \widehat{CMA}^c_{nj,t}, \hat{u}^c_{nj,t}\}$, where superscript c denotes for counterfactual values, are the path of the shocks under the counterfactual. After 2002, both baseline and counterfactual shocks are set to be one.

After feeding in the two sets of shocks, I compute baseline and counterfactual equilibrium allocation when migration costs are held constant. Then, I can compute changes of sectoral reallocation and welfare between the baseline and the counterfactual economies. The change in welfare from a change in shocks is measured in terms of consumption equivalent variation. The consumption equivalent changes are expressed as

$$\triangle V_{nt} = (1-\beta)\sum_{s=t}^{\infty} \beta^{s-t} \ln \left(\frac{\frac{W^c_{ns}}{W_{ns}} \frac{e^c_{ns}}{e_{ns}}}{\frac{P^c_{ns}}{P_{ns}} \left(\frac{\mu^c_{nn,s}}{\mu_{nn,s}}\right)^{\nu}} \right), \tag{5.1}$$

where superscript c is used to denote for counterfactual variables.[32] The aggregate welfare changes are the average of welfare changes across regions, weighted by the initial population shares:

$$\triangle V^{agg}_t = \sum_{n \in \mathcal{N}} \frac{L_{nt_0}}{\sum_{m\in\mathcal{N}} L_{mt_0}} \triangle V_{nt}. \tag{5.2}$$

Next, I examine how sectoral reallocation and welfare respond differently with different level of migration costs. To do so, I introduce additional migration cost shocks. When computing both baseline and counterfactual equilibrium allocation, I feed in additional migration cost shocks $\hat{m}_{nm,t} = exp(\tau^c_{nm,t} - \tau_{nm,t})$, where $\tau^c_{nm,t}$ is counterfactual migration friction. Then, I compute changes of welfare and sectoral reallocation. For different set of migration cost shocks, I compute the path of

[32]The derivation of this equation is derived in Appendix Section B.2.

Table 2: Summary of Calibration

Parameters		Description	Target
Elasticities			
β	0.96	Discount Factor	Calibrated
$1/\nu$	0.96	Migration Elasticity	Estimated, Migration Shares
θ	2.20	Sectoral Labor Supply Elasticity	Estimated, Variance of Hourly Wages
σ	9	Elasticity of Substitution	Literature
Geographic Frictions			
$\{\tau_{mn}\}$	Equation 5.11	Migration Cost	Estimated, Migration Shares
$\{\kappa_{mnj}\}$	1.2	Domestic Trade Cost	Estimated, Regional $\{GO_{nj,t}, X_{nj,t}\}$
$\{\tilde{\kappa}_{fnj}\}$		Observable Foreign Trade Cost	Estimated, Gravity
Regional Shocks			
$\{A_{nj}\}$	Figure 4 (a)	Productivity Shock	Estimated, $\{R_{nj,t}\}$
$\{FMA_{nj}\}$	Figure 4 (b)	Foreign Market Access Shock	Estimated, $\{GO_{nj,t}, EX_{nj,t}\}$
$\{CMA_{nj}\}$	Figure 4 (c)	Consumer Market Access Shock	Estimated, $\{GO_{nj,t}, IM_{nj,t}\}$
Production			
$\{\alpha_j^E, \alpha_j^k\}$		Factor Shares in Production	Calibrated, IO Table

Note. For the internal trade cost, I report the median value across region, sector and the sample period.

sectoral employment when the devaluation occur:

$$\frac{L_{jt}}{L_t} = \frac{\sum_{n\in\mathcal{N}} L_{nj,t}}{L_t} = \frac{\sum_{n\in\mathcal{N}} \lambda_{nj,t} L_{nt}}{L_t}. \tag{5.3}$$

5.2 Taking the Model to the Data

This section discusses the calibration procedure for the quantitative analysis. The counterfactual procedure requires values for the parameters, the initial values in 1997, the values for the set of parameters, and the baseline and counterfactual shocks. I also have to obtain migration frictions to examine how the economy responds differently depending on migration frictions. Table 2 reports a summary of the calibration procedure.

5.2.1 Parameters

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

$$\ln\frac{\mu_{nm,t}}{\mu_{mm,t}} = \frac{\beta}{\nu} ln\frac{W_{mt}(1-u_{mt})/P_{mt}}{W_{nt}(1-u_{nt})/P_{nt}} + \beta\ln\frac{\mu_{nm,t+1}}{\mu_{mm,t+1}} + \delta_{nm} + \tilde{\epsilon}_{nm,t}, \tag{5.4}$$

where δ_{nm} is region pair fixed effect, and $\tilde{\epsilon}_{nm,t}$ is a structural error term that is a function of innovations in migration costs.[33] The pair fixed effects δ_{nm} absorb the time-invariant component of migration costs between two regions. The intuition of the expression in Equation 5.4 is 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 $1/\nu$.

I obtain the following regression model after rewriting Equation 5.4:

$$\ln \frac{\mu_{nm,t}}{\mu_{mm,t}} - \beta \ln \frac{\mu_{nm,t+1}}{\mu_{mm,t+1}} = \theta \ln \frac{W_{mt}(1-u_{mt})/P_{mt}}{W_{nt}(1-u_{nt})/P_{nt}} + \delta_{nm} + \tilde{\epsilon}_{nm,t}. \tag{5.5}$$

All the variables in Equation 5.5 can be mapped to the data. W_{nt} is obtained by dividing the total sum of the value-added across sectors in region n $W_{nt}H_{nt}$ by the total number of the employed H_{nt} in the data. $(1-u_{nt})$ is mapped to employment share to population in each region, H_{nt}/L_{nt}. I construct a regional level P_{nt} using the regional Consumer Price Index (CPI) data. Although the level of price is not identifiable from the CPI price data, which only tracts price changes within each region, the inclusion of the pair fixed effects allows me to use CPI data to proxy for overall price level because the pair fixed effects absorb the initial price level.[34] Korea statistical agency only reports CPI data of the selected regions, so I impute regional CPI data using housing price data that is available across all regions following Moretti (2017).[35]

The endogeneity problem can arise if migration cost shocks in the error term is systematically correlated with other shocks in the model. Because real wages are determined at the equilibrium given the shocks, the OLS estimate can be biased because of the endogeneity problem. Another possible source of endogeneity is a measurement error of the real wage from the imputation procedure of regional CPI and the construction procedure of the regional variables.

I implement the IV strategy to deal with the endogeneity problem. I construct two instrumental variables (IV) to deal with the endogeneity problem, based on the regional exposure to exchange

[33] The derivation of Equation 5.4 is described in online Appendix Section B.1. In Section 4, migration costs are assumed to be constant, but the model admits time-varying migration costs, which will be additional source of the shock. With time-varying migration costs, the error term is

$$\tilde{\epsilon}_{nm,t} = \frac{1}{\nu}(\tau_{nm,t} - \beta\tau_{mn,t+1})$$

[34] Price level of region n, P_{nt}, is $CPI_{nt} * P_{n0}$. The inclusion of region pair fixed effect captures the initial difference of price level across regions, $\ln P_{m0} - \ln P_{n0}$ under the log utility function.

[35] I regress $\triangle P_{it}^{CPI} = \beta \triangle P_{it}^{Housing} + \epsilon_{it}$ for regions where both CPI and housing prices are available. Using the estimate $\hat{\beta}$, I impute CPI data for regions with no CPI data.

rate and the minimum distance to port:

$$IV_{nm,t}^{RegEX} = (RegEX_{mt_0} - RegEX_{nt_0}) * 1_{t\geq 1998} \tag{5.6}$$

and

$$IV_{nm,t}^{Port} = (lnDist_{mt_0}^{Port} - \ln Dist_{nt_0}^{Port}) * 1_{t\geq 1998} \tag{5.7}$$

where $RegEX$ and $lnDist^{port}$ are measured at 1994, and $1_{t\geq 1998}$ is a dummy variable of the post-devaluation years. The instruments utilize the variation that regions with more exporting sectors or closer to the ports are disproportionately affected by the real exchange rate changes during the devaluation, examined as the stylized facts in Section 3. The identifying assumption is that the innovations to amenity and migration costs are uncorrelated with the timing of the devaluation in Korea and predetermined characteristics of regions. I estimate Equation 5.5 using the fixed-effects model for the two sample periods, 1996 and 1999.

The results are reported in Table 3. Column (1) reports the OLS estimate, and Column (2) and (3) report the IV estimates using the IVs in Equation 5.6 and 5.7. The estimate when using the regional exposure IV is 1.03, and the estimate when using the port IV is 1.42. With $\beta = 0.96$, the estimates imply that the migration elasticity $1/\nu$ is 1.07-1.42.[36] The first stage results are reported in Panel B of Table 3. The F-statistics for the two instruments is 50 and 110. Column (1) reports the OLS estimate close to zero. Measurement errors and correlation between error terms and the real wage can result in a downward bias of the OLS estimate.

I use the three-period lagged independent variable as an alternative instrumental variable and estimate the model for the sample period between 2000 and 2005 following Artuc et al. (2010) and Caliendo et al. (2019). The identifying assumption is that there is no serial correlation of migration cost shocks conditioning on the pair fixed effects. The estimated coefficient is 0.83 reported in Column (4). The estimated value with the lagged variable is smaller than estimates based on the other two baseline instruments, indicating that the estimate with the lagged IV is downward biased. If the migration cost shocks are negatively serially correlated, this can result in a downward bias of the estimate.

[36] Estimates of internal migration elasticity at an annual frequency are scarce in the literature, and most papers in the literature have used lagged real wages variables as an instrument variable. Caliendo and Parro (2015) estimated $\nu = 5.34$ at quarterly frequency, implying $\nu = 2.02$ at an annual frequency. Artuc et al. (2010) estimated $\nu = 1.88$ with the linear utility function, and $1/\nu$ is a semi-elasticity. Caliendo et al. (2017) estimated annual international migration elasticity with $\nu = 2.3$. The estimated elasticities in the paper are higher than the previous estimates, which is natural given the spatial units analyzed in this paper are at a finer level than other papers. Estimates of migration elasticity in the long run under the static model are generally between 1 to 3 (Morten and Oliveira, 2016; Bryan and Morten, 2019; Fajgelbaum and Redding, 2018; Tombe and Zhu, 2019; Pellegrina and Sotelo, 2021).

Table 3: Migration Elasticity

Sample Period	1996 & 2001			2001-2006
IV	OLS	IV. *RegEX* IV	IV. Port	IV. Lagged
	(1)	(2)	(3)	(4)
Panel A: Second Stage				
$W_{nt}(1-u_{nt})/P_{nt}$	0.00	1.03**	1.42***	0.83***
	(0.05)	(0.42)	(0.28)	(0.25)
Panel B: First Stage				
		0.36***	0.02***	0.12***
		(0.05)	(0.00)	(0.01)
Pair FE	Y	Y	Y	Y
KP-F	.	49.40	111.89	89.38
N	5202	5202	5202	15606

Note. The table reports the estimates from the regression model in Equation 5.5. All regression models include pair fixed effects. Standard errors two-way are reported in parentheses, clustered at the pair level. $p < 0.1; **p < 0.05; ***p < 0.01$.

Labor Supply Elasticity and Elasticity of Substitution. The remaining elasticities are labor supply elasticity θ and elasticity of substitution σ. The parameter θ governs the elasticity of labor supply across sectors with respect to relative wages within region. To estimate θ, I rely on the fact that distributional assumption implies that wage per hour within region-sector follows a Frechét distribution with the shape parameter θ.[37] Using microdata from Korean Labor & Income Panel Study (KLIPS), I residualize cross-sectional log hourly wages on region-sector-age dummies in 1998 and apply maximum-likelihood estimation (MLE) to fit the distribution.[38] The resulting estimate is 2.2.[39] I set $\sigma = 9$ which is in line with the typical estimates of the trade elasticity $(\sigma - 1)$ in the literature.[40]

[37] Lagakos and Waugh (2016) and Hsieh et al. (2019) also use the wage dispersion to estimate labor supply elasticity.

[38] The data set contains individual-level panel data. It contains information on individual-level income, residential location, and working history, as well as other demographic variables.

[39] Although the calibration procedure heavily relies on the distributional assumption, the calibrated value is close to the estimates by the EK-Roy literature. Hsieh et al. (2019) and Galle et al. (2020) estimate a value of 2. Burstein et al. (2019) shows that the observed wage distribution are approximated well by the Frechét distribution.

[40] Many papers have estimated trade elasticity. Eaton and Kortum (2002) estimate a trade elasticity using trade shares and price data. Their estimates range from 3.60 and 12.86. Their preferred estimate is 8.22. Simonovska and Waugh (2014) estimate the trade elasticity to be 4. Using tariff changes, Caliendo and Parro (2015) estimate the average elasticity across sectors to be 4.55. Head and Ries (2001) find values between 7 and 11.4. Broda and Weinstein

Other Parameters. The remaining key parameters are the share of value-added in gross output α_j^E, the material good cost shares α_j^k, the final good consumption share γ^j, and the discount factor. I calibrate $\{\alpha_j^E, \alpha_j^k\}$ using the factor share in 1995 from the national level IO table from WIOD. Given the lack of data availability, I assume that these parameters are the same across regions. The discount factor β is set to 0.96.

5.2.2 Domestic Trade Costs and Domestic Trade Flows.

The model requires initial domestic trade shares, which are not directly observed from the data set. I calibrate internal trade cost using the gravity structure and observed data of the gross output, expenditure, exports, and imports of each region and sector.[41] Based on the calibrated internal domestic trade costs, I can construct domestic trade flows.

I parametrize the domestic costs as a function of distance between regions $d_{nm,t} = dist_{nm,jt}^{-\delta_{jt}}$, where $dist_{nm}$ is the distance between region n and m, and δ_{jt} is a sector-year specific parameter. Foreign imports (im) and exports (ex) trade costs are parametrized as $d_{nf,j}^z = dport_n^{-\delta_j^z}$ for $z \in \{ex, im\}$, where $dport_n$ is region n's distance to port and δ_j^z is a sector-specific parameter. δ_j^z is estimated from the gravity equation using regional imports and exports data.

For domestic trade costs, I pick δ_{jt} for each sector and year that minimizes the following objective function:

$$Var(\log \frac{EX_{nj,t}}{c_{nj,t}^{1-\sigma} X_{jt}^f}) = Var(\log e_{nj,t}^f) \tag{5.8}$$

subject to the gravity structure of the model

$$\begin{aligned} GO_{nj,t} - EX_{nj,t} &= \sum_{m \in \mathcal{N}} E_{nj,t} \frac{c_{nj,t} dist_{mn}^{-\delta_j}}{\sum_{n' \in \mathcal{N}} c_{n'j,t} dist_{n'm}^{-\delta_j} + CMA_{mj.t}} \\ IM_{nj,t} &= E_{nj,t} \frac{CMA_{nj,t}}{\sum_{m \in \mathcal{N}} (c_{mj,t} dist_{mn}^{-\delta_j})^{1-\sigma} + CMA_{nj,t}}. \end{aligned} \tag{5.9}$$

For a given value of δ_{jt} and observed data distribution of $\{GO_{nj,t}, E_{nj,}, EX_{nj,t}, IM_{nj,t}\}$, there exists a unique (to scale) $\{\{c_{nj,t}\}, CMA_{nj,t}\}$ that satisfies the gravity structure in Equation 5.9. For each value of δ_{jt}, I solve out for $c_{nj,t}$ and evaluate the objective function in Equation 5.8.[42]

The intuition behind the objective function in Equation 5.8 is that increase of domestic trade flows can be rationalized by either larger dispersion of the unit cost (or dispersion of comparative advantage)

(2006) find values between 4 and 17, depending on the aggregation level.

[41] Eckert (2019), and Gervais and Jensen (2019) also similarly propose a methodology to compute trade costs without directly observing trade flows.

[42] The algorithm is described in more detail in Appendix C.1.

across regions or a lower level of domestic trade costs. δ_{jt} is chosen in a way that it rationalizes the observed regional data while making backed-out unit costs have the most explanatory power for the dispersion of the observed level of exports. The variance of sector j's exports across regions captures the dispersion of unit cost of production across regions because exports decrease with the unit cost.[43] $\epsilon_{nj,t}$ is a residual that makes the model to be exactly fitted to any observed level of exports and for any values of $\{dist_{nm}^{-\delta_{jt}}\}$.

The median of the estimated coefficient is 1.2, which is in line with the existing estimate in the literature (Head and Mayer, 2014).[44]

5.2.3 Shocks

The baseline shocks are obtained by fitting the model exactly to the observed data. Each region's unemployment $\hat{u}_{nt}$ is taken directly from the data. Unemployment data is only available at the state level, so I assume that unemployment across regions within the same state is the same. $\hat{A}_{nj,t}$, $\widehat{CMA}_{nj,t}$, and $\widehat{FMA}_{nj,t}$ are backed out by fitting the model to the observed data between 1997 and 2002 using the invertibility of the static production and trade structure.[45] The details of the algorithm are explained in online Appendix 5.2.3.

First, using the static structure of production, I back out $CMA_{nj,t}$ and $FMA_{nj,t}$ in level. Given the observed gross outputs, expenditure and imports data, using Equation 4.15, 4.16, 4.17, and 4.18, I solve out for $c_{nj,t}$, $CMA_{nj,t}$ and $FMA_{nj,t}$. Decreases in unit cost increases both gross output and expenditure in the data, but decreases in $CMA_{nj,t}$ only increases expenditure, which pin down $c_{nj,t}$ and $CMA_{nj,t}$. Conditional on $c_{nj,t}$, the observed exports are rationalized by $FMA_{nj,t}$.[46] Then, I can obtain variables and shocks in changes: $\hat{c}_{nj,t}$, $\widehat{CMA}_{nj,t}$, and $\widehat{FMA}_{nj,t}$.

$c_{nj,t}$ is still an endogenous object which is a function of local prices and wages ($x_{nj,t}/A_{nj,t}$). TO identify $\hat{A}_{nj,t}$ separately from $\hat{c}_{nj,t}$, I need to solve for factor market clearing conditions, which depends on dynamic location choices of household. Given $\{\widehat{CMA}_{nj,t}, \widehat{FMA}_{nj,t}, \hat{u}_{nt}\}_{t=1997}^{2002}$ and data in 1997, I assume $\widehat{CMA}_{nj,t}$, $\widehat{FMA}_{nj,t}$, and $\hat{u}_{nt}$ are one after 2002 and solve for $\hat{A}_{nj,t}$ using the full model until $\hat{c}_{nj,t}$ from the model exactly fit the backed out $\hat{c}_{nj,t}$ in the data.

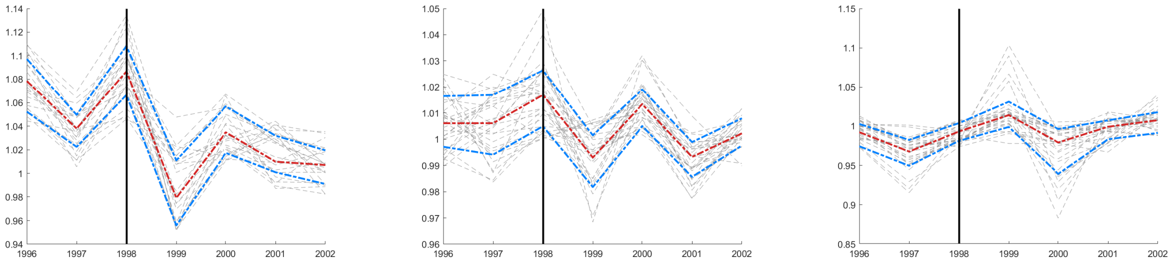
To examine the changes of the shocks during the devaluation, I aggregate each shock up to the

[43] If $\epsilon_{nj,t}$ is the same across all regions, then $Var(Ex_{nj,t}) = (1-\sigma)^2 Var(c_{nj,t})$ which is the dispersion of unit cost of production.

[44] Monte et al. (2018) estimates the same elasticity by estimating the gravity equation for goods trade across US states and find that $\theta = -1.29$; Allen and Costas (2014) estimates an elasticity between -0.95 and -1.35; the estimate of Eckert and Peters (2018) who uses a similar methodology is around -1.6 for the 2000s.

[45] Similarly, by fitting the model exactly to the data, Eaton et al. (2016) and Huo et al. (2019) similarly back out the sectoral shocks of each country and in the economic geography literature, Pellegrina and Sotelo (2021) recovers regional fundamentals.

[46] Note that $EX_{nj,t} = c_{nj,t}^{1-\sigma} FMA_{nj,t}$.



A. $\hat{A}^{reg}_{nt}$ B. $\widehat{FMA}^{reg}_{nt}$ C. $\widehat{CMA}^{reg}_{nt}$

Figure 4: Backed Out Shocks

Notes. The figure plots the shocks aggregated up to the regional-level as in Equation 5.10. For $\hat{A}_{nj,t}$, $\widehat{CMA}_{nj,t}$, and $\widehat{FMA}_{nj,t}$, gross output shares, import shares, and export shares within region are used as weights. Grey line represents each region level shocks between 95% and 5% percentiles. Regional A, CMA, and FMA shocks are calculated as the average of shocks weighted by value added, imports, and exports within region. The upper and lower blue lines represent the upper and lower quartiles and the red line is the median value of the shocks across regions in each year.

regional level as

$$\widehat{Shock}^{reg}_{nt} = \sum_{j \in \mathcal{J}} \omega_{nj,t} \times \widehat{Shock}_{nj,t} \tag{5.10}$$

where $\widehat{Shock}_{nj,t}$ is a shock of region-sector nj and $\omega_{nj,t}$ is a weight. For $\hat{A}_{nj,t}$, $\widehat{CMA}_{nj,t}$, and $\widehat{FMA}_{nj,t}$, gross output shares, import shares, and export shares within region are used as weights. Figure 4 plots the regional-level shocks. Panel A, B, and C reports $\hat{A}^{reg}_{nt}$, $\widehat{FMA}^{reg}_{nt}$, and $\widehat{CMA}^{reg}_{nt}$.

For the counterfactual shocks, I similarly back out $\hat{c}_{nj,t}$, $\widehat{CMA}_{nj,t}$, and $\widehat{FMA}_{nj,t}$ in level using the data between 1995 and 1997. Then, instead of using the full model as in the baseline shock, I back out $\hat{A}_{nj,t}$ using the observed employment shares and population data. Given the value of θ, the value-added obtained from the gross outputs and value-added shares, the employment shares, and the population, I solve out $W_{nj,t}$ and $E_{nj,t}$ using Equation 4.10 and 4.19. From the solved out $W_{nj,t}$, the unit cost of input bundle can be computed, which in turn gives $\hat{A}_{nj,t}$. The procedure gives me $\hat{A}_{nj,1996}$, $\widehat{FMA}_{nj,1996}$, and $\widehat{CMA}_{nj,1996}$. In the counterfactual economy, I set the shocks to evolve at the constant rate with values of $\hat{A}_{nj,1996}$, $\widehat{FMA}_{nj,1996}$, and $\widehat{CMA}_{nj,1996}$. $\hat{u}_{nt}$ are set to be one.

5.2.4 Migration Costs

I estimate migration cost in level nonparametrically under the symmetry, $\tau_{nm,t} = \tau_{mn,t}$. Following Head and Ries (2001), the migration cost can be backed our from the following equation:

$$\ln\left(\frac{\mu_{nm,t}}{\mu_{nn,t}}\right) + \ln\left(\frac{\mu_{mn,t}}{\mu_{mm.t}}\right) = -\frac{\tau_{nm,t} + \tau_{mn,t}}{\nu} = -\frac{2}{\nu}\tau_{nm,t}, \tag{5.11}$$

where the second equality holds under the symmetry. Given the estimate of ν, migration costs can be identified from the observable migration shares.[47]

Migration costs correlate with euclidean distance and political distance between regions, externally validating the estimated migration costs. Figure 5 plots log of estimated migration costs τ_{nm} against the log of distance and political distance.[48] One standard deviation increase of log of Euclidean cost and political distance are correlated with 0.70 and 0.38 standard deviation increase in log of measured migration costs.

In the main counterfactual, three different level of migration frictions are considered: 1) 10% reduction of baseline migration frictions, 2) infinite migration costs, and 3) migration costs in 2006. I compute the changes of migration costs for each pair between the two periods:

$$\hat{m}_{mn,t} = exp(\tau_{nm,c} - \tau_{nm,1996}), \tag{5.12}$$

where $\tau_{nm,c}$ is the counterfactual migration level. For 10% reduction of baseline migration frictions, $\tau_{nm,c} = 0.9 \times \tau_{nm,1996}$. For infinite migration costs, $\tau_{nm,c}$ is set to be infinite. For the level of the frictions in 2006, I compute the migration costs in 1996 and 2006. Then, I calculate the median of the migration friction changes $c_{med} = median_{n\in\mathcal{N},m\in\mathcal{N}}\{\tau_{nm,2006}/\tau_{nm,1996}\}$ and set $\tau_{nm,c} = c_{med} \times \tau_{nm,1996}$. Between 1996 and 2006, the median of migration costs decreased by 2.5%.[49]

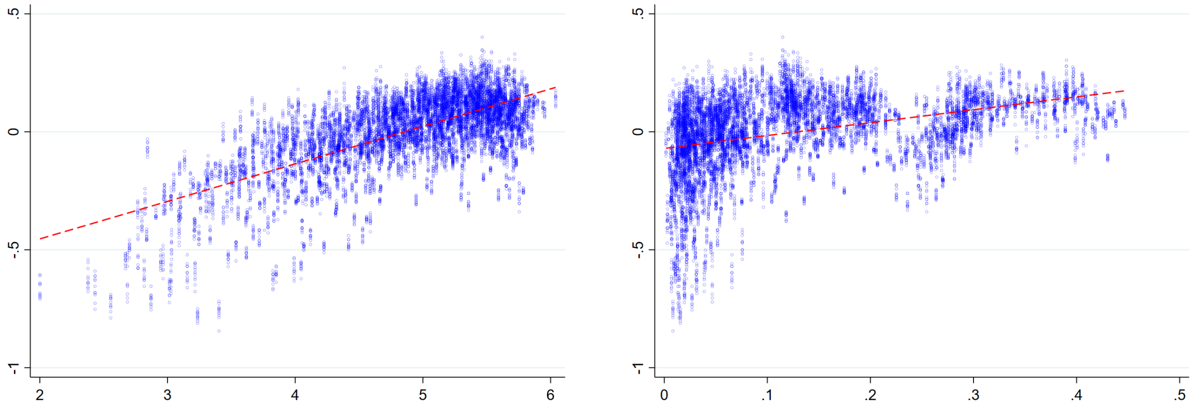
[47] Low movement can be caused by amenity and real wage differentials, or migration costs. However, migration costs are the only factor that decrease both bilateral movements of migrants. Higher amenity or real wage work as the pull factor that increases movements into regions with higher amenities or real wage asymmetrically. However, higher migration costs decrease both bilateral migration flows $\mu_{mn,t}$ and $\mu_{nm,t}$, increasing own migration flows $\mu_{nn,t}$ and $\mu_{mm,t}$. By using the migrant flows between region n and m relative to the own migrant flows as in Equation 5.11, these pull factors are exactly canceled out, capturing the symmetric bilateral cost components.

[48] I measure the political distance using each candidate's share of the vote of 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

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

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

[49] Online Appendix Figure A1 plots the evolution of quartiles of migration costs across pairs for each year.



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

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

FIGURE 5: Correlates of Migration Costs in Korea

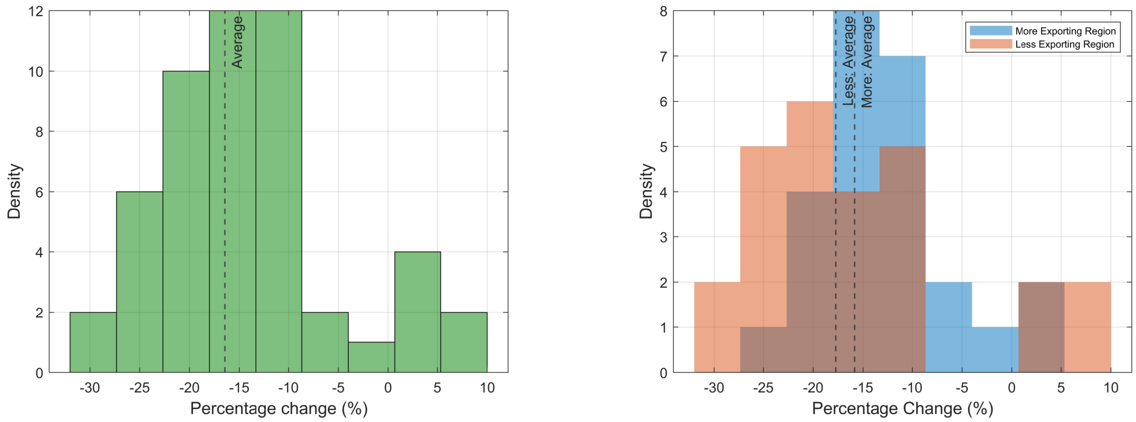
Notes. Panels A and B are the scatter plots between log of migration costs and log of Euclidean distance and political distance obtained from the 14th presidential election in 1992. Log of migration costs, log of Euclidean distance and political distance are standardized. Migration costs are backed out from Equation 5.11 and demeaned by year.

6 Quantitative Results

Welfare Changes. In this section, I examine the aggregate and regional welfare effects and sectoral reallocation during the devaluation. I compare the baseline and counterfactual economies while migration frictions are held constant at the 1997 level. Panel A of Figure 6 reports the histogram of the welfare changes of the devaluation across regions. The aggregate welfare effect of large devaluation was around -16.7%.

The aggregate welfare masks heterogeneity across regions, where the welfare changes range from -32% to 7.6%. In more exporting regions, the devaluation had the positive welfare effects through the expansionary effects of the devaluation on exports. Panel B plots the histogram for the two groups of regions categorized based on the regional exposure $RegEX$ defined in Equation 5.10. More exporting group whose regional exposure is above the median tend to have higher welfare changes than the less exporting group whose regional exposure is below the median. The average welfare changes of the more exporting group are -17.93% and the average welfare changes of the less exporting group are -16.12%.

I compute baseline and counterfactual economies while feeding in different migration friction shocks and calculate welfare changes across regions. The results are reported in Figure 7 and Table 7. Table 7 reports the summary statistics of the distribution of the welfare changes under the different levels of migration frictions. Higher migration frictions cause households in less-exporting regions more



A. All regions

B. High and low exposure regions

FIGURE 6: Regional Welfare Effects of South Korea's 1998 Large Devaluation

Notes. The figure presents the regional welfare effects of large devaluation. Welfare effects are in percentage points. Panel A is a histogram of welfare effects across all regions. The dotted line represents the aggregate welfare effects defined in 4.21. Panel B is a histogram for groups of regions based on the median of regional exposure to exchange rate $RegEX$ which is defined in Equation 3.2. Regions with higher $RegEX$ are more exporting regions. The dotted line represents the average weighted by initial population share within each group.

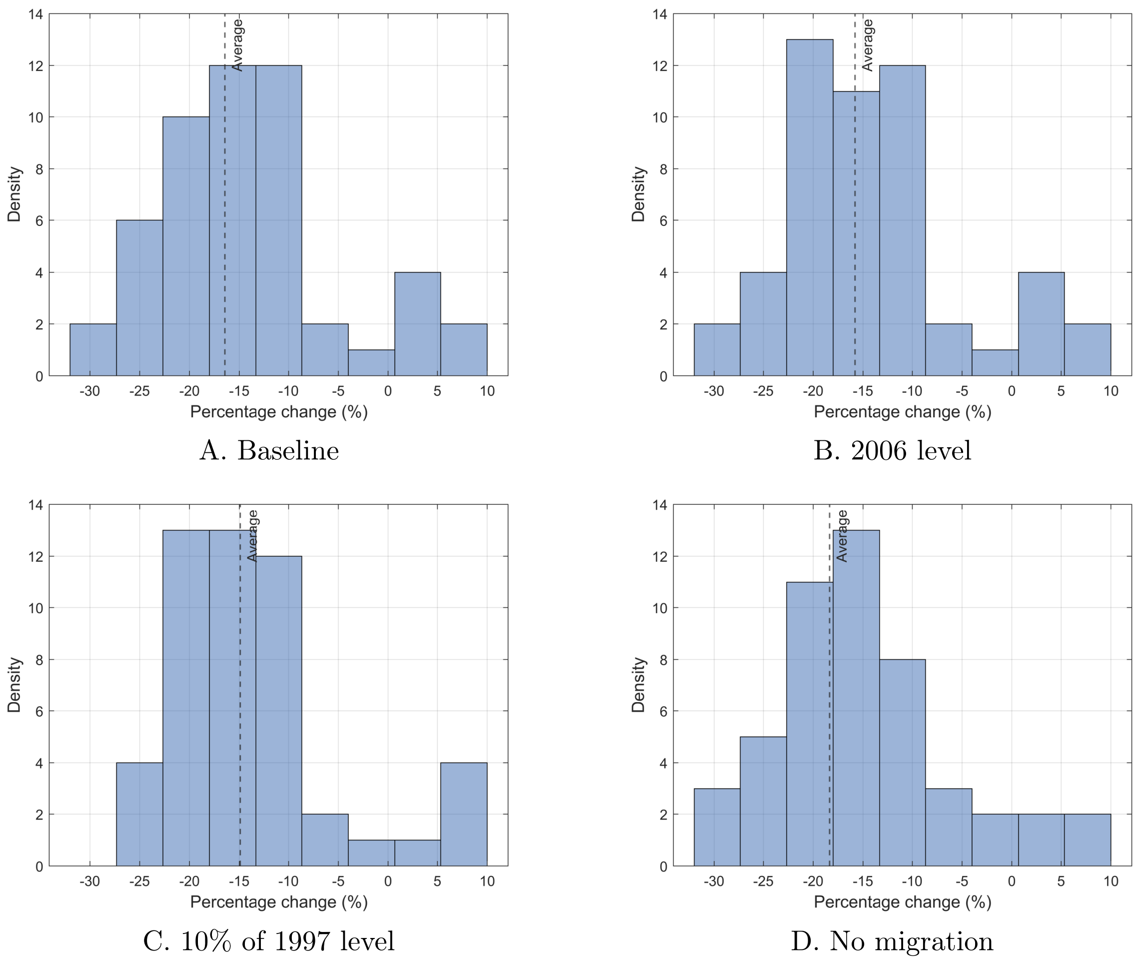
difficulty to move to more exporting regions, decreasing welfare changes even lower. On the other hand, higher migration frictions make households in more exporting regions relatively better off when compared to the case of lower migration frictions. With lower migration frictions, there will be a larger inflow of labor from less exporting regions, which increases the overall labor supply in more exporting regions, which lowers the workers' wages already staying there.

Sectoral Reallocation. I examine how amounts of sectoral reallocation are affected by the level of migration frictions after the devaluation. To do so, I compute the following annual sectoral reallocation index:

$$SecReallo_t = \frac{1}{2}\sum_{j\in\mathcal{J}} \left|\frac{\sum_{n\in\mathcal{N}} H_{nj,t}}{H_t} - \frac{\sum_{n\in\mathcal{N}} H_{nj,t-1}}{H_{t-1}}\right|, \tag{6.1}$$

which is defined as the sum of the absolute changes in the national share of sector j's employment to the total employment across sectors. $SecReallo_t$ measures the fraction of workers working in different sectors between $t-1$ and t. Similarly, to examine the cumulative changes of sectoral reallocation, I define the following cumulative sectoral reallocation index:

$$CumSecReallo_t = \frac{1}{2}\sum_{j\in\mathcal{J}} \left|\frac{\sum_{n\in\mathcal{N}} H_{nj,t}}{H_t} - \frac{\sum_{n\in\mathcal{N}} H_{nj,1997}}{H_{1997}}\right|. \tag{6.2}$$



A. Baseline

B. 2006 level

C. 10% of 1997 level

D. No migration

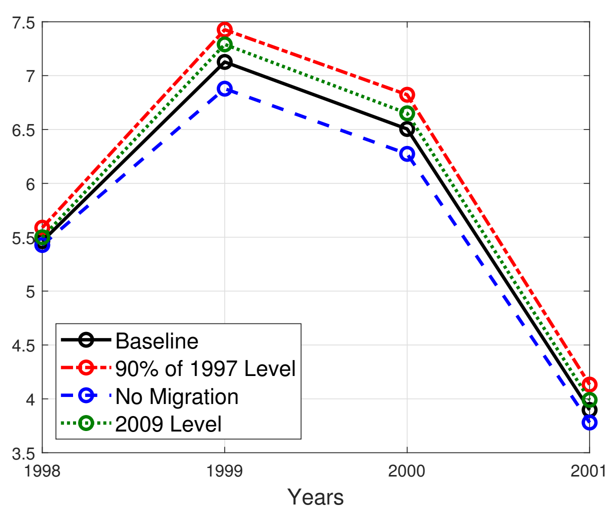
Figure 7: Distributional Consequences of Migration Frictions

Notes. This figure plots histograms of welfare changes across regions with different migration cost shocks. Panel A plots welfare changes under the migration cost held at the 1997 level. Panel B plots welfare changes under the migration costs held at the 2006 level. Panel C plots welfare changes under the migration costs held at 75% of the 1997 level. Panel D plots welfare changes when migration costs go to infinity.

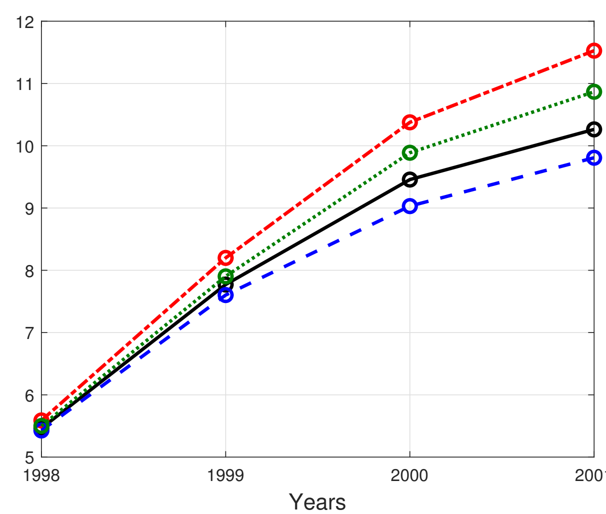
Table 4: Distributional Consequences of Migration Frictions

	$\triangle V^{agg}_{1997}$	std. $\triangle V_{n,1997}$	mean $\triangle V_{n,1997}$			$\min_{n\in\mathcal{N}}\{\triangle V_{nt}\}$	$\max_{n\in\mathcal{N}}\{\triangle V_{nt}\}$
			Low	High	All		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Baseline, $\tau_{nm,c} = \tau_{nm,1997}$	-16.69	9.16	-17.93	-16.12	-14.59	-31.75	7.57
$\tau_{nm,c} = 0.75 \times \tau_{nm,1997}$	-14.91	8.88	-15.70	-14.54	-13.19	-26.01	10.93
$\tau_{nm,c} = \tau_{nm,2006}$	-18.36	9.63	-19.82	-17.68	-16.05	-36.28	7.49
$\tau_{nm,c} = \infty$	-15.85	9.05	-17.08	-15.28	-13.92	-29.80	9.04

Notes. This table reports the summary statistics of the distribution of welfare changes with different levels of migration frictions. Column (1) reports the aggregate welfare change defined in Equation 5.2. Column (2) reports the standard deviation of the welfare changes across regions. Columns (3) and (4) report the mean of the welfare changes across regions whose regional exposure $RegEx$ is below and above the median, weighted by initial population. Column (5) reports the mean of the welfare changes across regions. Columns (6) and (7) report the minimum and the maximum of the welfare changes across regions. The first row reports the results when migration frictions are held fixed at the 1997 level. The second row reports the results when migration costs are at the 75% level of the 1997 level. The third row reports the results when migration costs are at the 2006 level. The fourth row reports the results when migration is restricted.



A. Annual Intersectoral Reallocation ($SecReallo_t$)



B. Cumulative Intersectoral Reallocation ($CumSecReallo_t$)

Figure 8: Sectoral Reallocation under Different Level of Migration Frictions

Notes. The panels A and B $SecReallo_t$ and $CumSecReallo_t$ defined in Equation 6.1 and 6.2. The black solid line plots the baseline results. The red, blue, and green dashed lines plot results when migration costs are 90% of the 1997 level, when migration costs are infinite, and when migration costs are at the 2006 level.

$CumSecReallo_t$ measures the fraction of workers working in different sectors between t and the base year 1997.[50]

[50] Kambourov (2009) calculates the same measures to examine sectoral reallocation after trade liberalization.

I compute $SecReallo_t$ and $CumSecReallo_t$ between 1998 and 2001 under different level of migration frictions. The results are reported in Figure 8 in which panel A reports $SecReallo_t$ and panel B reports $CumSecReallo_t$. Higher migration frictions decreased the amounts of sectoral reallocation. Between 1998 and 2001, on average, when compared to the baseline migration friction level in 1997, the annual sectoral reallocation index increases by 4.3% when migration frictions are 10% reduced, decreases by 2.7% when migration is restricted, and increases by 1.9% when migration frictions are at the 2006 level. The cumulative sectoral reallocation index increases by 7.5% when migration frictions are 10% reduced, decreases by 3% when migration is restricted, and increases by 3.2% when migration frictions are at the 2006 level.

7 Conclusion

This paper studies the role of internal migration and its frictions on the amounts of sectoral reallocation and welfare changes after the 1998 Korean devaluation. I document three facts. After the devaluation, there were large increases in exports in export-intensive sectors because of the depreciation of real exchange rates. These export-intensive sectors are geographically concentrated in a few regions. There were increases in migration flows into regions that have a comparative advantage in export-intensive sectors. Given the heterogeneity of sectoral export responses to the devaluation and geographical concentration of export-intensive sectors, migration frictions may hinder sectoral reallocation by restricting workers to reallocate themselves to regions with comparative advantage export-intensive sectors.

Based on these empirical facts, using the dynamic spatial general equilibrium model, I quantify the effects of migration frictions on sectoral reallocation and welfare after South Korea's devaluation. The model incorporates internal geography with migration frictions, input-output structure, and dynamic location decisions of households. A devaluation is modeled as four time-varying shocks that rationalize a large drop in TFP, increases in unemployment, and big changes of imports and exports after the devaluation. The quantitative results imply that Had migration been restricted, there would have been sizable decreases in the amounts of sectoral reallocation, and the negative welfare effects of the devaluation would have been amplified in South Korea. This implies that depending on internal geography and the level of migration frictions, an economy may respond differently to macroeconomic shocks.

While the empirical facts and quantitative results imply that migration may play an important role after a devaluation, there is still ample room for future research. Although capital accumulation and endogenous trade deficits may play an important role after a devaluation, they are not modeled in my framework. Incorporating these features with internal geography can be a fruitful avenue for future research (Reyes-Heroles, 2016; Dix-Carneiro et al., 2021, e.g.). Also, because of the data limitation, the model simplifies the sectoral choices of individuals. Using detailed individual-level microdata, comparing sectoral reallocation costs with spatial reallocation costs can be another interesting avenue for future research (Traiberman, 2019, e.g.).

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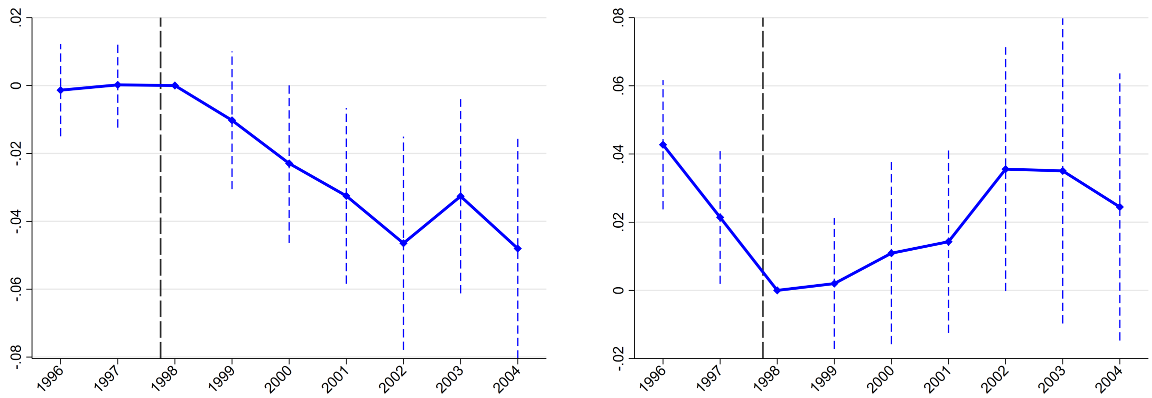
ONLINE APPENDIX

(NOT FOR PUBLICATION)

Appendix A Empirical Appendix

Figure A1: Event Study. Spatial Reallocation and Distance to Port



A. Origin Regional Exposure B. Destination Regional Exposure

Note. Panel A and B plot the estimated β_k coefficients from regressions in Equation 3.4 while controlling minimum distance to port of origin and destination, instead of the regional exposures. β_{-1} is normalized to be zero. Dependent variables are migration flows between regions. All regression models include pair and time fixed effects. Origin and destination specific time fixed effects are controlled in regressions of Panel A and B respectively. Error bars represent 95 percent confidence intervals from standard errors, two-way clustered at the origin and destination commuting zone levels.

Appendix B Theory Appendix

B.1 Derivation of the Regression Model of Migration Elasticity

This section derives Equation 5.4. Under the distributional assumption of Type 1 extreme distribution, the following equation holds:

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

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

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

Using Equation 4.3, this can be written as

$$\begin{aligned}
\ln\left(\frac{\mu_{nm,t}}{\mu_{nn,t}}\right) &= \frac{\beta}{\nu}\ln\left(\frac{W_{mt}(1-u_{mt})/P_{mt}}{W_{nt}(1-u_{nt})/P_{nt}}\right) \\
&+ \frac{\beta}{\nu}\Bigg(\nu \ln \sum_{n'} exp(\beta V_{n',t+1} - \tau_{mn',t+1} + B_{n',t+1}) - \nu \ln \sum_{n'} exp(\beta V_{n',t+1} - \tau_{nn',t+1} + B_{n',t+1}\Bigg) \\
&- \frac{1}{\nu}\tau_{nm,t} + \frac{1}{\nu}(B_{mt} - B_{nt}).
\end{aligned} \tag{B.3}$$

Subtracting and adding $\beta V_{m,t+2} - \tau_{mn,t+1} - (B_{n,t+1} - B_{m,t+1})$, I obtain that

$$\ln\left(\frac{\mu_{nm,t}}{\mu_{nn,t}}\right) = \frac{\beta}{\nu}\ln\left(\frac{W_{mt}(1-u_{mt})/P_{mt}}{W_{nt}(1-u_{nt})/P_{nt}}\right) + \beta\ln\left(\frac{\mu_{mn,t+1}}{\mu_{mm,t+1}}\right) + \tilde{\epsilon}_{nm,t} \tag{B.4}$$

where

$$\tilde{\epsilon}_{nm,t} = \frac{1}{\nu}(\tau_{nm,t} - \beta\tau_{mn,t+1}) + \frac{1}{\nu}((B_{mt} - B_{nt}) - \beta(B_{n,t+1} - B_{m,t+1}))$$

B.2 Derivation of 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

$$V_{nt} = \ln C_{nt} + \beta V_{n,t+1} + \nu \ln \left(\sum_m exp(\beta(V_{m,t+1} - V_{n,t+1}) - \tau_{nm,t} + B_{n,t})^{\frac{1}{\nu}} \right) \tag{B.5}$$

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

$$\nu \ln \left(\sum_m exp(\beta(V_{m,t+1} - V_{n,t+1}) - \tau_{nm,t} + B_{n,t})^{\frac{1}{\nu}} \right) = -\nu \ln \mu_{nn,t}. \tag{B.6}$$

Plugging this into the value function, I get

$$V_{nt} = \ln C_{nt} + \beta V_{n,t+1} - \nu \ln \mu_{nn,t}. \tag{B.7}$$

Iterating the above equation, I obtain

$$V_{nt} = \sum_{s=0}^{\infty} \beta^{s-t} \ln C_{ns} - \nu \sum_{s=t}^{\infty} \beta^{s-t} \ln \mu_{nn,s}. \tag{B.8}$$

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

$$V_{nt} = \sum_{s=t}^{\infty} \beta^{s-t} \ln \left(\frac{C_{ns}}{(\mu_{nn,s})^{\nu}} \right), \qquad V'_{nt} = \sum_{s=t}^{\infty} \beta^{s-t} \ln \left(\frac{C'_{ns}}{(\mu'_{nn,s})^{\nu}} \right) \tag{B.9}$$

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

$$\sum_{s=t}^{\infty} \beta^{s-t} \ln\left(\frac{\delta_n^{wel} C_{ns}}{(\mu_{nn,s})^{\nu}}\right) = V'_{nt}. \tag{B.10}$$

Rearranging the equation,

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

Appendix C Quantification Appendix

C.1 Details on Inferring Internal Trade Frictions

I describe the algorithm of the calibration procedure of domestic trade costs and trade flows. Domestic trade costs are parametrized as a function of bilateral distance between regions: $K_{nm,j} = dist_{nm,j}^{-\delta_j}$. Foreign import $K_{nf,j}^{im}$ and export trade costs $K_{nf,j}^{ex}$ are parametrized as a function of distance to port: $K_{nf,j}^{im} = dport_n^{-\delta_j^{im}}$ $K_{nf,j}^{ex} = dport_n^{-\delta_j^{ex}}$.

Given the data of gross output, expenditure imports and exports ($\{GO_{nj}, E_{nj}, IM_{nj}, EX_{nj}\}$), the static production and trade structure of the model can be expressed into the following gravity equations for each year:

$$
\begin{aligned}
GO_{nj} - EX_{nj} &= \sum_{m \in N} E_{mj} \frac{(c_{nj} d_{nm,j})^{1-\sigma}}{\sum_k (c_k d_{km,j})^{1-\sigma} + CMA_{nj}} \\
IM_{nj} &= E_{nj} \frac{CMA_{nj,t}}{\sum_k (c_{kj} d_{kn,j})^{1-\sigma} + CMA_{nj}} \\
EX_{nj} &= c_{nj}^{1-\sigma} FMA_{nj} \\
CMA_{nj} &= (d_{fn,j} e_{fj}^{im} c_{fj})^{1-\sigma} \\
FMA_{nj} &= (d_{nf,j} e_{fj}^{ex})^{1-\sigma} X_{fj} \\
d_{nm,j} &= dist_{nm,j}^{-\delta_j} \\
d_{fn,j} &= dport_n^{-\delta_j^{im}} \\
d_{nf,j} &= dport_n^{-\delta_j^{ex}}.
\end{aligned}
$$

The following lemma gives the rationale for inferring domestic trade cost given regional level data of gross output, expenditures, import and export data, $\{GO_{nj}, E_{nj}, IM_{nj}, EX_{nj}\}$.

Lemma C.1. *Consider a mapping*

$$A_n = \sum_{m=1}^{N} B_m \frac{\lambda_n K_{nm}}{\sum_{n'} \lambda_{n'} K_{n'm} + C_m}, \forall i = 1, \ldots, N \tag{C.1}$$

For any strictly positive vector $\{A_n\} > 0$ and $\{B_n\} > 0$, and any strictly positive matrix $\mathbf{K} > 0$ whose (nm)th element is K_{nm}, there exists a unique strictly positive vector $\{\lambda_n\}$.

Proof. Define $\mu_n = \sum_n K_{nm}\lambda_n + C_m$. The above equation can be rewritten as the system of equation

$$\begin{aligned}
\lambda_n^{-1} &= \sum_{m=1}^{N} \mu_m^{-1} \times \left(\frac{B_m}{A_n} K_{nm}\right) \\
\mu_n &= C_n + \sum_{n'} K_{n'n}\lambda_{n'}
\end{aligned}$$

We can obtain the desired results by applying cite[Theorem 2]Allen2020. □

Unlike the typical gravity equation system, the constant term C_n appears which is mapped to CMA_{nj} in the model under the small open economy setting. Substituting $GO_{nj} - EX_{nj}$, E_{nj} and CMA_{nj} to A_n, B_n and C_n respectively and $K_{nj} = dist_{nj}^{-\delta_j}$, I can solve out the set of unit costs $\{c_{nj}\}_{n\in\mathcal{N}}$ that rationalize the data for given δ_j.

C.1.1 Algorithm

I apply the following algorithm for each sector and year.

Step 0. Estimate δ_j^{im} and δ_j^{ex} using the gravity equation using the distance to port. Using the pooled sample across 2000-2002, I estimate the following gravity model separately for imports and exports:

$$\begin{aligned}
\ln Import_{nj,t} &= \delta_j^{im} dport_n + \beta E_{nj} + \delta_n + \delta_t + \epsilon_{nj} \\
\ln Export_{nj,t} &= \delta_j^{ex} dport_n + \beta GO_{nj} + \delta_n + \delta_t + \epsilon_{nj}
\end{aligned}$$

where δ_n and δ_t are region and year fixed effects. I assume that δ_j^{im} and δ_j^{ex} are time-invariant.

Step 1. Make a guess on δ_j

Step 2. Make a guess of $\{c_{nj}\}$ and c_{fj}.

Step 3. Make a guess of $e_{nj}^{im}\}$, which captures the region-specific increase in foreign import costs by the devaluation. Given guess on e_{nj}^{im} and c_{fj}, I can compute $CMA_{nj,t} = (d_{fn,j}e_{fj}^{im}c_{fj})^{1-\sigma}$. Iterate the following two equations until e_{fj}^{im} and c_{fj} until convergence:

$$\begin{aligned} c_{fj} &= \sum_n IM_{mj} / \left(\frac{\sum_m CMA_{mj}}{\sum_{n'} c_{n'j} d_{n'm,j} + CMA_{mj}} \right) \\ IM_{nj} &= E_{nj} \frac{CMA_{nj}}{\sum_{n'} c_{n'j} d_{kn,j} + CMA_{nj}} \end{aligned}$$

The sum of all imports identify c_{fj} which is common across regions, and regional imports data identify region-specific component e_{nj}^{im} conditional on c_{fj}. I normalize one region-sector's e_{nj}^{im} to be one, because e_{nj}^{im} only identifies relative difference across regions.

Step 4. From obtained c_{fj} and e_{nj}^{im}, compute CMA_{nj}. The, solve out for c_{nj} using the following equation:

$$GO_{nj} - EX_{nj} = \sum_{m \in N} E_{mj} \frac{c_{nj} d_{nm,j}}{\sum_{n'} c_{n'} d_{n'm,j} + CMA_{mj}}$$

The existence and uniqueness are guaranteed by Lemma C.1.[51]

Step 5. Iterate Step 2-4 until the convergence.

[51] Note that the solution is not up-to scale because of the constant term. If there were no constant term in Lemma C.1, the equation becomes the standard gravity model, where c_{nj} are identified only up to scale.

Step 6. Using the backed out c_{nj} from Step 2-5, solve out for e_{nj}^{ex} and X_{fj} using the following two equations:

$$
\begin{aligned}
X_{fj} &= \sum_n EX_{nj} \Big/ \left(\sum_n (c_{nj} dport^{-\delta_j^{ex}})^{1-\sigma} \right) \\
EX_{nj} &= (c_{nj} e_{nj}^{ex} dport_n^{-\delta_j^{ex}})^{1-\sigma} X_{fj}
\end{aligned}
$$

Using the above system of equation and obtained value of $\{\lambda_{nj}\}$, I back out λ_{fj}^{ex} and $\{u_{nj}^{im}\}$ similarly to Step 2. They rationalize the overall level of exports and difference export level between regions.

Step 7. I evaluate the following objective function:

$$
Var((1-\sigma)\log(e_{nj}^{ex})) = Var\left(\log \frac{EX_{nj}}{(d_{n,Port}^{-\delta_j^{ex}})^{1-\sigma} X_{fj}} \right)
$$

Step 8. For each sector and year, I repeat Step 1-7 for a grid of values of δ_j and pick the value that minimizes the criterion function. This makes $dport_n^{(1-\sigma)} X_{fj}$, the observed trade costs and the common component of FMA_{nj} across regions, to explain the most part of the dispersion of unit cost captured by the variance of regional exports.

After finishing the algorithm, I pick δ_j as the median across the sample period for each sector.

C.1.2 Domestic Trade Cost Estimates

C.2 Details on Recovering the Shocks

C.2.1 Algorithm

To back out the shocks, I only use the production side of the model. This is convenient because, unlike the dynamic decision of migration, the production side of the model is static. I compute $\{A_{nj,t}, FMA_{nj,t}, CMA_{nj,t}\}$ using the following algorithm.

Table A1: Estimates of Domestic Trade Cost Coefficients

Sector & Estimates	
Food Beverage & Tobacco	1.35
Chemical	1.71
Miscellaneous	1.47
Agricultural, Fishing & Tobacco	2.20
Electric	1.96
Metal & Mineral	2.2
Other Service	9.31
Textile	2.08
Construction, Transportation, Retail & Utility	6.45
Transport Equipment	1.47
Wood	1.47

Step 1. Guess of composite productivity $T_{nj,t} = c_{nj,t}$ and foreign unit cost $c_{fj,t}$ and unobserved international trade cost component $u^{IM}_{fj,t}$. Then, compute price index.

Step 2. Given $T_{nj,t}$ and price index, compute new $e_{fj,t}c_{fj,t}$ and $u_{fnj,t}$ by fitting the total imports and regional imports exactly as in Equation C.2 and C.2. Iterate until price index, $e_{fj,t}c_{fj,t}$ and $u^{IM}_{fnj,t}$ are consistent with the imports data. This gives $CMA_{nj,t} = e_{fj,t}c_{fj,t}\tilde{\kappa}_{fnj,t}u_{fnj,t}$ where $\kappa_{fnj,t}$ is the observable component, which is obtained from the gravity estimation.

Step 3. Make a guess on $u_{nf,jt}$ and $e^{\sigma-1}_{fj,t}X_{fj,t}$. Given $T_{nj,t}$ and $CMA_{nj,t}$, iterate until they fit both total sum of exports and regional export data exactly. This gives $FMA_{nj,t} = \tilde{\kappa}_{fj}u_{nf,jt}e^{\sigma-1}_{fj,t}X_{fj,t}$.

$$\lambda^{ex}_{fj} = \sum_n EX_{nj} \Big/ \left(\sum_n \lambda_{nj} K_{nf,j} \right) \tag{C.2}$$

$$EX_{nj} = \lambda_{nj}\lambda^{ex}_{fj}K_{nf,j} \tag{C.3}$$

The total sum of exports (Equation C.2) identify $\lambda_{fj,t}$ which is common across all regions for sector j. Region level export (Equation C.3) identify region specific unobservable trade cost shock.

Step 4. Given $\{T_{nj,t}, FMA_{nj,t}, CMA_{nj,t}\}$, I construct new revenue for each region and sector. Iterate Step 1-4 until the observed revenue from the data matches the model implied revenue.

The following goods market condition identifies $T_{nj,t} = c_{nj,t}$ given $\{FMA_{nj,t}, CMA_{nj,t}\}$:

$$\begin{aligned} X_{nj,t} &= \sum_{k=1}^{J} \alpha_k^j R_{nk,t} + \beta_j (\sum_{k=1}^{J} w_{nk,t} L_{nk,t}) && \text{(C.4)} \\ GO_{nj,t} &= \sum_{m \in \mathcal{N}} \pi_{nm,jt} X_{mj,t} + c_{nj,t}^{1-\sigma} \times \underbrace{\tau_{nf,jt}^{1-\sigma} e_{ft}^{\sigma-1} E_{fj,t}}_{=FMA_{nj,t}} && \text{(C.5)} \end{aligned}$$

For each time t, the above equation system imply that there are NJ unknowns $(T_{nj,t})$ with NJ number of equations, which is exactly identified.

Step 5. Once I recover $\{T_{nj,t}\}$, I have to tease out natural productivity $\{A_{nj,t}\}$ by computing $c_{nj,t}$. I use the following equation to recover average wage per working hour W_{nt}:

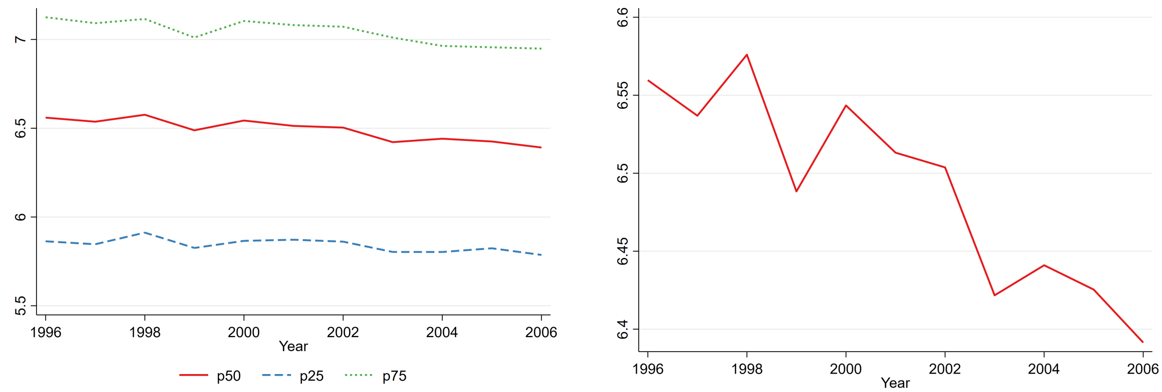
$$W_{nt} H_{nt} = \sum_j \alpha_j^E R_{nj,t} \tag{C.6}$$

where H_{nt} and the RHS can be directly obtained from the data. Using obtained W_{nt} and observed working houre share $\{\lambda_{nj,t}\}$ within each region, I can compute $w_{nj,t}$ using the following equation

$$\lambda_{nj,t} = \frac{w_{nj,t}^\theta}{W_{nt}^\theta}. \tag{C.7}$$

Then, using price index and $w_{nj,t}$, I can compute unit cost $c_{nj,t}$.

C.3 Additional Results on Migration Costs



A. p25, p50, and p75

B. Median

FIGURE A1: Percentiles of Migration Costs

Notes. Panel A plots the p25, p50, and p75 of migration costs across pairs for each year. Panel B plots the median of migration costs across pairs for each year. Migration costs are calculated using Equation 5.11.

C.4 Dynamic Hat Algebra

C.4.1 Static and Dynamic Equilibrium in Changes

Following Caliendo et al. (2019), I break down the equilibrium into two parts: a static equilibrium, which is a goods market equilibrium that takes the migration flows as given, and a sequential equilibrium that solves households' dynamic problem and satisfies a static equilibrium for each period.

Static Equilibrium. The static equilibrium can be expressed as the time differences:

$$\text{(Unit Cost)} \quad \hat{c}_{nj,t} = \frac{1}{\hat{A}_{nj,t}}(\hat{w}_{nj,t})^{\alpha_L^j} \prod_{k=1}^{J} (\hat{P}_{nj,t})^{\alpha_k^j} \tag{C.8}$$

$$\text{(Price Index)} \quad \hat{P}_{nj,t} = \left(\sum_{m \in \mathcal{N}} \pi_{mn,t}(\hat{\tau}_{mn,t}\hat{c}_{mn,t})^{1-\sigma} + \pi_{fn,t}\widehat{CMA}_{nj,t}^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \tag{C.9}$$

$$\text{(Average Wage)} \quad \hat{W}_{n,t} = \left(\sum_{j=1}^{J} \lambda_{nj,t}\hat{w}_{nj,t}^{\theta} \right)^{\frac{1}{\theta}} \tag{C.10}$$

$$\text{(Domestic Trade Share)} \quad \pi_{mn,jt+1} = \pi_{mn,jt}\left(\frac{\hat{c}_{mj,t}\hat{\kappa}_{nj,t}}{\hat{P}_{nj,t}} \right)^{1-\sigma} \tag{C.11}$$

$$\text{(Foreign Trade Share)} \quad \pi_{fn,jt+1} = \pi_{fn,jt}\left(\frac{\widehat{CMA}_{mj,t}}{\hat{P}_{nj,t}} \right)^{1-\sigma} \tag{C.12}$$

$$\text{(Sectoral Labor Supply)} \quad \lambda_{nj,t+1} = \lambda_{nj,t}\left(\frac{\hat{w}_{nj,t}}{\hat{W}_{nt}} \right)^{\theta} \tag{C.13}$$

$$\text{(Aggregate Labor Supply)} \quad \hat{H}_{nt} = \hat{e}_{nt}\hat{L}_{nt} \tag{C.14}$$

$$\text{(Gross Output)} \quad R_{nj,t+1} = \sum_{m=1}^{N} \pi_{mn,jt+1}X_{mj,t+1} + \hat{c}_{nj,t+1}\widehat{FMA}_{nj,t+1}EX_{nj,t} \tag{C.15}$$

$$\text{(Goods Market Clearing)} \quad X_{nj,t+1} = \sum_{k=1}^{K} \alpha_k^j R_{nk,t+1} + \beta^j \hat{W}_{nt}\hat{H}_{nt}W_{nt}H_{nt} \tag{C.16}$$

$$\text{(Labor Market Clearing)} \quad \hat{\lambda}_{nj,t}\hat{W}_{nt}\hat{H}_{nt}\lambda_{nj,t}W_{nt}H_{nt} = \alpha_j^E \sum_{m=1}^{N} \pi_{mnj,t+1}X_{mj,t+1} \tag{C.17}$$

Dynamic Equilibrium Define $u_{n,t} = exp(V_{nt})$, $b_{nt} = exp(B_{nt})$ and $m_{nm,t} = exp(\tau_{nm,t})$. Then, $\hat{u}_{nt} = exp(V_{nt+1} - V_{nt})$ and $\hat{m}_{nm,t} = exp(\tau_{nm,t+1} - \tau_{nm,t})$. Conditional on initial allocation, $\{L_0, \pi_0, \lambda_0, X_0, \mu_{-1}\}$, given an anticipated convergence sequence of changes in shocks, $\{\hat{\Theta}\}_{t=1}^{\infty}$, dynamic equilibrium satisfies the following system of nonlinear equations:

$$\mu_{nm,t+1} = \frac{\mu_{nm,t}(\hat{u}_{m,t+1})^{\frac{\beta}{\nu}}(\hat{m}_{m,t})^{-\frac{1}{\nu}}(\hat{b}_{m,t})^{\frac{1}{\nu}}}{\sum_{m'=1}^{N} \mu_{nm',t}(\hat{u}_{nm',t+1})^{\frac{\beta}{\nu}}(\hat{m}_{m,t})^{-\frac{1}{\nu}}(\hat{b}_{m,t})^{\frac{1}{\nu}}} \tag{C.18}$$

$$\hat{u}_{nm,t+1} = \hat{\omega}_m(\hat{L}_t, \hat{\Theta}_t)\left(\sum_{m'} \mu_{m't}(\hat{u}_{m',t+1})^{\frac{\beta}{\nu}}(\hat{m}_{m',t})^{-\frac{1}{\nu}}(\hat{b}_{m',t})^{\frac{1}{\nu}} \right)^{\nu} \tag{C.19}$$

$$L_{n,t+1} = \sum_{m} \mu_{mn,t}L_{mt} \tag{C.20}$$

for all n at each t, where $\{\hat{\omega}(\hat{L}_t, \hat{\Theta}_t\}$ is the changes of the indirect utility in the static equilibrium defined as $\omega(\hat{L}_{nt}, \hat{\Theta}_{nt}) = \ln(\hat{W}_{nt}\hat{e}_{nt}/\hat{P}_{nt})$.

I first derive Equation C.18 and then Equation C.19. Migration shares can be expressed as

$$\mu_{nm,t} = \frac{exp(\beta V_{nt+1} + B_{mt} - \tau_{nm,t})}{\sum_{m'} exp(\beta V_{m't+1} + B_{m't} - \tau_{nm',t})}$$
$$= \frac{\hat{u}_{nt}^{\frac{\beta}{\nu}} \hat{b}_{mt-1}^{\frac{1}{\nu}} \hat{m}_{mn,t-1}^{-\frac{1}{\nu}} exp(\beta V_{nt} + B_{mt-1} - \tau_{nm,t-1})}{\sum_{m'} \hat{u}_{nt}^{\frac{\beta}{\nu}} \hat{b}_{m't-1}^{\frac{1}{\nu}} \hat{m}_{m'n,t-1}^{-\frac{1}{\nu}} exp(\beta V_{m't} + B_{m't-1} - \tau_{nm',t-1})}$$

Dividing both the denominator and numerator of the RHS of the above equation by $\sum_{m'} exp(\beta V_{m',t} + B_{m',t-1} - \tau_{nm',t-1})$, I can obtain the desired results.

Take Equation 4.3 in time differences:

$$V_{n,t+1} - V_{n,t} = ln\left(\frac{W_{n,t+1} e_{n,t+1}}{P_{n,t+1}}\right) - ln\left(\frac{W_{n,t} e_{n,t}}{P_{n,t}}\right) + \nu \log \frac{\sum_m exp(\beta V_{n,t+2} + B_{n,t+1} - \tau_{nm,t+1})}{\sum_m exp(\beta V_{n,t+1} + B_{n,t} - \tau_{nm,t})}$$

Taking exponential from both sides and using the definition of u_{nt},

$$\hat{u}_{nt} = \omega(\hat{L}_{nt}, \hat{\Theta}_{nt}) \left(\sum_n \mu_{nt} (\hat{u}_{n,t+1})^{\frac{\beta}{\nu}} (\hat{b}_{nt})^{\frac{1}{\nu}} (\hat{m}_{nt})^{-\frac{1}{\nu}} \right)^{\nu}.$$

C.4.2 Algorithm for Solving the Model

To solve the model, given values of the parameters of the model, I require the shocks $\{\hat{\Psi}\}_{t=1}^{\infty}$, initial equilibrium allocation in $t = 0$. The model's algorithm is as follows:

For sufficiently large T, given the shocks $\{\Psi_t\}_{t=0}^{T}$ and $\{\hat{m}_{mn,t}\}_{t=0}^{T}$,

1. Guess the path of $\{\hat{V}_{nt}\}_{t=0}^{T}$.
2. For all t, use initial migration shares $\mu_{mn,-1}$ and the guess of $\{\hat{V}_{nt}\}_{t=0}^{T}$ to compute the path of migration shares $\{\mu_{mn,s}\}_{t=0}^{T}$.
3. Using the path of migration shares $\{\mu_{mn,s}\}_{t=0}^{T}$ obtained in the previous step, calculate the path of $\{L_{nt}\}_{t=0}^{T}$ using Equation 4.5

4. Given the path of $\{L_{nt}\}_{t=0}^{T}$ obtained from the previous step, for each period t, solve Equation C.8-C.17.
5. From the previous step, compute $\{\omega(\hat{L}_{nt}, \hat{\Theta}_{nt})\}_{t=0}^{T}$.
6. Using the computed $\{\omega(\hat{L}_{nt}, \hat{\Theta}_{nt})\}_{t=0}^{T}$ in the previous step, compute a new path of $\{\hat{V}_{nt}^{(1)}\}_{t=0}^{T}$.
7. Take the $\{\hat{V}_{nt}^{(1)}\}_{t=0}^{T}$ as a new guess.
8. Iterate steps 2-7 until $\{\hat{V}_{nt}^{(1)}\}_{t=0}^{T}$ converge.