Quantifying the Benefits of Labor Mobility in a Currency Union*†

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Abstract

Cyclical unemployment rates differ substantially more between countries in the euro area than between states in the United States. We find that net migration is responsive to unemployment differentials, but the response is smaller in Europe relative to the U.S. This paper explores to what extent the lack of labor mobility in Europe makes it more difficult for the euro area to adjust to shocks. We develop a multi-country DSGE model of a currency union with cross-border migration and search frictions in the labor market. The model is calibrated to the 50-state U.S. economy and to the 31-country European economy and replicates, for each region, the relationship between net migration and unemployment differentials. The model allows us to quantify the benefits if Europe had enjoyed levels of labor mobility as high as those in the U.S. during the most recent crisis, and contrasts these gains to those observed if Europe had flexible exchange rates.

Keywords: international migration, optimal currency areas, international business cycles.

JEL Codes: F22, F41, F45

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1 Introduction

Cyclical unemployment rates differ substantially more between countries in the euro area than between states in the United States. Figure 1 plots unemployment rates in 12 Western European euro area economies and 48 US states between 1995 and 2015, together with the euro area and U.S. averages (blue, thick lines). Overall, the aggregate euro area experience is similar to that of the United States, with similar average unemployment rates and upticks during both the 2001 and the 2008/09 recessions. The corresponding standard deviations of the average unemployment rates are also of comparable size (1.4% for the United States and 1.7% for the euro area). This similarity, however, masks a tremendous amount of variation across the euro area. The cross-sectional standard deviation, averaged over 1995 - 2015, is more than three times larger in the euro area than the United States (3.85% vs. 1.21%).

A widespread view among economists and policymakers is that large and increasing unemployment rate differentials within the euro area pose a significant risk to the common currency because a euro-area wide monetary policy cannot be tailored to country-specific economic conditions. Mundell (1961) famously advocated for labor mobility as a pre-condition for an optimal currency area. Despite concerns about the extent of labor market integration in Europe, member states moved ahead with the adoption of the euro. Today the question remains: are European markets flexible enough to adjust to macroeconomic shocks in the absence of independent monetary policy? If they are not, what is the opportunity cost to euro area economies of a currency union given the current degree of market integration? Our main empirical finding is that there is indeed a quantitatively higher degree of net migration in response to unemployment differentials within the United States that helps regions adjust to location-specific shocks. But how important is this margin of adjustment for explaining macroeconomic performance in the United States relative to Europe?

To answer these questions, we develop a multi-region DSGE model that contains the standard elements of business cycle models (consumption choice, capital accumulation, etc.), a search and matching framework in the labor market giving rise to unemployment, and most importantly, cross-border labor mobility where household members choose their work location. We calibrate the model to the multi-state economy of the United States, and to the multi-country economy of Europe to capture state/country size, migration stocks, openness to trade and migration, unemployment rates and the currency regime. We then feed in region-specific shocks to the demand of a region's produced goods, where we recover the realizations of these shocks to perfectly match the observed unemployment rates in the data. By adjusting the parameter that governs the degree of labor mobility, we are able to match the empirically found elasticity of net migration to unemployment rates.

We then take the model as a benchmark for conducting a set of model-based counterfactuals. For example, the model allows us to ask, what would have been Europe's experience (in terms of unemployment rates and other macroeconomic variables) during and following the Great Recession if labor mobility were similar to that of the United States? Our main result from these counterfactual experiments is that labor migration can partly act as a substitute for independent monetary policy. Cross-sectional variation in unemployment rates in the euro area would have been by about 8% lower between 1995 - 2015 if workers were as geographically mobile as their U.S. counterparts, but by about 24% if countries had pursued independent monetary policy.

While the counterfactual unemployment rates are somewhat similar under flexible exchange rates and greater labor mobility, the mechanisms that achieve these similar unemployment rate responses are very different. In the first case, countries with high unemployment rates would have loosened their monetary policy to stimulate the economy, leading to strong currency depreciations. These depreciations would have raised demand for domestic products, both through higher local demand and higher exports. In the second case more labor mobility within the currency union - a substantial outflow of workers would have directly lowered unemployment rates through tighter labor markets. For the GIIPS economies, the required outflow between 2009 and 2014 would have been about 5 percent of the population, instead of the 0.5 percent outflow observed in the data.

Our research relates to the classic literature on "optimal currency areas", going back at least to Friedman's *Case for Flexible Exchange Rates* (Friedman, 1953). The European debt crisis and the divergence in economic outcomes across the euro area spurred a resurgence of research in the area. Among the papers most closely related to our work is Farhi and Werning (2014) who study labor migration in response to external demand shortfalls and the impact on the economies that receive the labor inflow as well as on those economies experiencing the ouflow. They find that labor outflows can benefit those who are staying, especially if economies are tightly linked through trade. Extending this model to include search and matching frictions, Hauser and Seneca (2018) argue that a mobile labor force reduces the welfare costs of joining a monetary union.

On the empirical side, Blanchard and Katz (1992) estimate the joint behavior of employment growth, the employment rate and the participation rate in response to a positive region-specific labor demand shock. They back out migration rates indirectly from data on employment and participation rates. For US states, they find that a decrease in employment by 100 workers leads to an outmigration of 65 workers in the first year, together with an increase in unemployment by 30 workers. This seminal work spurred several studies that applied their methodology to other geographical areas and time periods. For instance, Beyer and Smets (2015) find a somewhat smaller migration response using more recent data for the United States, but more importantly, report that outmigration accounts for less than 20 percent of the adjustment for European countries. Both Beyer and Smets (2015) and Jauer et al. (2014) report that migration responses within European countries in response to local demand shocks are comparable to those observed within the United States. Our results differ from theirs in that we use bilateral migration data and focus on the response to unemployment differentials at the business cycle frequency.

2 Empirical Analysis

2.1 Data

Geographical Coverage We analyze migration flows in three geographical areas: The United States, Canada and Europe. The sample for the US consists of 48 states (excluding Alaska and Hawaii due to their geographical particular location vis-a-vis the rest of the United States). For Canada, it consists of all ten provinces. For Europe, it is more difficult to establish a time-invariant geographical unit for two reasons: First, the euro area was only established in 1999 and thereafter has witnessed several rounds of enlargements. Second, and more importantly, some restrictions on labor mobility were still present throughout the 2000s, especially for Central and Eastern European countries. We therefore choose two samples based on a “ narrow” and a “wide” definition of Europe: Our first sample only includes the twelve core euro area countries of Western Europe (including Denmark whose currency has always been pegged to the euro). These countries form a fairly homogenous block in terms of economic development and lifted restrictions on the movement of labor in the late 80s / early 90s.[1] Our second sample adds another 17 European countries to our first sample.

[1] Belgium, Denmark, Germany, Ireland, Greece, Spain, France, Italy, Netherlands, Austria, Portugal, Finland. We exclude Luxembourg due to its tiny size, the paucity of migration data and the high share of cross-border commuters in the total share of the workforce, which was above 40 percent in 2010 according to

These countries are either part of the European Union or part of the European Free Trade Association.[2]

Sample Period For the US and Canada, our sample period is 1977-2014. The sample choice is mostly governed by the lack of unemployment and migration data at the subnational level prior to the mid 70s. For the European sample, we focus on 1995-2015 because migration data is only availabe for a handful of countries prior to 1995 and restrictions on labor mobility were still prevalent in the core euro area in the late 1980s and early 1990s.

Data Sources For every region, we collect data on population, unemployment rates and migration data. Data on annual, bilateral migration flows at the US state level is provided by the Internal Revenue Service (IRS) and starts in 1975. Based on the universe of tax filers, the data reports the number of returns that migrated (as indicated by the mailing address on the tax return) between any two states, and the number of returns that did not migrate.[3] We use these two numbers to calculate migration rates between states. We choose this IRS data set to analyze labor mobility across states - as opposed to alternative sources used in the literature, such as the American Community Survey and the Current Population Survey) - for two reasons: i) the universe of tax filers has a strong overlap with the universe of *workers* (as opposed to the entire population), and ii) it does not suffer from small sample sizes that would be particularly problematic for measuring migration flows between smaller states. This data is also used by the US Census to calculate state-level net migration rates.[4] Data on state population and unemployment rates are provided by the Bureau of Economic Analysis and the Bureau of Labor Statistics.[5].

Data for Canadian provinces comes from Statistics Canada. Migration data starts in 1972 and unemploymen rate data starts in 1977.

Data on total immigration and emigration in Europe is provided by both Eurostat and national statistical agencies. To create a database of migration for European countries, we

Statistics Luxembourg.

[2]Bulgaria, Czech Republic, Estonia, Cyprus, Latvia, Lithuania, Hungary, Malta, Poland, Romania, Slovenia, Slovak Republic, Sweden, United Kingdom, Iceland, Norway, Switzerland

[3]Starting in 1991 it also reports the total of last year's income associated with those migrating returns, by state of origin and state of destination. This could be used to analyze migration of income.

[4]An overview on internal migration is given in Molloy, Smith and Wozniak (2011).

[5]Population as of July 1st: BEA, starting in 1969, Regional Data > GDP & Personal Income > SA1 Personal Income Summary: Personal Income, Population, Per Capita Personal Income; Unemployment rate: BLS, starting in 1976, Series: LASST010000000000003

adjust this data to account for varying definitions of 'migration' across countries. Starting in 2008 Eurostat has asked member states to provide data on migration flows according to the UN definition, which defines migrants as any person moving in or out of a country for at least 12 months, irrespective of their nationality or their country of birth.[6] Data prior to 2008 based on national definitions is then adjusted by a country-specific factor estimated on data post 2008. Our panel data for Europe is unbalanced, as displayed in Table A4. We have complete data for twelve countries. For another nine countries, data starts by 1998.[7]. We also create a database of bilateral migration flows to report statistics on the share of migration coming from European countries.[8] Data on unemployment rates is collected through national labor force surveys and reported by Eurostat. The Appendix provides more details on data sources and the construction of the migration database for Europe.

2.2 Facts on Subregional Unemployment and Migration

Unemployment Rates We start by documenting the cross-sectional dispersion in unemployment rates across the three regions in our sample. For that purpose, we first demean unemployment rates in both the cross-sectional and the time dimension. That way, we clean the data from long-run differences in unemployment rates as well as national business cycles, which are not the focus of this paper.

Denoting state i's unemployment rate at time t by $u_{i,t}$, the average unemployment rate in state i $u_i = \frac{1}{T}\sum_{t=1}^{T} u_{i,t}$, the national unemployment rate at time t $u_t = \frac{1}{N}\sum_{i=1}^{N} \frac{pop_i}{pop} u_{i,t}$ and the total average $\bar{u} = \frac{1}{T}\sum_{t=1}^{T} u_t$, we calculate this double-demeaned unemployment rate as

$$\hat{u}_{i,t} = u_{i,t} - u_i - (u_t - \bar{u}). \tag{2.1}$$

Here, the national unemployment rate is calculated based on the average state population

[6]Importantly, our data captures migration by previous / next residence. For instance, both a German and French citizen moving from France to Germany are counted as emigrants from France and immigrants to Germany.

[7]The first group consists of Belgium, Czech Republic, Denmark, Germany, Italy, Netherlands, Slovenia, Finland, Sweden, Iceland, Norway, Switzerland. The second group consists of Ireland, Greece, Spain, Cyprus, Latvia, Lithuania, Austria, Portugal, United Kingdom

[8]Setting up such a database requires an additional cleaning step: We have to reconcile so-called 'mirror' flows. For the same flow of migrants between two countries, we potentially observe two different values reported by the two countries. That is, we observe two data values for bilateral flows, one reported by the origin country, and one reported by the destination country. We reconcile these values following a methodology used in bilateral trade data that gives a larger weight on data from "high-quality" reporters. See the Appendix for details.

over the sample period.

As mentioned in the introduction, these demeaned unemployment rates display a stronger dispersion in Europe than in North America. Table 1 reports the average standard deviations of the demeaned unemployment rates, $\sum_t std\,(\hat{u}_{i,t})$. For the US and Canada, this standard deviation is about 1, whereas it is about 2.5 for the two European samples. Interestingly, we also observe that regions tend to drift apart during certain economic downturns: As displayed in Figure 2, unemployment rates were particularly dispersed in the U.S. during the crisis at the beginning of the 1980s and the Great Recession, but not during the 2001 recession. Europe saw its unemployment rates diverge especially during the debt crisis in 2011 - 2013, with a standard deviation of almost 5 percentage points in the core euro area.

We next examine the persistency of these unemployment rate differentials. If these differentials were only temporary, they could be considered less threatening to the economic cohesion of a monetary union. Following Blanchard and Katz (1992), we estimate a simple AR(2) process for the demeaned unemployment rate:

$$\hat{u}_{i,t} = \beta_i + \beta_1 \hat{u}_{i,t-1} + \beta_2 \hat{u}_{i,t-2} + \epsilon^u_{i,t}. \tag{2.2}$$

The results are presented in Table 1. From these estimated coefficients, we can also derive the associated impulse response, which gives the response of the unemployment rate to an innovation in $\epsilon^u_{i,t}$ by equation (2.2). Figure 3 plots these impulse responses for our three regions. They reveal that unemployment rate differentials are somewhat persistent across all regions, especially in the euro area. In response to an innovation of 1, unemployment rates initially increase (except for in Canada) before returning to zero. The half life ranges between 3 years (Canada) and 5 years (euro area).

To summarize, this section has shown that (demeaned) unemployment rates are more dispersed across European countries than US states and that this dispersion is quite persistent, especially in the euro area. Before we ask how migration patterns react to these unemployment rate differentials, we first present a few stylist facts about migration in our three regions.

Migration In this section we show that migration is more prevalent in North America than in Europe. We also see that migration rates have been declining in the US, but increasing in Europe.

We define *migration rates* as the ratio of the average of inflows and outflows over one year to the population at the beginning of the year.[9] That is, the migration rate of state i at time t is

$$\text{migr}_{i,t} = \frac{1}{2}\frac{v_{i,t} + v_t^i}{N_{i,t}},$$

where $v_{i,t}$ is total inflow of migrants to state i in year t, v_t^i are total outflows of migrants, and $N_{i,t}$ is state i's population at the beginning of t.[10]

Table 2 reports migration rates for our four regions. Migration rates are first averaged over time, and then averaged across states, using simple averages. The table shows that migration rates are substantially higher in North America than in Europe. In the US, the migration rate is a bit more than 3 percent, while it is only 0.7 percent in Europe. Canada lies in between the two with a migration rate of 2 percent. These differences in migration rates could be due to geographical differences between these three regions. For instance, a basic "gravity" model (see e.g Anderson, 2011) would suggest that migration rates are a function of migration costs and population sizes, with smaller countries, all else being equal, having higher migration rates. Table 2 indicates that US states are on average smaller than European countries, which could explain the low migration rates in European countries. When we plot migration rates against population size (see Figure 4), we find, however, that even for a similar population size, countries in Europe have substantially lower migration rates than US states. Migration rates in Canadian provinces are higher than in Europe, but lower than in the US, which potentially indicates that the geographical distance between states, which is larger in Canada compared to the US, proxies for migration costs.[11] We can conclude that geography alone is unlikely to explain the low migration rates in Europe, leaving room for other explanatory factors (e.g. language and culture barriers, recognition of qualifications,...).[12] We also see that there is no

[9] For the US, we divide the average number of migrating tax returns by the number of all tax returns observed in t that originate from state i. This is also the approach used by the US Census.

[10] For the US, a time period starts on July 1st of the previous year. Migration is not directly observed, but only location changes between two calendar years, e.g. a tax filer living in Ohio in 1999 and in Michigan in 2000. Our best guess is that the move took place between July 1st 1999 and June 30th 2000. We adjust all variables for the US for this timing convention.

[11] This exercise is analogous to the standard gravity approach in the international trade literature. A quick comparison for US states shows that openness in goods markets is little correlated with migration rates (openness in labor markets), although both are clearly negatively correlated with population size. This indicates that migration costs and trade costs might be quite different.

[12] The lower migration rates in Canada compared to the US could also reflect language barriers and institutional barriers, such as the lack of mutual recognition of professional or trade credentials across provinces and costs associated with switching health care insurance, which is organized at the province level (see Gomez and Gunderson, 2007). In addition, measured migration related to oil price fluctuations (from eastern provinces to Alberta and Saskatchewan) is baised downwards due to "inter-provincial employees", i.e. individuals who maintain a permanent residence in a given province or territory, but work in another (see Laporte et al., 2013).

strong difference in migration rates between the full European sample and the subsample of core euro area countries. Even though migration rates are somewhat lower in the core euro area countries, this is mainly due to the larger average country size in that sample.

Figure 5 displays migration rates, averaged across all states, over time for each of the three regions. We can see that migration rates have been downward trending in US states and Canadian provinces, as observed e.g. in Molloy, Smith and Wozniak (2011). Since the mid-70s migration rates have fallen from 3.75% to 3% in the US, and from 3.2% to 1.75% in Canada. At the same, migration rates have been generally upward trending across European countries, from around 0.5% to 0.9%.

Not all migrants moving to a US state come from another US state. The *internal migration rate* is the number of state i's (in- and out-) migrants coming from / going to another state, as a share of state i's total migrants:

$$\text{dom}_{i,t} = \frac{\sum_{j \in \mathcal{N}} \left(v_{i,t}^{j} + v_{j,t}^{i} \right)}{N_{i,t}},$$

where $\mathcal{N}$ is the number of US states (including Alaska and Hawaii, as well as Washington D.C.).[13] Table 2 indicates that the differences in migration rates discussed above are even bigger when one solely focuses on internal migrants. Almost all of the migrants in the US states come from other US states. In Canada, the share of internal migrants is about three quarters. In contrast, in Europe, only 60% of all migrants come from or go to other European countries.[14]

To get a sense of how volatile migration is, the last row in Table 2 reports the standard deviation of the *net immigration rate* over time. The *net migration* rate is the ratio of a state's total inflows net of total outflows to its population:

$$\text{netm}_{i,t} = \frac{v_{i,t} - v_{t}^{i}}{N_{i,t}}.$$

For every state we calculate its standard deviation over time. The average across all states is about 0.5 in North America, and only 0.3 in Europe.

[13]Similarly, we include Canadian territories in $\mathcal{N}$ in the Canadian case, and all 29 European countries in $\mathcal{N}$ in both the 'Europe' and 'Core euro area' cases.

[14]Table A6 in the Appendix indicates that Europe's colonial history could play a role in explaining these low numbers, with France, Spain and the United Kingdom having especially low internal migration rates. In constrast, internal migration rates tend to be higher in Eastern European countries.

2.3 Unemployment Rates and Net Migration

We now analyze the relationship between unemployment rates and net migration rates. We choose a parsimonious regression setup based on double-demeaned variables:

$$\widehat{netm}_{i,t} = \beta_0 + \beta \hat{u}_{i,t} + \epsilon_{i,t}, \tag{2.3}$$

where $\hat{u}_{i,t}$ is the double-demeaned unemployment rate as defined in (2.1) and $\widehat{netm}_{i,t}$ is the double-demeaned net migration rate (including both internal and external migration). It is important to use demeaned variables. First, we demean every observation by its state average to control for constant state-specific factors: Some states are generally more attractive to migrants than others (e.g. Florida) and some states enjoy lower unemployment rates than others (e.g. South Dakato). Our paper focuses on changes in migration patterns at the business cycle frequency and we therefore control for these constant factors. This choice is also consistent with our model, which does not speak to these long-run differences across states.

Second, we demean every observation by the national average. This choice is imposed by the nature of our variables. As we saw before, most of net migration at the state level is *internal* migration, i.e. from and to other US states. Internal migration at the national level has to be zero, both in periods of high national unemployment and low national unemployment. That is, even though most U.S. states experienced one of their highest unemployment rates in our sample during the Great Recession, we cannot observe net outmigration in all states at the same time. What matters for an individual's choice to emigrate depends on its state's unemployment rate *relative to the national unemployment rate.*[15]

APPENDIX: COMPARISON TO HURST ET AL?

Table 3 displays the results of this regression. As before, the time period for the North American samples is 1977-2014, and 1995-2015 for the European samples. For the United

[15] In all our samples, the estimated β coefficient from a regression using state and time fixed effects

$$netm_{i,t} = \beta_0 + \beta_i + \beta_t + \beta u_{i,t} + \epsilon_{i,t}$$

is quantitatively very similar to the β coefficients from regression (2.3) and reported in Table 3. This regression with state and time fixed effects is indeed equivalent to a regression on double-demeaned variables if (i) the panel is balanced and (ii) means are calculated as *simple* averages. We prefer our original formulation, (2.3), where we calculate the national mean as a *weighted* average because this is in line with 'gravity' models of migration, where migration flows between regions are functions of the regions' population (see e.g Anderson, 2011). For instance, for a Michigan household, California's unemployment rate is supposedly more relevant for its migration decision than Rhode Island's unemployment rate.

States, the coefficient β is fairly precisely estimated at -0.27 (0.01) (see also Figure 6a). This implies that in years where a state has an unemployment rate 1 percentage above the national mean, the net migration rate falls by 0.27 percentage points. In other words, for an increase of unemployment of 100 workers, 27 workers leave the state. These regressions are not meant to recover the underlying structural shocks that cause fluctuations in unemployment and net migration. We simply observe that periods with high unemployment are correlated with periods of net outmigration. We can, however, link these numbers back to our estimated impulse response functions for the unemployment rate derived from equation (2.2). A positive innovation to the unemployment rate equal to 1 percentage point upon impact is associated with an outflow of .27 percent of the population in the first year. This innovation raises the unemployment rate further to 1.15 percentage point above its mean in the second year, which will be associated with another outflow of about .31 percent of the population. Over a horizon of 20 years, as the unemployment rate falls back to its long-term average, the population will have shrunk by about 1.35 percent (see Figure 7). This indicates that these migration patterns are of economically significant magnitude, at least for the U.S.

Figure 8 displays the estimated β coefficients for the U.S. when we run regression (2.3) separately for all years in our sample. The coefficient has slightly diminished over time, which is consistent with lower migration across U.S. states found in Figure 5. Some papers have argued that migration only played a minor role during the Great Recession as compared to other recessions.[16] The estimated coefficients in Figure 8 do not lend support for this hypothesis. In 2010 the estimated coefficient is $\hat{\beta} = -0.25(0.05)$, which is very close to the coefficient estimated on the entire sample (see panel (b) of Figure 9). One explanation for these different findings is that we control for long-run trends by demeaning the data. States in the Sun Belt have seen substantial migration inflows over the last 40 years. But these states also belonged to the most-affected states during the Great Recession. Their rise in unemployment lowered migration inflows and pushed their migration rates down to those observed in other states, flattening out the relationship between unemployment and net migration. Panel (a) of Figure 9 indeed shows that the coefficient falls to $\hat{\beta} = -0.05(0.03)$ if we do not control for these long-run trends.[17]

[16] For instance, using micro data from the American Community Survey (ACS) Yagan (2014) reports that migration only played a minor insurance role during the Great Recession as compared to the 2001 recession. Similarly, Beraja, Hurst and Ospina (2016) maintain a "no cross-state migration" assumption in their analysis of regional business cycles based on a small correlation between interstate migration and employment growth during the Great Recession.

[17] Beraja, Hurst and Ospina (2016) find a zero slope in a plot similar to our plot in panel (a). The somewhat

The relationship between unemployment rates and net migration is somewhat weaker for Canada ($\hat{\beta} = -0.23(0.02)$), and less than one third the size for Europe. Most of this difference to the U.S. can be attributed to lower migration rates per se, as reported in Table 2. The estimated coefficient for the core euro area is almost identical to the one for Europe as a whole ($\hat{\beta} = -0.09(0.01)$ vs. $\hat{\beta} = -0.08(0.01)$). Recall that the latter sample includes several countries with floating exchange rates. The type of exchange rates therefore does not seem to strongly affect the link of unemployment and migration. It is, however, true that countries in a currency union experience stronger cross-country dispersions in unemployment rates (especially after 2009 as seen in Figure 2). The similar estimated coefficient indicates that net migration flows *conditional on these unemployment rate differentials* seem unaffected by the exchange rate regime.

The finding of less labor mobility in Europe compared to Northern America is fairly robust across time periods, samples and methods. In the Appendix, we exploit the bilateral nature of our migration flows and calculate the response of both outmigration and inmigration to fluctuations in the unemployment rate in the destination and origin states. Overall, these regressions tell a very similar story. Of course, these regressions do not allow us to disentangle any causal relationship between unemployment and migration rates because differences in unemployment rates across states are likely to be a function of the degree of labor mobility. For example, the relatively low unemployment differentials and their lower persistence across US states compared to European countries could be the result of higher labor mobility. The purpose of this section has been to document the relationship between unemployment rate differentials and net migration rates. In the next section, we set up a model and calibrate it to replicate this relationship. Our model simulations will produce series for unemployment rates and net migration rates that we then use to run the same regression (2.3) as we did with the data.

3 A DSGE Model with Cross-Country Labor Mobility

In this section, we describe a multi-country DSGE model with cross-border migration. We then analyze numerically to what extent labor mobility reduces the cost of a common currency in the presence of asymmetric regional shocks. The distinctive features of our model are i)

stronger relationship that we find can be attributed to a different data source for migration data (we use IRS data instead of ACS data) and the fact that we focus on the unemployment rate instead of the employment rate.

labor mobility across countries, ii) unemployment, and iii) price rigidity. The first two features allow us to directly compare the model to the empirical patterns in Section 2. The third feature allows monetary policy to affect an economy's real variables. We introduce labor mobility in a tractable way into our dynamic framework, making use of the "large" household assumption as in Merz (1995). We introduce unemployment into our model through the standard Diamond-Mortensen-Pissarides (DMP) search-and-matching framework (see Diamond, 1982; Mortensen, 1982; Pissarides, 1985).

3.1 Households

The world is populated by $i = 1, ..., \mathcal{N}$ countries. The number of households born in country i is fixed and given by $\mathbb{N}^i$. Country i's representative household consists of a unit mass of members that live and work in any country $j = 1, ..., \mathcal{N}$. We abstract from commuting and impose that household members have to live in the same place that they work in. The share of country i's household members that *live* in country j at time t is denoted by $n^i_{j,t}$, with $\sum_j n^i_{j,t} = 1$. We use superscripts to denote the birth place and subscripts to denote the current living and working place of a household and its members.

Due to migration, the population of country i, denoted by $\mathbb{N}_{i,t}$, might differ from the number of households born in country i, $\mathbb{N}^i$, and can be calculated as:

$$\mathbb{N}_{i,t} = \sum_j n^j_{i,t} \mathbb{N}^j. \tag{3.1}$$

The model is written in per capita terms. To convert any quantity variable $X_{i,t}$ to a national total, we scale by the population of country i at time t.

Household members born in country i but who live in j consume country j's consumption good (their consumption is denoted $c^i_{j,t}$). This consumption good provides the same utility to all households within a country, independent of the household's origin. The consumption good cannot be traded across countries. As described later, firms in every country produce this consumption good using distinct combinations of intermediate goods sourced from different countries. That is, the production of the consumption good features home bias, so that the law of one price does not hold. Still, we assume that the consumption good is uniform and thereby abstract from compositional differences of consumption baskets across countries that might affect a migrant's utility from consumption. We do however allow for time-invariant utility gains / losses from living in a certain location (see below).

Household members supply labor in the country of their current residence. The labor supplied by a member of household i living in country j is denoted by $l^i_{j,t}$. Total labor supply in country j is then:

$$l_{j,t}\mathbb{N}_{j,t} = \sum_i n^i_{j,t} l^i_{j,t} \mathbb{N}^i \tag{3.2}$$

where $l_{j,t}$ is labor supply per capita in country j. Similarly, total labor supplied by household i is

$$l^i_t = \sum_j n^i_{j,t} l^i_{j,t}.$$

Household members receive utility from consumption, but incur disutility from supplying labor. In addition, household members receive a time-invariant utility gain or loss tied to their current residence, as is commonly assumed in the literature in spatial economics (see e.g. Redding and Rossi-Hansberg, 2017, for a literature survey).[18] We think of this utility term as representing location-specific amenities, e.g. climate, scenery, other characacteristics of physical geography, but also language and culture. Even though some countries might be generally more attractive than others, we allow a country's "appeal" to differ between households from different countries. For instance, Denmark might be generally less attractive due to its rainy climate, but small language and cultural differences might make it easier for a Swedish household to move to Denmark compared than for a Spanish one. We denote this utility gain from living in j for a household member from country i by A^i_j and assume that it is common to all members within the same household. We normalize the 'home' amenity parameter to $A^i_i = 0$ for all i.

Finally, we assume that within each representative household, members differ in their taste for a specific location. In equilibrium, only the most "cosmopolitan" members choose to live abroad, i.e. those household members with the strongest taste for living abroad. To increase that share of "expats", $n^i_{j,t}$, less cosmopolitan household members have to move abroad, which leads to a decrease in the *average* utility gain per expat. We formalize this idea by assuming that the average utility gain from living abroad—beyond utility differences due to different

[18] Papers specifically applying this framework to the question of migration include e.g. Kaplan and Schulhofer-Wohl (2012) and Sterk (2015). In addition, one could assume that agents' income differ across locations after controling for a country's wage rate, as in Borjas (1987). For instance, a worker from country i would earn a wage W_i in country i, but a wage $A^i_j W_j$ in country j, with $A^i_j < 1$.

consumption and labor supply levels—is $A^i_j - \frac{\ln(n^i_{j,t})}{\gamma}$, which is decreasing in $n^i_{j,t}$ for $\gamma > 0$.[19] The parameter $\frac{1}{\gamma}$ governs the heterogeneity across members' tastes and, as we will see, will discipline how migration flows react to economic conditions. We later estimate it to match our empirical results on the relationship between migration flows and unemployment.

Taken together, the expected discounted sum of future period utilities for a household, as of date 0, is given by

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \sum_j n^i_{j,t} u(c^i_{j,t}, l^i_{j,t}) + \sum_{j \neq i} n^i_{j,t} \left(A^i_j - \frac{\ln(n^i_{j,t})}{\gamma} \right) \right\}. \tag{3.3}$$

Here $\mathbb{E}_0$ is the expectation operator at time 0 and β is the discount factor. The utility function over consumption and labor is described by

$$u(c^i_{j,t}, l^i_{j,t}) = \upsilon_i \left(c^i_{j,t} - \kappa_j \frac{\left(l^i_{j,t}\right)^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}} \right)^{1-\frac{1}{\sigma}},$$

where σ is the intertemporal elasticity of substitution, υ_i is a household-specific utility weight, κ_j is a disutility weight on labor and η is the Frisch elasticity of labor supply.

Households receive income from various sources: Labor income, capital income, profits of various types of firms, bond payments, and lump-sum transfers / taxes. Since household members might live in different countries, we have to specify where these incomes are earned. By abstracting from commuting we impose that labor income is earned in the country of residence. In contrast, we assume that both the capital stock and the firms of country i are owned by the household members *born* in country i. A household member from country i that has moved to country j therefore still receives capital income and profits from its country of birth i. Our model features both (constant) lump-sum transfers and (time-varying) lump-sum taxes. Lump-sum transfers are paid by governments to all residents of their country,

[19] We can "microfound" this setup as follows: Assume that each household can be partitioned into $\mathcal{N}-1$ subunits, each consisting of a continuum of household members indexed by $\iota^i_j \in (0,1]$. Each subunit is assigned a specific foreign country. Members of subunit $j \neq i$ have to choose whether to either live at home (i.e. in i) or abroad (i.e. in j). For a member with ι^i_j, the utility gain from living in country j is described by $A^i_j - \frac{1}{\gamma}\left(\ln(\iota^i_j)+1\right)$, with $\gamma > 0$. That is, members with a larger ι^i_j incur a larger loss from living in j. The sum of country i's household members' utility gain from living in country j is then

$$\int_{\varepsilon}^{n^i_{j,t}} \left(A^i_j - \frac{1}{\gamma}\left(\ln(\iota^i_j)+1\right)\right) d\iota^i_j = n^i_{j,t}\left(A^i_j - \frac{1}{\gamma}\ln(n^i_{j,t})\right) - \varepsilon\left(A^i_j - \frac{1}{\gamma}\ln(\varepsilon)\right),$$

where ϵ is a small positive number that ensures that the integral is finite.

independent of their country of birth, whereas lump-sum taxes are levied on a country's household, independent of its members' current residence.[20]

To be more precise, let $S_{i,t}$ be the exchange rate to convert country i's currency into a reserve currency, and define $S_{i,t}^{j} = \frac{S_{j,t}}{S_{i,t}}$ as the exchange rate to convert country j's currency into country i's currency. If countries i and j are part of the same currency union, $S_{i,t} = S_{j,t}$ for all t. Household i's labor income, converted into country i's currency, equals $\sum_j S_{i,t}^{j} W_{j,t}^{h} n_{j,t}^{i} l_{j,t}^{i}$. Here, $n_{j,t}^{i} l_{j,t}^{i}$ describes the household's labor supplied in country j at time t. As we discuss below, households rent out the labor of their household members to "employment agencies".[21] Since labor is assumed to be uniform across countries, employment agencies in country j pay the same wage rate $W_{j,t}^{h}$ to any household member, irrespective of their country of birth.

In addition to labor income, households receive income from renting out capital to firms. Let $K_{i,t-1}$ denote the value of capital in country i at the beginning of period t, divided by country i's population in period $t-1$. Before renting it out to firms, households can adjust the rate at which this capital stock is utilized, $u_{i,t}$, freely depending on the date-t realization of the state. Varying the utilization of capital requires $\mathbb{N}_{i,t-1} K_{i,t-1} a\left(u_{i,t}\right)$ units of the final good. Households then rent out $u_{i,t} K_{i,t}$ effective units of capital to the intermediate-good-producing firms and earn a rental price of $R_{i,t}^{k}$ per effective unit of capital.

Households also receive nominal profits from various types of firms, denoted by $\mathbb{N}_{i,t} \Pi_{i,t}$, and lump-sum transfers, $P_{j,t} tr_{j}^{i}$, from the government of their country of residence. The government in j sets a constant transfer payment that is specific to a resident's country of birth. Finally, households also receive income from bonds purchased in the last period. These bonds are denominated in the reserve currency. Let B_{t-1}^{i} denote the amount of bonds purchased by a household born in i. Then, income from bond holdings are $\frac{B_{t-1}^{i}}{S_{i,t}}$.

Households use the receipts to pay for consumption, $\sum_j S_{i,t}^{j} P_{j,t} n_{j,t}^{i} c_{j,t}^{i}$, invest in the capital stock of their country of birth, $\mathbb{N}_{i,t} P_{i,t} X_{i,t}$, purchase state-noncontingent bonds, $\frac{B_{t}^{i}}{(1+i_t) S_{i,t}}$, pay for utilization costs, $\mathbb{N}_{i,t-1} K_{i,t-1} P_{i,t} a(u_{i,t})$, pay lump-sum taxes, $T_{i,t}$, to the government of their country of birth, and pay for any moving cost for members that choose to move. These moving costs are in units of the final consumption good of a mover's country of residence. Total moving costs for household i are therefore, $\sum_{j \neq i} S_{i,t}^{j} P_{j,t} n_{j,t}^{i} \Phi\left(\frac{n_{j,t}^{i}}{n_{j,t-1}^{i}}\right)$. Similar to the restrictions on the investment adjustment cost function, we assume that Φ is convex with

[20] We discuss how these transfers and taxes are set in Section 3.3.

[21] Workers are assumed to incur a utility loss for supplying their labor to the employment agency, even if they end up not being employed in an output-producing firm. That is, both employed and unemployed workers incur the same utility loss.

$\Phi(1) = \Phi'(1) = 0$, and $\Phi''(1) > 0$. We assume that moving occurs within the period, so that moving household members are immediately available for work in their new country of residence.

Households choose their members' location $n^i_{j,t}$, their consumption $c^i_{j,t}$, their labor supply $l^i_{j,t}$, investment $X_{i,t}$, the rate of capital utilization $u_{i,t}$, next period's capital stock, $K_{i,t}$, and bond holdings B^i_t for all $t \geq 0$ to maximize the expected discounted sum of future period utilities subject to the following sequence of budget constraints:

$$\mathbb{N}^i \left[\left(\sum_j S^j_{i,t} P_{j,t} n^i_{j,t} c^i_{j,t} \right) + \left(\sum_{j \neq i} S^j_{i,t} P_{j,t} n^i_{j,t} \Phi \left(\frac{n^i_{j,t}}{n^i_{j,t-1}} \right) \right) \right] + \mathbb{N}_{i,t} P_{i,t} X_{i,t} + \mathbb{N}^i \frac{B^i_t}{(1+i_t) S_{i,t}}$$
$$= \mathbb{N}^i \left(\sum_j S^j_{i,t} n^i_{j,t} \left(W^h_{j,t} l^i_{j,t} + P_{j,t} tr^i_j \right) \right) + \mathbb{N}_{i,t-1} K_{i,t-1} \left(R^k_{i,t} u_{i,t} - P_{i,t} a(u_{i,t}) \right) + \mathbb{N}_{i,t} \left(\Pi_{i,t} - T_{i,t} \right) + \mathbb{N}^i \frac{B^i_{t-1}}{S_{i,t}},$$

the capital accumulation constraint[22]

$$\mathbb{N}_{i,t} K_{i,t} = \mathbb{N}_{i,t-1} K_{i,t-1} (1-\delta) + \left[1 - \Lambda \left(\frac{\mathbb{N}_{i,t} X_{i,t}}{\mathbb{N}_{i,t-1} X_{i,t-1}} \right) \right] \mathbb{N}_{i,t} X_{i,t},$$

and the add-up constraint

$$\sum_j n^i_{j,t} = 1.$$

The first-order condition for consumption is

$$u^i_{1,i,t} s^j_{i,t} = u^i_{1,j,t},$$

where $u^i_{1,j,t}$ denotes the marginal utility of consumption, $c^i_{j,t}$, and $s^j_i = \frac{S^j_i P_j}{P_i}$ is the real exchange rate between country i and j. According to this Backus-Smith risk-sharing condition, the household shifts consumption towards members that live in countries with low real exchange rates (Backus and Smith, 1993). The labor supplied to an employment agency in country j by a household member born in country i is described by the standard condition

$$-\frac{u^i_{2,j,t}}{u^i_{1,j,t}} = w^h_{j,t},$$

where $w^h_{j,t} = \frac{W^h_{j,t}}{P_{j,t}}$ is the real wage received by household members living in country j. The

[22] We assume adjustment costs in investment as in Christiano, Eichenbaum and Evans (2005), with $\Lambda(1) = \Lambda'(1) = 0$ and $\Lambda''(1) > 0$.

first-order condition for the location choice $n^i_{j,t}$ is[23]

$$u(c^i_{j,t}, l^i_{j,t}) - u(c^i_{i,t}, l^i_{i,t}) + A^i_j - \frac{1}{\gamma}\left(\ln(n^i_{j,t}) + 1\right)$$
$$= \left(c^i_{j,t} - w^h_{j,t} l^i_{j,t} - tr^i_j\right) u^i_{1,j,t} - \left(c^i_{i,t} - w^h_{i,t} l^i_{i,t} - tr^i_i\right) u^i_{1,i,t}$$
$$+ \left(\frac{n^i_{j,t}}{n^i_{j,t-1}}\left(\Phi^i_{j,t}\right)' + \Phi^i_{j,t}\right) u^i_{1,j,t} - \beta \mathbb{E}_t \left\{ \left(\frac{n^j_{i,t+1}}{n^j_{i,t}}\right)^2 \left(\Phi^i_{j,t+1}\right)' u^i_{1,j,t+1} \right\}, \tag{3.4}$$

where we have written $\Phi^i_{j,t}$ for $\Phi\left(\frac{n^i_{j,t}}{n^i_{j,t-1}}\right)$. The left hand side describes the gain in utility terms of moving an additional household member from i to j. This gain consists of (i) the difference in consumption- and labor-related utility and (ii) the utility gain from the amenities provided in j. The right hand side describes the marginal cost, in utility terms: Moving a household member from i to j affects the household's budget constraint by shifting consumption expenditure, but also labor income and government transfers from i to j. In addition, the move generates moving costs, captured by the terms related to Φ^i_j, both in period t and in future periods. All these terms are multiplied by the marginal utility of consumption to transform the effects on the budget constraint into utils.

The remaining first-order conditions are standard: The Euler equations associated with the non-contingent bonds, B^i_t, require:

$$\frac{u^i_{1,i,t}}{s_{i,t}} = \beta(1 + i_t)\mathbb{E}_t \left\{ \frac{u^i_{1,i,t+1}}{s_{i,t+1}} \right\}.$$

The utilization choice requires the first order condition

$$r^k_{i,t} = a'(u_{i,t}),$$

where $r^k_{i,t} = \frac{R^k_{i,t}}{P_{i,t}}$ is the real rental price of capital. We assume that $a'(1) = r^k$, so that $u = 1$ in steady state. Also, we assume that $a(1) = 0$. The curvature $a''(1) > 0$ governs how costly it is to increase or decrease utilization from its steady-state value. The optimal choice for

[23] A household's location choice will affect a country's population and therefore the per-capita value of the capital stock. We assume that each country is populated by a continuum of households, so that each household takes the evolution of a country's population as given when taking its decisions. Similarly, the household also takes the evolution of lump-sum taxes, $\tau^i_{j,t}$, as given.

investment requires

$$1=\frac{\mu_{i,t}}{P_{i,t}}\left(1-\Lambda_{i,t}-\frac{\mathbb{N}_{i,t}X_{i,t}}{\mathbb{N}_{i,t-1}X_{i,t-1}}\Lambda'_{i,t}\right)+\beta\mathbb{E}_t\left\{\frac{u^i_{1,i,t+1}}{u^i_{1,i,t}}\frac{\mu_{i,t+1}}{P_{i,t+1}}\left(\frac{\mathbb{N}_{i,t+1}X_{i,t+1}}{\mathbb{N}_{i,t}X_{i,t}}\right)^2\Lambda'_{i,t+1}\right\},$$

where $\mu_{i,t}$ denotes the nominal shadow value of capital and where we have written $\Lambda_{i,t}$ for $\Lambda\left(\frac{\mathbb{N}_{i,t}X_{i,t}}{\mathbb{N}_{i,t-1}X_{i,t-1}}\right)$. Finally, $K_{i,t}$ is chosen to satisfy

$$\frac{\mu_{i,t}}{P_{i,t}}=\beta\mathbb{E}_t\left\{\frac{u^i_{1,i,t+1}}{u^i_{1,i,t}}\left[u_{i,t+1}r^k_{i,t+1}+\frac{\mu_{i,t+1}}{P_{i,t+1}}(1-\delta)-a\left(u_{i,t+1}\right)\right]\right\}.$$

3.2 Firms

There are two groups of firms in the model. First, there are firms that produce a non-tradable "final good" used for consumption, investment and government purchases. The final good producers take intermediate goods sourced from different countries as inputs. Second, there are intermediate goods firms that produce the inputs for the final good. These intermediate goods are produced in a two-stage process: Variety producers use capital and labor as inputs and then supply their goods to intermediate goods firms. We assume that the prices of the sub-intermediate variety goods are adjusted only infrequently according to the standard Calvo mechanism.

3.2.1 Tradable Intermediate Goods

Each country produces a single (country-specific) type of tradable intermediate good. We employ a two-stage production process to allow us to use a Calvo price setting mechanism. In the first stage, monopolistically competitive domestic firms produce differentiated "sub-intermediate" goods which are used as inputs into the assembly of the tradable intermediate good for country i. In the second stage, competitive intermediate goods firms produce the tradable intermediate good from a CES combination of the sub-intermediates. These firms then sell the intermediate good on international markets at the nominal price $p_{i,t}$. We describe the production of the intermediate goods in reverse, starting with the second stage.

Second-Stage Producers The second stage producers assemble in a competitive way the tradable intermediate good from the sub-intermediate varieties using a CES production function with an elasticity of substitution equal to ψ_q. Denoting the price of a sub-intermediate good ξ by $p_{i,t}(\xi)$, it is straightforward to show that the demand for each sub-intermediate good has an iso-elastic form

$$q_{i,t}(\xi) = Q_{i,t}\left(\frac{p_{i,t}(\xi)}{p_{i,t}}\right)^{-\psi_q}, \tag{3.5}$$

where $Q_{i,t}$ is the real quantity of country i's tradable intermediate good produced at time t, and $p_{i,t}$ is its price. This price is a combination of the prices of the sub-intermediates. In particular,

$$p_{i,t} = \left[\int_0^1 (p_{i,t}(\xi))^{1-\psi_q}\, d\xi\right]^{\frac{1}{1-\psi_q}}. \tag{3.6}$$

First-Stage Producers The sub-intermediate goods $q_{i,t}(\xi)$ which are used to assemble the tradable intermediate good $Q_{i,t}$ are produced in the first stage. The first-stage producers hire workers, $L_{i,t}(\xi)$, through human resource agencies at the nominal wage $W^f_{i,t}$ and rent capital, $K_{i,t}(\xi)$, at the nominal rental price $R_{i,t}$. Unlike the firms in the second stage, the first-stage, sub-intermediate goods firms are monopolistically competitive. They minimize costs taking the demand curve for their product (3.5) as given. These firms have a Cobb-Douglas production function:

$$q_{i,t}(\xi) = Z_{i,t}\,(K_{i,t}(\xi))^{\alpha}\,(L_{i,t}(\xi))^{1-\alpha}.$$

First-stage producers charge a markup for their products. The desired price naturally depends on the demand curve (3.5). Each type of sub-intermediate good producer ξ freely chooses capital and labor each period but there is a chance that their nominal price $p_{i,t}(\xi)$ is fixed to some exogenous level. In this case, the first-stage producers choose an input mix to minimize costs taking the date-t price $p_{i,t}(\xi)$ as given. Cost minimization implies that all sub-intermediate firms choose the same capital-to-labor ratio,

$$\frac{K_{i,t}(\xi)}{L_{i,t}(\xi)} = \frac{\alpha}{1-\alpha}\frac{W^f_{i,t}}{R_{i,t}} = \frac{\mathbb{N}_{i,t-1}u_{i,t}K_{i,t-1}}{\mathbb{N}_{i,t}L_{i,t}},$$

whcih equals the ratio of the total amount of capital services, $\mathbb{N}_{i,t-1}u_{i,t}K_{i,t-1}$ to the total number of employed workers, $\mathbb{N}_{i,t}L_{i,t}$ in country i at time t. It follows that the nominal marginal cost of production is common across all the sub-intermediate goods firms:

$$MC_{i,t} = \frac{\left(W^f_{i,t}\right)^{1-\alpha} R^{\alpha}_{i,t}}{Z_{i,t}}\left(\frac{1}{1-\alpha}\right)^{1-\alpha}\left(\frac{1}{\alpha}\right)^{\alpha}.$$

Pricing The nominal prices of the sub-intermediate goods are adjusted only infrequently according to the standard Calvo mechanism. In particular, for any firm, there is a probability θ^p that the firm cannot change its price that period. When a firm can reset its price it chooses an optimal reset price to maximize the discounted value of profits per household. Firms in country i act in the interest of the representative household born in i, so they apply the household's stochastic discount factor to all future income streams. It is well known that the solution to this optimization problem requires

$$p_{i,t}^{*} = \frac{\psi_q}{\psi_q - 1} \frac{\sum_{j=0}^{\infty} (\theta^p \beta)^j \sum_{s^{t+j}} \pi(s^{t+j}|s^t) \frac{u_{1,i,t+j}^{i}}{P_{i,t+j}} (p_{i,t+j})^{\psi_q} MC_{i,t+j} \mathbb{N}_{i,t+j} Q_{i,t+j}}{\sum_{j=0}^{\infty} (\theta^p \beta)^j \sum_{s^{t+j}} \pi(s^{t+j}|s^t) \frac{u_{1,t+j,i}^{i}}{P_{i,t+j}} (p_{i,t+j})^{\psi_q} \mathbb{N}_{i,t+j} Q_{i,t+j}}.$$

Because the sub-intermediate goods firms adjust their prices infrequently, the nominal price of the tradable intermediate goods is sticky. In particular, using (3.6), the nominal price of the tradable intermediate good evolves according to

$$p_{i,t} = \left[\theta^p p_{i,t-1}^{1-\psi_q} + (1-\theta^p) \left(p_{i,t}^{*}\right)^{1-\psi_q}\right]^{\frac{1}{1-\psi_q}}. \tag{3.7}$$

3.2.2 Nontradable Final Goods

The final goods are assembled from a (country-specific) CES combination of tradable intermediates produced by the various countries in the model. The final goods firms are competitive in both the global input markets and the final goods market. The final goods producers solve

$$\max_{y_{i,t}^{j}} \left\{ P_{i,t} Y_{i,t} - \sum_{j=1}^{\mathcal{N}} S_{i,t}^{j} p_{j,t} y_{i,t}^{j} \right\}$$

subject to the CES production function

$$Y_{i,t} = \left(\sum_{j=1}^{\mathcal{N}} \left(\omega_{i,t}^{j}\right)^{\frac{1}{\psi_y}} \left(y_{i,t}^{j}\right)^{\frac{\psi_y - 1}{\psi_y}} \right)^{\frac{\psi_y}{\psi_y - 1}} \tag{3.8}$$

Here, $y_{i,t}^{j}$ is the amount of country-j intermediate good used in production by country i at time t and ψ_y is the trade elasticity.

We assume that the preference weights, $\omega_{i,t}^{j}$, consist of a time-invariant and a time-varying part:

$$\omega_{i,t}^{j} = \frac{\bar{\omega}_{i}^{j} \exp\left(\varepsilon_{t}^{j}\right)}{\sum_{k} \omega_{i,t}^{k}}. \tag{3.9}$$

The time-invariant part, $\bar{\omega}_i^j$ with $\sum_j \bar{\omega}_i^j = 1$, is later calibrated to match average bilateral trade shares. The time-varying part, ε_t^j, are fluctuations in the optimal input mix for the final good, either due to changes in technology or taste.[24] Our formulation ensures that even though preference weights fluctuate, they always sum up to 1 for every final good producer, i.e. $\sum_j \omega_{i,t}^j = 1$ for all t. These changes in taste translate into fluctuations in demand for goods produced in a specific location j. In particular, demand for country-specific intermediate goods is isoelastic and is shifted by changes in $\omega_{i,t}^j$:

$$y_{i,t}^{j} = Y_{i,t}\omega_{i,t}^{j}\left(S_{i,t}^{j}\frac{p_{j,t}}{P_{i,t}}\right)^{-\psi_y}$$

These changes in taste are common to all countries that use goods from j, including the country j itself. As we explain later, changes in ε_t^j and hence $\omega_{i,t}^j$ are our main forcing variables in our model.

3.3 Government Policy

The model includes both fiscal and monetary policy variables. On the fiscal side, a government's expenditure consists of government purchases, unemployment benefits and lump-sum transfers. These lump-sum transfers are constant and are specific to a resident's country of birth. They are set to close the resident's gap between their consumption expenditure and labor income in steady state, that is[25]

$$tr_i^j = c_i^j - w_i^h l_i^j.$$

Government purchases per capita, G_i, and unemployment benefits per unemployed, b_i, are assumed to be constant. Fluctuations in population and the number of unemployed, however,

[24] See e.g. Itskhoki and Mukhin (2017) for a similar setup.

[25] The purpose of these steady-state transfers is to eliminate net transfers across household members in steady state. Every migrant is self-sufficient in steady state in the sense that their income equals their expenditure. Without steady-state transfers, changes in real exchange rates will directly affect migration decisions in the log-linearized version of the model.

entail changes in these expenditures that are financed through lump-sum taxes levied on the household.[26] The government budget constraint is therefore balanced every period and given by

$$P_{i,t}\left(b_i\mathbb{N}_{i,t}U_{i,t}+\mathbb{N}_{i,t}G_i+\sum_j \mathbb{N}^j n^j_{i,t} tr^j_i\right)=\mathbb{N}_{i,t}T_{i,t}.$$

Monetary policy is conducted through a Taylor Rule of the form

$$i_{i,t}=\bar{\imath}_i+\phi_i i_{i,t-1}+(1-\phi_i)\left(\phi_Q Q_{i,t}+\phi_\pi \pi_{i,t}\right), \tag{3.10}$$

where we assume the same reaction parameters ϕ_i, ϕ_Q and ϕ_π across all countries. Countries in the euro area have a fixed nominal exchange rate for every country in the union and a common nominal interest rate. Monetary policy for these countries is set by the ECB, which follows the same Taylor rule as in (3.10), with the exception that it reacts to GDP-weighted averages of innovations in GDP and inflation for the countries in the union.

3.4 Labor Market

The labor market is described by a search-and-matching framework. For a worker to be employed by a sub-intermediate good firm they first have to be hired by an employment agency. This employment agency hires unemployed workers and searches for vacancies in sub-intermediate good firms. These vacancies, in turn, are posted by human resources (HR) firms. If the employment agency finds a match for the worker, it rents out the worker to the HR firm, which in turn rents out the worker to the sub-intermediate good firm. Next, we describe the labor market in more detail, starting with the worker / employment agency side.

3.4.1 Value Functions

Workers: Workers can only find jobs through an employment agency. Employment agencies hire workers and try to match them with firms. In particular, at the beginning of every period t, they offer workers the following contract: They promise workers a wage payment for the duration of the contract. If the employment agency cannot immediately match the worker with a firm, the agency pays the worker a real wage $w^h_{i,t}$, but retains the worker's

[26] We assume that household i pays lump-sum taxes in country i, independent of its members' current residence. Changes in lump-sum taxes therefore do not affect a household's migration decision.

unemployment benefit $b_i \geq 0$, The contract between the worker and the employment agency immediately ends at the end of the period. If, however, the employment agency matches the worker with a vacancy posted by an HR firm, it will collect the real wage paid by the HR firm, $w_{i,t}, w_{i,t+1}, w_{i,t+2}, \ldots$, as long as the worker keeps its job. The worker receives the real wage $w^h_{i,t}, w^h_{i,t+1}, w^h_{i,t+2}, \ldots$ from the employment agency until the contract ends with the worker's job loss. This contract guarantees all workers the same wage, $w^h_{i,t}$, and therefore operates as an insurance mechanism against unemployment. However, neither the wage paid by the HR firm, $w_{i,t}$, nor the wage received by the worker, $w^h_{i,t}$, are necessarily constant over the period of the contract. Instead, these wages respond to aggregate conditions and can change from period to period.

We denote the match probability for a "job hunter" hired by an employment agency in country i at time t by $f_{i,t}$. This probability is endogenous and discussed later. With that probability, the employment agency receives the value from the match, denoted by $\mathcal{E}_{i,t}$, which is the wage received from the producing firm, $w_{i,t}$, less the wage paid to the worker, $w^h_{i,t}$, for the duration of the match. We assume a share $d \in (0,1)$ of workers loose their job every period. The value of having an employed worker is therefore

$$\mathcal{E}_{i,t} = w_{i,t} - w^h_{i,t} + (1-d)\beta \mathbb{E}_t \left\{ \Psi_{i,t+1} \mathcal{E}_{i,t+1} \right\}, \tag{3.11}$$

where $\Psi_{i,t+1} = \frac{u^i_{1,i,t+1}}{u^i_{1,i,t}}$ is the stochastic discount factor.[27] With probability $1 - f_{i,t}$, the employment agency cannot match the job hunter. In that case, it only receives the unemployment benefit, b_i, net of the wage paid to the worker, $w^h_{i,t}$. The profit from hiring a job hunter is:

$$\mathcal{H}_{i,t} = f_{i,t}\mathcal{E}_{i,t} + (1 - f_{i,t})(b_i - w^h_{i,t}).$$

We assume free entry in the market of employment agencies, so that the profit from hiring a job hunter, $\mathcal{H}_{i,t}$, must be zero in equilibrium. This implies that

$$\mathcal{E}_{i,t} = -\frac{1 - f_{i,t}}{f_{i,t}}(b_i - w^h_{i,t}).$$

Firms: At the beginning of every period, HR firms post vacancies $V_{i,t}$ to hire workers. There is no initial setup cost of posting a new vacancy, but every vacancy, no matter whether it is new or old, requires the firm to pay a per-period cost $\varsigma > 0$ in terms of the final good.

[27] All firms in the model, are owned by the household of their respective country.

We denote the probability that a vacancy gets filled by $g_{i,t}$. If a vacancy gets filled, the HR firm immediately receives the value of a filled vacancy, denoted by $\mathcal{J}_{i,t}$. If not, the vacancy stays posted the next period. The value of a posted vacancy to a firm is then given by the following value function:

$$\mathcal{V}_{i,t} = -\varsigma + g_{i,t}\mathcal{J}_{i,t} + (1 - g_{i,t})\,\beta\mathbb{E}_t\left\{\Psi_{i,t+1}\mathcal{V}_{i,t+1}\right\}.$$

The value to an HR firm of having a filled job is the difference between the wage received from the producing firm, $w^f_{i,t}$, and the wage paid to the employment agency, $w_{i,t}$. With probability d, the job gets destroyed and the HR firm has to post a new vacancy. The value of having a filled vacancy is therefore

$$\mathcal{J}_{i,t} = w^f_{i,t} - w_{i,t} + (1 - d)\,\beta\mathcal{J}_{i,t+1} + d\beta\mathbb{E}_t\left\{\Psi_{i,t+1}\mathcal{V}_{i,t+1}\right\}$$

We assume that HR firms have to incur a quadratic cost for adjusting the number of posted vacancies. HR firms choose the number of posted vacancies to maximize the discounted stream of expected net profits

$$\max_{V_t}\mathbb{E}_t\sum_{s=0}^{\infty}\beta^{t+s}\left\{\Psi_{i,t+s}V_{t+s}\left(\mathcal{V}_{i,t+s} - \Upsilon\left(\frac{V_{i,t+s}}{V_{i,t+s-1}}\right)\right)\right\},$$

with $\Upsilon(1) = \Upsilon'(1) = 0$ and $\Upsilon''(1) \geq 0$. Taking the first-order condition with respect to V_t gives

$$\mathcal{V}_{i,t} = \Upsilon_{i,t} + \frac{V_{i,t}}{V_{i,t-1}}\Upsilon'_t - \beta\mathbb{E}_t\left\{\Psi_{i,t+1}\left(\frac{V_{i,t+1}}{V_{i,t}}\right)^2\Upsilon'_{t+1}\right\}, \tag{3.12}$$

where $\Upsilon_{i,t}$ is short for $\Upsilon\left(\frac{V_{i,t}}{V_{i,t-1}}\right)$.

3.4.2 Matching

Every period, job hunters, $H_{i,t}$, are matched with vacancies, $V_{i,t}$. Recall that $\mathbb{N}_{i,t}$ denotes the population of country i at time t. Then, the total number of job hunters in country i, $\mathbb{N}_{i,t}H_{i,t}$, consists of three groups: (i) everyone who was unemployed at the end of the previous period, $\mathbb{N}_{i,t-1}U_{i,t-1}$, (ii) all the workers who were employed last period but got laid off over night, $d\mathbb{N}_{i,t-1}L_{i,t-1}$ and (iii) new entrants into the labor force pool, $\mathbb{N}_{i,t}l_{i,t} - \mathbb{N}_{i,t-1}l_{i,t-1}$. That is, the number of job hunters in country i is

$$\mathbb{N}_{i,t}H_{i,t} = \mathbb{N}_{i,t-1}U_{i,t-1} + d\mathbb{N}_{i,t-1}L_{i,t-1} + \mathbb{N}_{i,t}l_{i,t} - \mathbb{N}_{i,t-1}l_{i,t-1}.$$

In our framework, an increase in the labor force can come from either an increase in labor supplied by any household member living in i, $l^j_{i,t} > l^j_{i,t-1}$, or an increase in the number of household members living in i, $n^j_{i,t} > n^j_{i,t-1}$, i.e. net immigration. We treat these two cases symmetrically and assume that any increase in labor supply is channeled through the search pool. A reduction in the labor force, i.e. $\mathbb{N}_{i,t}l_{i,t} - \mathbb{N}_{i,t-1}l_{i,t-1} < 0$, either due to reduced labor supply per household member or net emigration, reduces the number of job hunters.[28]

We assume that job hunters $H_{i,t}$ and vacancies $V_{i,t}$ are matched according to a standard matching function. The number of matches per period is

$$M_{i,t} = \bar{m}H^{\zeta}_{i,t}V^{1-\zeta}_{i,t}$$

where $\bar{m} > 0$ is a match efficiency parameter. The job finding rate, $f_{i,t}$, is defined as matches per job hunter:

$$f_{i,t} \equiv \frac{M_{i,t}}{H_{i,t}} = \bar{m}\left(\frac{V_{i,t}}{H_{i,t}}\right)^{1-\zeta} = \bar{m}\lambda^{1-\zeta}_{i,t},$$

where $\lambda = \frac{V}{H}$ is often referred to as "labor market tightness." Similarly, the job filling rate is

$$g_{i,t} \equiv \frac{M_{i,t}}{V_{i,t}} = \bar{m}\lambda^{-\zeta}_{i,t}.$$

Firms produce output using labor from both the already employed and the newly matched job hunters. The law of motion for employment is therefore

$$\mathbb{N}_{i,t}L_{i,t} = (1-d)\mathbb{N}_{i,t-1}L_{i,t-1} + \mathbb{N}_{i,t}M_{i,t}.$$

The number of unemployed at the end of the period, $U_{i,t}$, is the labor force, $l_{i,t}$, less the number of people employed, $L_{i,t}$:

$$U_{i,t} = l_{i,t} - L_{i,t}. \tag{3.13}$$

[28] That is, we assume that 'employed workers' never directly exit the labor force. Any fluctuations in the labor force fully affect the number of job hunters, but keep the number of employed workers constant. This symmetry assumption between entry and exit keeps the model tractable.

3.4.3 Wages

Following Shimer (2010), we introduce wage rigidity through backward-looking wage setting. The actual wage, $w_{i,t}$, is a weighted average of the past actual wage, $w_{i,t-1}$ and the current target wage, denoted $w^*_{i,t}$:

$$w_{i,t} = \theta^w w_{i,t-1} + (1 - \theta^w) w^*_{i,t}.$$

This target wage, $w^*_{i,t}$ is determined through Nash bargaining. In particular, suppose we have a specific match (indexed by ξ) between a worker and a firm. The (HR) firm and the worker (or: the employment agency on behalf of the worker) bargain over the target wage, say $w^*_{i,t}(\xi)$, taking the other variables in the economy as given. We assume the target wage will be the solution to the following Nash bargaining problem:

$$w^*_{i,t}(\xi) = \arg\max_{w_{i,t}(\xi)} \left\{ \left(\mathcal{E}_{i,t}\left(w_{i,t}(\xi)\right) - (b_i - w^h_{i,t}) \right)^{\varrho} \mathcal{J}_{i,t}\left(w_{i,t}(\xi)\right)^{1-\varrho} \right\}$$

Here, we are writing $\mathcal{E}\left(w_{i,t}(\xi)\right)$ to indicate that the value of being in this job will depend on the deal the worker strikes with the firm for this match. Similarly, the value of the job depends on the wage the firm has to pay, i.e. $\mathcal{J}\left(w_{i,t}(\xi)\right)$. In what follows, we suppress the index ξ because in equilibrium, all matches will result in the same wage. The worker's bargaining power is denoted by $\varrho \in (0, 1)$. Differentiating the bargaining objective with respect to $w^*_{i,t}$ gives[29]

$$\varrho \mathcal{J}(w^*_{i,t}) = (1 - \varrho) \left(\mathcal{E}(w^*_{i,t}) - (b_i - w^h_{i,t}) \right).$$

The value to the employment agency of having an employed worker that receives a wage $w^*_{i,t}$ this period can be rewritten as $\mathcal{E}(w^*_{i,t}) = w^*_{i,t} - w_{i,t} + \mathcal{E}(w_{i,t})$, where $\mathcal{E}(w_{i,t})$ is the value of having an employed worker that receives the equilibrium wage $w_{i,t}$, as defined in (3.11). For short, we write $\mathcal{E}(w_{i,t}) = \mathcal{E}_{i,t}$. Similarly, we have $\mathcal{J}(w^*_{i,t}) = -w^*_{i,t} + w_{i,t} + \mathcal{J}(w_{i,t})$. Using these expressions, the target wage satisfies

$$w^*_{i,t} = w_{i,t} + \varrho \mathcal{J}_{i,t} - (1 - \varrho) \left(\mathcal{E}_{i,t} - (b_i - w^h_{i,t}) \right)$$

---

[29]

$$\varrho \left(\frac{\mathcal{E}'(w^*_{i,t})}{\mathcal{E}(w^*_{i,t}) - (b_i - w^h_{i,t})} \right) + (1 - \varrho) \frac{\mathcal{J}'(w^*_{i,t})}{\mathcal{J}(w^*_{i,t})} = 0$$

$$\varrho \mathcal{J}(w^*_{i,t}) = (1 - \varrho) \left(\mathcal{E}(w^*_{i,t}) - (b_i - w^h_{i,t}) \right),$$

where we used that $\mathcal{E}'(w^*_{i,t}) = 1$ and $\mathcal{J}'(w^*_{i,t}) = -1$.

Replacing this into the law of motion for the actual wage, $w_{i,t}$, we get

$$\theta^w w_{i,t} = \theta^w w_{i,t-1} + (1-\theta^w)\left[\varrho \mathcal{J}_{i,t} - (1-\varrho)\left(\mathcal{E}_{i,t} - (b_i - w^h_{i,t})\right)\right].$$

Notice that for $\theta^w = 0$, we obtain the standard Nash bargaining solution that the equilibrium wage is a weighted average of the worker's and firm's revervation wages, with ϱ being the weight on the firm's reservation wage. In this case, the wage immediately responds to any changes in the reservations wages. With $\theta^w = 1$, the equilibrium wage does not respond to any reservation wages, but stays put at an exogenous initial value.

3.5 Forcing Variables

Countries receive taste shocks for the demand of the intermediate goods that they produce. These relative demand shocks are denoted by ϵ^j_t in equation (3.9) and directly affect the trade preference weights, $\omega^j_{i,t}$, in the production function of each country's final good in equation (3.8), $Y_{i,t}$. We assume that these preference shocks follow an AR(1) process with persistence ρ:

$$\varepsilon^j_t = \rho\varepsilon^j_{t-1} + \epsilon^j_t \qquad \forall j = 1, ..., N-1$$

3.6 Aggregation and Market Clearing

For each country i, aggregate production of the tradable intermediate goods is given by[30]

$$\mathbb{N}_{i,t}Q_{i,t} = Z_{i,t}\left(\mathbb{N}_{i,t-1}K_{i,t-1}\right)^{\alpha}\left(\mathbb{N}_{i,t}L_{i,t}\right)^{1-\alpha}.$$

The market clearing condition for these goods is

$$\mathbb{N}_{i,t}Q_{i,t} = \sum_{j=1}^{\mathcal{N}} \mathbb{N}_{j,t} y^i_{j,t}$$

Final goods production is given by (3.8). The market clearing condition for the final good is

$$\mathbb{N}_{i,t}Y_{i,t} = \mathbb{N}_{i,t}C_{i,t} + \mathbb{N}_{i,t}X_{i,t} + \mathbb{N}_{i,t}G_{i,t} + a(u_{i,t})\mathbb{N}_{i,t-1}K_{i,t-1} + \varsigma\mathbb{N}_{i,t}V_{i,t},$$

[30] This holds up to a first-order approximation.

where

$$\mathbb{N}_{i,t}C_{i,t} = \sum_{j=1}^{N} n_{i,t}^{j} c_{i,t}^{j} \mathbb{N}^{j}$$

is total consumption in country i. Total labor supply in country i is given by (3.2) and the labor market clearing condition is given by (3.13). Finally, the bond market clearing condition requires

$$\sum_{i=1}^{\mathcal{N}} \mathbb{N}^{i} B_{t}^{i} = 0.$$

3.7 Steady State

We give a brief overview of how we solve for the steady state.[31] We will exploit structural relationships in the model to recover certain parameters from the data.

We solve the model by log-linearizing the equilibrium conditions around a non-stochastic steady state with zero inflation. We first solve for real rental price of capital, r_i^k and the real price of the intermediate good, $\frac{p_i}{P_i}$. We adjust the technology levels Z_i so that the real price of the intermediate good, and hence the real exchange rates, are unity in all countries. We then solve for the share of net exports in GDP, which depends among other things, on the trade preference weights, ω_i^j, and countries' size, measured by their domestic absorption, $\mathbb{N}_i Y_i$. Given the shares of net exports and government purchases in GDP, we can derive the shares of investment and consumption in GDP.

We next solve for the steady-state values related to migration and the labor market. With GHH preferences, labor supply of household members from i living in j is

$$l_j^i = \left(\frac{w_j^h}{\kappa_j} \right)^{\eta}.$$

It follows that labor supply is uniform within countries, i.e. $l_j^i = l_j$. We directly calibrate l_j to the data and adjust κ_j accordingly, so that the labor supply elasticity is satsified. Similarly, we recover the amenity values A_j^i by inverting the structural relationship describing the location choice, (3.4), which, in steady state, is given by

$$u(c_j^i, l_j^i) - u(c_i^i, l_i^i) + A_j^i = \frac{1}{\gamma} \left(\ln(n_j^i) + 1 \right).$$

[31] The Technical Appendix shows in detail how we solve for the steady state.

Since steady-state values for c^i_j and l^i_j are independent of A^i_j, there is a direct one-to-one mapping of A^i_j to the migration shares n^i_j. We directly calibrate n^i_j to the data and adjust A^i_j accordingly. Given n^i_j and data on population, $\mathbb{N}_i$, we solve for the size of households, $\mathbb{N}^j$, from (3.1).

The real wage paid by firms, w^f_i, is proportional to GDP per employed worker.

$$w^f_i = (1-\alpha)\frac{\psi_q - 1}{\psi_q}\frac{Q_i}{L_i},$$

where we directly back out employment, L_i, from data on the labor force, l_i, and the unemployment rate, ur_i. From the optimality conditions of the labor market, we then derive the real wage received by the household, w^h_i. Finally, we solve for the consumption values of migrants, c^j_i, by solving the linear equation system

$$C_i\mathbb{N}_i = \sum_j n^j_i c^j_i \mathbb{N}^j = \sum_j n^j_i \left(c^j_j - \frac{w^h_j l_j - w^h_i l_i}{1+\frac{1}{\eta}} \right) \mathbb{N}^j.$$

3.8 Calibration and Estimation

We calibrate and estimate our model at a quarterly frequency, considering two sets of parameter values, one for the U.S. states (1977 - 2014) and one for Europe (1991 - 2014). Our sample of U.S. states contains all 48 contiguous states plus an aggregate of the rest of the U.S. Similarly, our European sample consists of all 31 countries as well as a rest-of-the-world aggregate. The Data Appendix contains all information on the exact data series used for the calibration.

We partition the models' parameters into two groups: for the first group of parameters, we choose values commonly adopted in the literature or we directly calibrate them to ratios observed in the data. Given these parameter values, we then estimate the remaining five parameters that are either new to our model or where we have little guidance from previous studies.

Preferences We assume a discount factor of $\beta = 0.99$, which implies a real annual interest rate of about 4 percent. The intertemporal elasticity of substitution is set to $\sigma = 0.5$. We set the disutility weights of labor, κ_j, to match the ratios of labor force to population observed in every state / country. We set the Frisch elasticity of labor supply to 0.2, which is in line of estimates for the *extensive* labor supply elasticity at the individual's level reported in the surveys by Reichling and Whalen (2012) and Blundell and MaCurdy (1999). The aggregate labor supply elasticity in our model is larger than 0.2 because it encompasses both changes in the labor force and changes in the number of people working.

Technology The elasticity of substitution between varieties is set to $\psi_q = 10$, which implies a markup of roughly 11 percent, which is in line with studies by Basu and Fernald (1995) and Basu and Kimball (1997) among others. We calibrate the curvate of the production function, α, to match the average labor income share, defined as $\frac{w^f L}{Q} = (1-\alpha)\frac{\psi_q - 1}{\psi_q}$.[32] Karabarbounis and Neiman (2013) report a labor income share for both the U.S. and Germany of about 0.63 between 1975 and 2010. This corresponds to $\alpha = .30$. We set the depreciation rate to 0.021 for both samples, which implies an annual depreciation rate of 10 percent. For the utilization cost function we follow Del Negro et al. (2013) by setting $a'' = 0.286$. This implies that a one percent increase in the real rental price causes an increase in the capital utilization rate of 3.5 percent.

Nominal Price Rigidity We calibrate the Calvo price hazards to roughly match observed frequencies of price adjustment in the micro data. For the U.S., Nakamura and Steinsson (2008) report that prices change roughly once every 8 to 11 months. For a quarterly model, a duration of 10 months corresponds to $\theta_p = 0.70$. Evidence on price adjustment in Europe suggests somewhat slower adjustments. Alvarez et al. (2006) find that the average duration of prices is 13 months, corresponding to $\theta_p = 0.77$.

Trade and Country Size We set the trade elasticity, ψ_y, to 2, which is in line with the values used in the IRBC literature (e.g. Backus, Kehoe and Kydland, 1994, estimate a value of 1.5)

In steady state, our trade preference weights, ω_i^j, are equal to the share of imports in domestic absorption:

$$\omega_i^j = \frac{y_i^j}{\sum_j y_i^j}. \tag{3.14}$$

[32] Note that our model features several "wages". For the purpose of our calibration, we count any income generated by HR firms and employment agencies towards labor income, so that the relevant labor income is $w^f L$.

To calibrate ω_i^j, we therefore rely on bilateral trade data. Data on interstate trade is taken from the freight analysis framework, which calculates trade in goods based on the commodity flow survey and other sources. Importantly, this database also contains information on trade within states, y_i^i, which allows us to calculate the denominator in (3.14). The data is available at five-year intervals starting in 1997. We take the data from 1997 because this is somewhat in the middle of our sample. We adjust this data a little bit because trade in goods across states in 1997 was far from balanced. These imbalances would affect steady-state levels of net exports and consumption, leading to large differences in consumption shares across U.S. states. To avoid these artefacts from affecting our results we adjust the bilateral matrix of preference parameters, ω, to ensure that net exports are zero in steady state and consumption shares are the same across states.[33] For the average U.S. state, the import share is about 55 percent (see Table 6b). With zero net exports, domestic absorption, $\mathbb{N}_i Y_i$, is equal to GDP. Data on nominal GDP for 1997, comes from the Bureau of Economic Analysis.

For Europe, we use data from the OECD on trade in value added (TiVA). The data has information on the value added content of final demand by source country for all country pairs in our European data sample, which allows us to calculate both ω_i^j and $\mathbb{N}_i Y_i$. As for the U.S. data, we adjust the data to ensure that net exports are zero in steady state. We use an average over the years 2000 and 2005. In contrast to the U.S. data, TiVA also captures trade in services. For the average European country in our sample, the import share is about 40 percent, somewhat smaller than for the average U.S. state.[34]

Migration We approximate the number of households born in state j, $\mathbb{N}^j$, with data on population residing in the U.S. by state of birth from the U.S. 1990 and 2000 Censuses. The same data source also breaks down a state birth's population by its current state residence. We use these figures to calculate the share of people from state j living in state i, n_i^j.

For our European sample, we use data from the U.N. report "International Migrant Stock: The 2017 Revision". The U.N. reports data on total migrant stocks by country of current residence and by country of birth at five-year intervals starting in 1990. From this data, we derive the share of people born in country i living in country j for all European countries in

[33] See the Technical Appendix for more details.

[34] The reader should keep in mind that the U.S. data only contains information on goods in trade. Since trade in goods is likely to be more pervasive than trade in services, our estimate of the import share for U.S. states is a higher bound. To the best of our knowledge, data on trade in services is not available for U.S. states.

our sample plus a rest-of-the-world aggregate. We then take an average across all reported time periods. As can be seen from Table 6a, the average share of people from country i living abroad is 8 percent in our sample, substantially smaller than the corresponding share of 36.9 percent for the sample of U.S. states. Overall, U.S. states are more integrated than European countries, both in good markets and particularly in labor markets.

Labor Market As discussed in the empirical section, unemployment rates for the U.S. are provided by the Bureau of Labor Statistics. Data for Europe is provided by Eurostat. State-specific steady-state unemployment rates are measured as the sample averages, u_i. For the average U.S. state, the steady-state unemployment rate is 6.1 percent. Engen and Gruber (2001) run simulations of each U.S. state's unemployment insurance system between 1983-1991. They report an average replacement value of 0.44 across all U.S. states. That is, we set b_i to $0.44w_i$ for the U.S. The OECD publication "Benefits and Wages" reports official net replacement rates as a function of unemployment duration, previous income and a worker's family situation. On average, the data suggests that unemployment benefits are about 15 percentage points larger in Europe compared to the U.S. We therefore set b_i to $0.59w_i$ in Europe. There is no strong evidence that the matching elasticity differs between the U.S. and Europe. Shimer (2005) reports an estimate of 0.72 based on U.S. data for 1951 - 2003, close to the estimate by Burda and Wyplosz (1994) of 0.70 for France, Germany and Spain. We set the elasticity to 0.72 in both samples. As is common in this literature, we set the household's bargaining power equal to the matching elasticity. For the U.S., Shimer (2005) reports a job separation rate of about 3.4 percent per month between 1951 and 2003, similar to the estimate by Hall (2005). Hobijn and Şahin (2009) estimate comparable separation rates across the U.S. and Europe. Given this evidence, we set the quarterly separation rates to 10 percent ($\approx 1 - (1 - 0.034)^3$) for both the U.S. and the European sample.

Fiscal and Monetary Policy For our European sample, we set the steady-state ratio of government purchases to GDP to the observed value in each country across our sample period. For the U.S., we lack data on state-specific government purchases. We therefore assume the same value across all states, which we calibrate to the national figure of 0.19. For the U.S., all states belong to the same currency union. The Central Bank is assumed to follow a Taylor rule with parameters set to $\phi_i = 0.75$, $\phi_{GDP} = 0.50$ and $\phi_\pi = 1.50$, which in line with estimates reported by Galí and Gertler (1999). For our European sample, countries changed monetary policy over the sample period, especially during 1990s and the introduction of the euro in 1999. In our model, we do not account for these changes. Instead, we assign countries to the euro area according to their currency as of 2010.[35] Some countries followed a peg with the euro over (most of) the data period.[36] The remaining countries follow an independent monetary policy. All monetary authorities follow a Taylor rule with the same parameters as in the U.S. model.

Estimation Given these parameter values, we next estimate the remaining six parameter values of the model. These parameters are the parameter describing the heterogeneity across members' tastes for different locations, γ, the curvature of the moving cost function, Φ'', the curvature of the vacancy adjustment cost function, Υ'', the degree of real wage rigidity, θ_w, the persistence of the shock process, ρ, and the curvature of the investment adjustment cost function, Λ''.

To estimate these parameters, we proceed as follows: Given a first guess for the parameter values, we simulate the model by choosing the realizations of ϵ_t^j that perfectly match the observed (state or country-level) unemployment rate differentials $\hat{u}_{j,t}$ in equation (2.1) for every state / country.[37] We then calculate the following five moments from the simulated data and compare them to their counterparts in the data: the slope coefficient from regressing net migration rates on unemployment rate differentials, as in equation (2.3), the standard deviation of nominal wages, the persistence of the net migration rate (measured as the first-order autocorrelation coefficient), the persistence of investment, and the correlation between net exports over GDP and GDP. In addition, we target an autocorrelation coefficient of zero for the shocks ϵ_t^j. We adjust our six parameter values to minimize the squared distance between simulated and data moments...

Table 5 displays the results of our estimation. We estimate the shock process to be fairly persistent with $\rho = 0.98$. For the investment adjustment cost function, we estimate $\Lambda'' = 0.10$, which implies that a one percent increase in Tobin's Q causes investment to increase by roughly 10 percent.

To interpret the estimate of Υ'', we log-linearize the first-order conditions for HR firms,

[35] This includes Belgium, Germany, Ireland, Greece, Spain, France, Italy, Cyprus, Luxembourg, Netherlands, Austria, Portugal, Slovenia, Slovakia and Finland.

[36] Bulgaria, Denmark, Estonia, Latvia and Lithuania. The latter three joined the euro area in 2011, 2014 and 2015, respectively.

[37] Note that while our empirical analysis was based on annual data, we calibrate our model at a *quarterly* frequency. We therefore recover the innovations ϵ_t^j to match the quarterly unemployment rate differentials.

(3.12), around the steady state to obtain:

$$\tilde{V}_t = \tilde{V}_{t-1} + \frac{1}{\Upsilon''} \sum_{s=0}^{\infty} \beta^s \mathbb{E}_t \Delta \mathcal{V}_{t+s}$$

It follows that $\frac{1}{\Upsilon''}$ is the semi-elasticity of the number of vacancies to the current value of a vacancy. Our estimate of Υ'' implies that cutting the cost of posting a vacancy, ς, by half in the current period, raises the number of posted vacancies by 50 percent ($= \frac{0.002}{0.004}$). Our estimate therefore implies that the cost of adjusting the number of vacancies is relatively small.

There is little guidance on the parameter governing real wage rigidity. We estimate it to be $\theta_w = 0.86$ at quarterly frequency, which is in the range of values studied by Shimer (2010) and lower than the value adopted by e.g. Gorodnichenko, Mendoza and Tesar (2012).[38]

The last part of Table 5 displays selected non-targeted moments in both the data and the model. The model matches the persistence of GDP, but generates insufficient volatility in GDP although, by construction, it perfectly matches the path of unemployment rates. One reason for this could be that our model does not feature any TFP shocks, which would move GDP beyond movements in unemployment rates. This is also reflected by the higher negative correlation between unemployment rates and GDP in the model than the data. As a measure of the the degree of risk sharing, we consider the relative standard deviation of consumption to GDP. According to this measure the model features slightly more risk sharing than observed in the data.

4 Model and Data Comparison

4.1 Quantifying the Benefits of Labor Mobility

Given the series of demand shocks ϵ_t^j recovered in the previous section we can now take the model as a benchmark for conducting a set of model-based counterfactuals. For example, the model allows us to ask, what would Europes experience (both in terms of unemployment rates and real GDP) during the Great Recession had been if labor mobility were similar to that of the United States? What are the 'costs' of a currency union as a function of the degree of

[38] Our formulation follows Shimer (2010) who studies a large range of values centered around $\theta_w = 0.86$ (or $\theta_w = 0.95$ at monthly frequency). Assuming that the real wage is a weighted average of last period's real wage and the household's marginal rate of substitution, Gorodnichenko, Mendoza and Tesar (2012) set the weight on last period's real wage to 0.99.

labor mobility? Are both trade openness and labor mobility required to lower the costs of a currency union, or do they act as substitutes?

We start by comparing our benchmark model to two counterfactual experiments. The first experiment considers the effect of eliminating the common currency and instead having country specific monetary policy with floating exchange. The second experiment examines the effect of having labor as mobile across countries as observed across US states. Our main interest lies in the effect on the path of unemployment rates and their cross-sectional standard deviation, as well as the implications for migration, exchange rates and other macroeconomic variables.

Figure 10 displays simulated paths of unemployment rate differentials, $\hat{u}_{i,t}$, and cumulative net migration ("population"), $\sum_{s=1}^{t} \widehat{netm}_{i,s}$, for two groups of countries: GIIPS and EU10.[39] Since we adjust the shock realizations to match the observed unemployment rates, the paths of unemployment rates for the data and the baseline calibration perfectly overlap. The lower panels show that the cumulative net migration response in the model is quite similar to the one oberseved in the data. In particular, we can clearly see the inflow (outflow) of migrants to the GIIPS (from the EU10) countries before the crisis and the subsequent decline. Both for GIIPS and EU10, the reversal happens one to two years too early, which suggests that migration responds to unemployment rate differentials more sluggishly in the data than the model. Table 7 displays some corresponding statistics: the cross-sectional standard deviation in unemployment rates over the entire time period, as well as the average unemployment rates and the cumulative population change for the peak-to-trough period 2006 - 2014. Between 2006 and 2014, GIIPS lost a bit more than 2 percent of its population due to migration, whereas the EU10 gained about half a percentage point, both in the data and the model.

We next run two counterfactual experiments. For each experiment, we simulate the data and demean both the unemployment rates $\hat{u}_{i,t}$ and net migration figures $\widehat{netm}_{i,t}$ as before, but using the means from the *benchmark* model. Our comparisons across experiments therefore include potential changes in mean values.

In the first experiment, we remove all fixed exchange rates from the model so that every country can run its own monetary policy. The effects of such a policy clearly depend on the Taylor rule coefficients. To give this policy sufficient bite, we choose "aggressive" parameters: $\phi_i = 0$, $\phi_\pi = 1.1$ and $\phi_{GDP} = 0.5$. In response to an increase in the unemployment rate,

[39] GIIPS: Greece, Ireland, Italy, Portugal, Spain. EU10: Austria, Belgium, Estonia, Finland, France, Germany, Luxembourg, Netherlands, Slovakia, Slovenia.

the monetary policy lets the exchange rate depreciate and tolerates the following increase in inflation.

Such a policy would have reduced cross-sectional variation in unemployment rates across countries by about 24 percent in Europe ($= 1 - 1.97/2.59$) and 26 percent in the euro area. The aggressive monetary policy would have muted the increase in the unemployment rates in GIIPS between 2006 and 2014 by 1.5 percentage points, while raising it in EU10 by 0.9 percentage points. These smaller unemployment rate differentials would have also lowered net migration flows by about one half. The implied exchange rate fluctuations are rather large. Facing a series of negative demand shocks over the 2006 - 2014 period, the GIIPS economies would have easened monetary policy leading to a strong depreciation of 23% of their currency. This depreciation would have reversed the fall in prices by more than 4 percent over the time period, actually leading to an increase in the price level by more than 0.5 percent.

In the second experiment, we lower the migration propensity parameter γ to replicate the relationship between unemployment rate differentials and migration observed in the U.S, i.e. we target a slope coefficient of $\beta = -0.272$ (instead of $\beta = -0.082$) for the regression of net migration on unemployment rates. In this scenario, Europeans are supposed to be as mobile as Americans. The purple line in Figure 10 as well as the last column in Table 7 show that the implied path of unemployment rates would have been smoother than in the data, but not as smooth as in the previous experiment with floating exchange rates. The cross-sectional standard deviation in the euro area would have declined by 7.5 percent. This partially vindicates Mundell's claim that labor mobility can operate as a substitute for floating exchange rates. The required population changes, however, are quite big. The GIIPS countries would have lost almost 2.5 percent of its population between 2006 and 2014 relative to the 1 percent decline in the benchmark.

The table also reveals that the two counterfactuals - floating vs. higher labor mobility - have opposite effects on macroeconomic aggregates such as real GDP and consumption. A floating exchange rate policy would stimulate labor demand during recessions through a currency depreciation. This would dampen the fall in real GDP by almost one half observed in the GIIPS countries. In contrast, higher labor mobility would have accentuated the fall in GDP, simply because more workers would have left the GIIPS countries.

[Results are in progress]

5 Conclusion

[To be completed]

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Table 1: UNEMPLOYMENT RATE STATISTICS

	US	CAN	Europe	Euro
Std. Deviation	0.99	1.03	2.51	2.53
	(0.05)	(0.05)	(0.14)	(0.21)
Estimated Coefficients				
$\hat{\beta}_1$	1.18	0.98	1.36	1.51
	(0.02)	(0.05)	(0.03)	(0.05)
$\hat{\beta}_2$	−0.37	−0.18	−0.59	−0.67
	(0.02)	(0.05)	(0.03)	(0.04)
R^2	0.76	0.69	0.85	0.93

Notes: The first part of the table reports the average standard deviation of the demeaned unemployment rates, $\sum_t std(\hat{u}_{i,t})$, for the four regions, as well as the standard error associated with that standard deviation. The estimation periods are '77-'14 for the U.S. and Canada, and '95-'15 for the European samples. The second part of the table reports the estimated coefficients of regressing the unemployment rate on its own two lags (see equation (2.2) in the text).

Table 2: MIGRATION STATISTICS

	Unit	US	CAN	Europe	Euro
Regions	#	48	10	29	12
Population	m	5.57	2.94	17.30	26.28
Migration rate	%	3.23	1.96	0.73	0.64
Internal migration	%	3.11	1.53	0.46	0.34
SD(Net migration rate)	%	0.48	0.48	0.32	0.30

Notes: Table displays the number of regions (States / Provinces / Countries) for the US, Canada and Europe, their average population (in millions), their average migration rate, the average internal migration rate, and the average standard deviation across time of the net-migration rate. Migration is the average of inmigration and outmigration. Values are simple averages across regions and time ('77-'15 for North America, '95-'15 for Europe).

Table 3: UNEMPLOYMENT RATES AND NET MIGRATION

	US	CAN	Europe	Euro
β	-0.272	-0.223	-0.082	-0.090
	(0.011)	(0.021)	(0.006)	(0.006)
R^2	0.26	0.24	0.28	0.51
No. Obs.	1,872	390	460	224

Notes: Table displays the regression coefficient of the regression (2.3). Time period: '77-'14 for US and Canada, '91-'14 for Europe. Standard errors in parentheses.

Table 4: Calibration

Parameter		US	Europe	Target / Source
Preferences				
Discount factor	β	0.99		4% real interest rate
Coefficient of relative risk aversion	$\frac{1}{\sigma}$	2		Standard value
Labor disutility weight	κ_j	x	x	Labor force per capita, US: , Europe: Eurostat ('95 - '15)
Frisch elasticity of labor supply	η	0.20		see e.g. Reichling and Whalen (2012), Blundell and MaCurdy (1999)
Trade and Country Size				
Trade demand elasticity	ψ_y	2		e.g. Backus, Kehoe and Kydland (1994)
Trade preference weights	ω_i^j	x	x	Share of imports from j; US: FAF (1997); Europe: OECD TiVA (2005)
Country's absorption	$\mathbb{N}_n Y_n$	x	x	Nominal GDP; US: BEA (1997), Europe: Eurostat (2005)
Technology				
Curvate of production function	α	0.30		Labor income share of 0.63, US and Germany (Karabarbounis and Neiman (2013))
Depreciation rate	δ	0.021		Annual depreciation rate of 10 percent
Utilization cost	a''	0.286		Del Negro et al. (2013)
Elasticity of substitution bw. varieties	ψ_q	10		e.g. Basu and Fernald (1995), Basu and Kimball (1997)
Nominal Rigidities				
Sticky price probability	θ_p	0.70	0.77	Price duration: 10 months (US, Nakamura and Steinsson (2008)) 13 months (Europe, Alvarez et al. (2006))
Migration				
Population	$\mathbb{N}_i$	x	x	US: US Census (1990, 2000), Europe: Eurostat ('91-'14)
Amenity value	A_i^j	x	x	Share of people from j living in i, US: US Census (1990, 2000), Europe: Eurostat ('95-'15)
Labor Markets				
Unemployment rate	ur	x	x	US: BLS ('77-'14), Europe: Eurostat ('95-'15)
Separation rate	d	0.10	0.10	US: Shimer (2005), Europe: Hobijn and Şahin (2009)
Matching elasticity to tightness	ζ	0.72		Shimer (2005), Burda and Wyplosz (1994), Petrongolo and Pissarides (2001)
Bargaining power of workers	ϱ	0.72		Shimer (2005)
Unemployment benefits	bw^h	0.44	0.59	Net replacement rate, US: Engen and Gruber (2001), Europe: OECD "Benefits and Wages"
Vacancy cost	$\frac{\varsigma V_i}{Y_i}$	0.004		Shimer (2010)
Fiscal and Monetary Policy				
Gov't purchases over final demand	$\frac{G_i}{Y_i}$	0.19	x	US: BEA ('77-'14), Europe: Eurostat ('95-'15)
Taylor rule persistence	ϕ_i	0.75		Clarida, Gali and Gertler (2000)
Taylor rule GDP coefficient	ϕ_{GDP}	0.50		Clarida, Gali and Gertler (2000)
Taylor rule inflation coefficient	ϕ_π	1.50		Clarida, Gali and Gertler (2000)

Notes: Values marked with x are country- or country-pair specific. FAF: Freight Analysis Framework; TiVA: Trade in Value Added Database.

Table 5: Estimation

Description		Target	Model
Estimated Parameters			
Shock persistence	ρ		0.979
Migration propensity	γ		2.127
Migration adjustment cost	Φ''		22.362
Vacancy adjustment cost	Υ''		0.004
Investment adjustment cost	Λ''		0.105
Real wage rigidity	θ_w		0.855
Targeted Moments			
Slope coefficient $\widehat{netm}_{i,t}$ on $\widehat{u}_{i,t}$		-0.081	-0.080
Standard deviation $\widehat{W}_{i,t}$		5.208	5.208
Persistence $\widehat{netm}_{i,t}$		0.616	0.632
Correlation $\widehat{\frac{nx_{i,t}}{Qi,t}}$ and $\widehat{Q}_{i,t}$		-0.303	-0.303
Persistence $\hat{X}_{i,t}$		0.671	0.671
Persistence ϵ_t^j		0.000	-0.001
Free Moments			
Std. dev. $\widehat{Q}_{i,t}$		3.540	2.181
Std. dev. $\widehat{C}_{i,t}$ rel. to std. dev. $\widehat{Q}_{i,t}$		1.365	1.121
Persistence $\widehat{Q}_{i,t}$		0.712	0.718
Persistence $\widehat{C}_{i,t}$		0.750	0.761
Correlation $\widehat{C}_{i,t}$ and $\widehat{Q}_{i,t}$		0.735	0.837
Correlation $\widehat{u}_{i,t}$ and $\widehat{Q}_{i,t}$		-0.587	-0.858

Notes: Target refers to data moments for the European sample.

Table 6a: STEADY-STATE: EUROPEAN SAMPLE

Country	GDP	Import share	Pop	Expat share	Unem rate	Country	GDP	Import share	Pop	Expat share	Unem rate
Austria	4.9%	37.3%	1.6%	6.7%	4.8%	Latvia	0.7%	33.1%	0.5%	12.6%	12.8%
Belgium	4.5%	39.1%	2.1%	4.4%	8.2%	Lithuania	1.3%	59.0%	0.6%	11.8%	11.2%
Bulgaria	0.5%	63.0%	1.6%	10.0%	11.6%	Malta	3.2%	65.9%	0.1%	22.1%	6.5%
Cyprus	4.3%	65.8%	0.1%	21.1%	6.7%	Netherlands	5.0%	36.3%	3.2%	5.3%	5.4%
Czech Republic	1.2%	42.1%	2.1%	5.1%	6.6%	Norway	7.4%	44.2%	0.9%	3.8%	3.6%
Denmark	6.0%	35.8%	1.1%	4.3%	5.6%	Poland	0.9%	23.9%	7.6%	6.8%	12.7%
Estonia	1.0%	48.9%	0.2%	11.7%	9.9%	Portugal	2.3%	23.9%	2.1%	16.9%	9.4%
Finland	4.8%	37.4%	1.1%	5.4%	9.4%	Romania	0.6%	57.1%	4.3%	8.4%	7.0%
France	4.4%	24.9%	12.5%	2.9%	9.3%	Slovak Republic	0.8%	44.7%	1.1%	4.5%	14.3%
Germany	4.8%	26.8%	16.3%	4.7%	7.9%	Slovenia	2.2%	42.1%	0.4%	6.0%	7.1%
Greece	2.4%	21.9%	2.2%	8.8%	13.5%	Spain	2.8%	25.9%	8.5%	3.1%	16.2%
Hungary	0.9%	43.4%	2.0%	4.6%	8.2%	Sweden	5.7%	37.9%	1.8%	3.2%	7.5%
Iceland	5.6%	33.4%	0.1%	9.4%	4.0%	Switzerland	7.6%	39.8%	1.5%	7.6%	3.6%
Ireland	5.0%	55.9%	0.8%	18.8%	8.5%	United Kingdom	5.1%	24.6%	12.1%	7.0%	6.3%
Italy	3.9%	25.7%	11.6%	5.2%	9.5%	RoW	1.0%	4.7%	1176.3%	0.4%	6.0%
Average	-	40.0%	-	8.3%	8.5%						

Notes: Table displays the 29 countries plus the Rest of the World in our sample. GDP and population are measured relative to the European aggregate. The import share is measured as the share of (value added) imports in final demand using the OECD TiVA database. The migration share is the share of nationals living abroad. The average import share and migration share are calculated based on the 29 European countries.

Table 6b: STEADY-STATE: U.S. SAMPLE

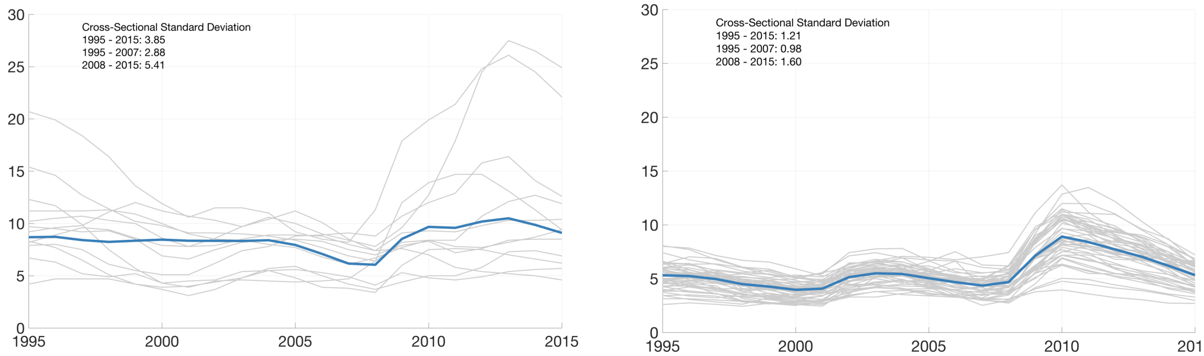
Country	GDP	Import share	Pop	Expat share	Unem rate	Country	GDP	Import share	Pop	Expat share	Unem rate
Alabama	1.7%	58.9%	1.6%	34.9%	7.4%	Nevada	2.6%	70.7%	0.6%	39.1%	6.6%
Arizona	2.1%	52.0%	1.7%	32.2%	6.4%	New Hampshire	2.2%	78.6%	0.4%	40.2%	4.4%
Arkansas	1.6%	60.6%	1.0%	45.5%	6.7%	New Jersey	2.6%	66.7%	3.1%	33.2%	6.4%
California	2.3%	27.8%	12.1%	18.3%	7.4%	New Mexico	2.2%	52.0%	0.6%	42.2%	6.8%
Colorado	2.5%	47.5%	1.4%	40.8%	5.6%	New York	2.6%	37.3%	7.0%	33.4%	6.7%
Connecticut	2.9%	64.8%	1.3%	33.8%	5.5%	North Carolina	2.2%	50.3%	2.8%	27.0%	5.9%
Delaware	3.2%	77.9%	0.3%	38.4%	5.5%	North Dakota	1.7%	44.0%	0.2%	57.5%	4.0%
Florida	1.9%	32.1%	5.5%	24.8%	6.3%	Ohio	2.1%	56.0%	4.2%	30.9%	6.9%
Georgia	2.3%	56.4%	2.8%	28.8%	6.1%	Oklahoma	1.6%	48.1%	1.3%	43.7%	5.2%
Idaho	1.8%	42.5%	0.4%	48.1%	6.2%	Oregon	2.2%	43.4%	1.2%	35.6%	7.3%
Illinois	2.4%	52.3%	4.5%	33.9%	7.1%	Pennsylvania	2.0%	59.0%	4.6%	32.8%	6.6%
Indiana	2.0%	63.3%	2.2%	33.0%	6.4%	Rhode Island	1.9%	72.0%	0.4%	38.8%	6.6%
Iowa	2.0%	54.0%	1.1%	43.4%	4.7%	South Carolina	1.8%	62.5%	1.4%	32.7%	6.7%
Kansas	2.0%	59.9%	1.0%	46.3%	4.7%	South Dakota	1.8%	56.1%	0.3%	53.6%	3.8%
Kentucky	1.8%	67.2%	1.5%	36.7%	7.0%	Tennessee	2.0%	62.7%	2.0%	31.9%	6.6%
Louisiana	1.8%	44.4%	1.7%	30.4%	7.4%	Texas	2.2%	37.3%	7.2%	20.4%	6.2%
Maine	1.7%	56.3%	0.5%	35.3%	6.0%	Utah	2.0%	55.1%	0.8%	31.7%	5.0%
Maryland	2.2%	59.3%	1.9%	30.7%	5.4%	Vermont	1.8%	75.8%	0.2%	42.7%	4.8%
Massachusetts	2.6%	54.1%	2.3%	32.9%	5.6%	Virginia	2.2%	59.5%	2.5%	33.2%	4.8%
Michigan	2.1%	46.5%	3.7%	27.6%	8.2%	Washington	2.5%	48.4%	2.0%	30.8%	7.2%
Minnesota	2.3%	47.3%	1.8%	30.8%	5.0%	West Virginia	1.5%	69.0%	0.7%	49.8%	8.4%
Mississippi	1.5%	65.0%	1.0%	42.8%	7.7%	Wisconsin	2.1%	56.2%	2.0%	28.5%	5.7%
Missouri	2.1%	61.4%	2.0%	36.9%	6.1%	Wyoming	2.1%	52.0%	0.2%	59.0%	5.0%
Montana	1.5%	40.0%	0.3%	49.9%	5.9%	RoW	3.3%	59.8%	0.9%	58.1%	6.9%
Average	-	55.2%	-	36.9%	6.1%						

Notes: Table displays the 48 U.S. states plus the Rest of the US in our sample. GDP and population are measured relative to the European aggregate. The import share is measured based on the commodity flow survey. The migration share is the share of people born in state i, but living in a different state. The average import share and migration share are calculated based on the 48 U.S. states.

Table 7: COUNTERFACTUAL EXPERIMENTS

	Data	Bench-mark	Flexible exch rate	High mobility
Cross-Sect. Std. Deviation Unempl. Rate				
Europe	2.59	2.59	1.97	2.38
Euro Area	2.62	2.62	1.94	2.37
Change Unempl. Rate '06-'14				
GIIPS	7.58	7.58	6.09	6.69
EU10	−3.44	−3.44	−2.58	−2.87
Pop. Change '06-'14				
GIIPS	0.04	−0.96	−0.43	−3.43
EU10	0.12	1.11	0.61	2.44
Change Exchange Rate '06-'14				
GIIPS	0.00	−0.00	−22.78	−0.00
EU10	0.00	0.00	10.98	0.00
Change Price Level '06-'14				
GIIPS	2.34	−4.38	0.62	−4.62
EU10	6.96	3.10	0.81	3.06
Change Real GDP '06-'14				
GIIPS	−6.12	−8.40	−4.60	−9.74
EU10	5.66	4.64	2.50	5.42
Change Real Consumption '06-'14				
GIIPS	−5.38	−11.20	−8.78	−12.40
EU10	7.32	5.58	4.25	6.59

Notes: Table displays several statistics as observed in the data and various model settings. Besides the benchmark model results, the table also displays results of the model with flexible exchange rates, and the model with a higher degree of labor mobility (with γ adjusted to match the slope coefficient of net migration on unemployment across US states).



(a) Euro area

(b) US

Figure 1: Unemployment Rates in Euro Area Countries and US States

Notes: Figure displays unemployment rates for Western European euro area countries and the US states (grey, thin lines), as well as their respective averages (blue, thick lines).

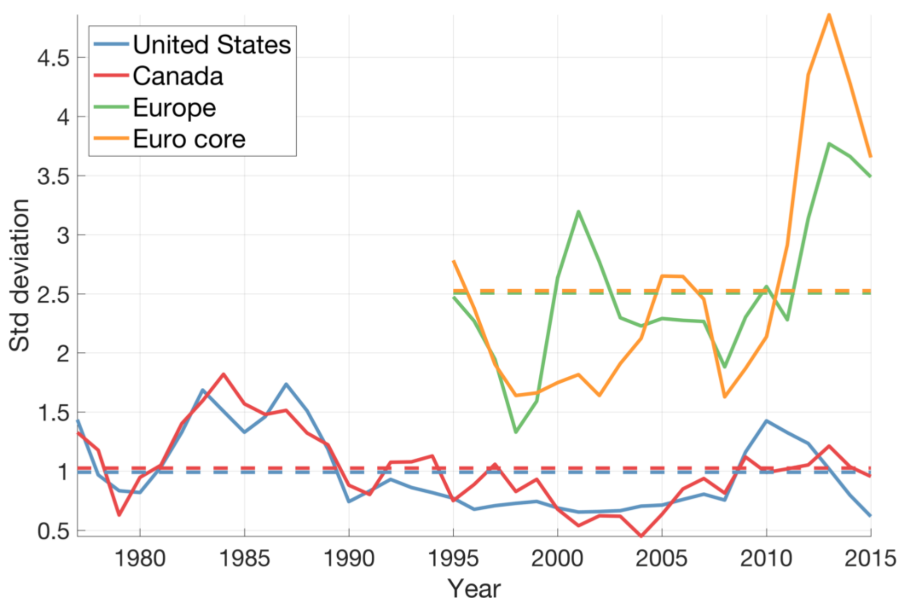


Figure 2: Cross-Sectional Standard Deviations in Demeaned Unemployment Rates

Note: The figure plots cross-sectional standard deviation in demeaned unemployment rates, $\hat{u}_{i,t}$, for four regions: US states, Canadian provinces, European countries and core Euro countries. The dotted lines are the respective time averages. See the text for the definition of demeaned unemployment rates.

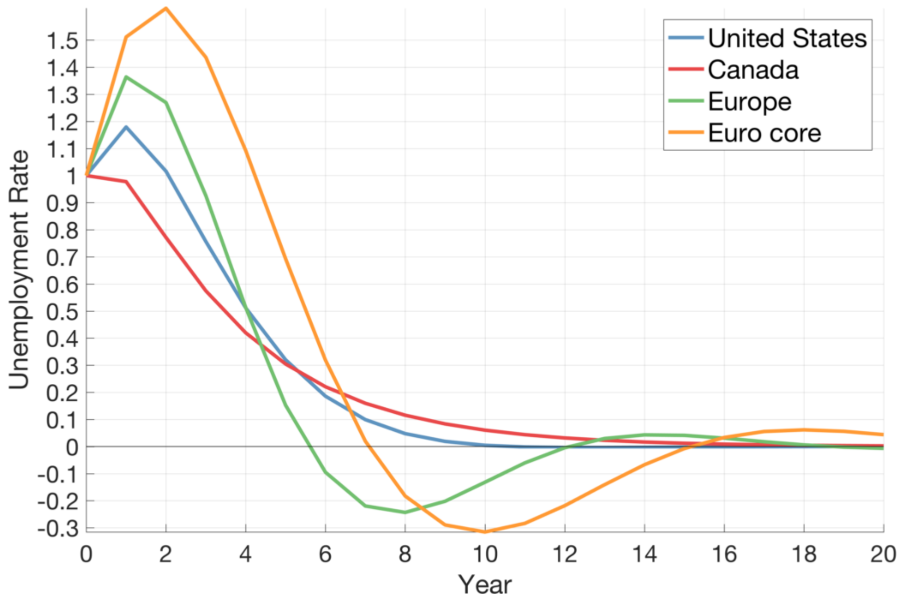


Figure 3: Impulse Response to Unemployment Rate Innovation

Note: The figure plots the impulse response to a 1 percentage point positive shock to the demeaned unemployment rate, $\hat{u}_{i,t}$, i.e. $\epsilon^u_{i,0} = 1$ and $\epsilon^u_{i,t} = 0$ for $t > 0$, for four regions: US states, Canadian provinces, European countries and core Euro countries. See equation (2.2

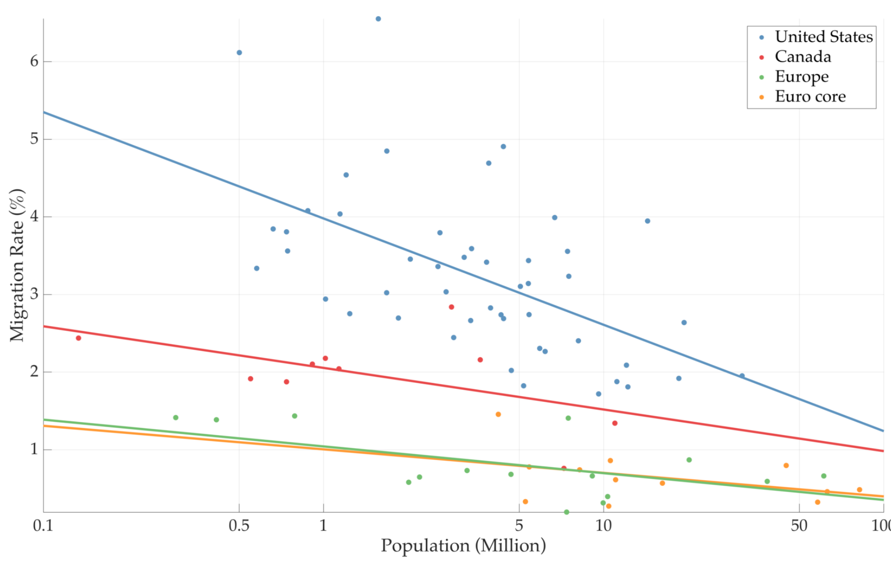


Figure 4: Migration Rates vs. Population

Note: The figure plots the migration-to-population ratio against population for US States, Canadian Provincesn and Western European countries. Migration is measured as the average of immigration and emigration. Values are averages over 1991 - 2014.

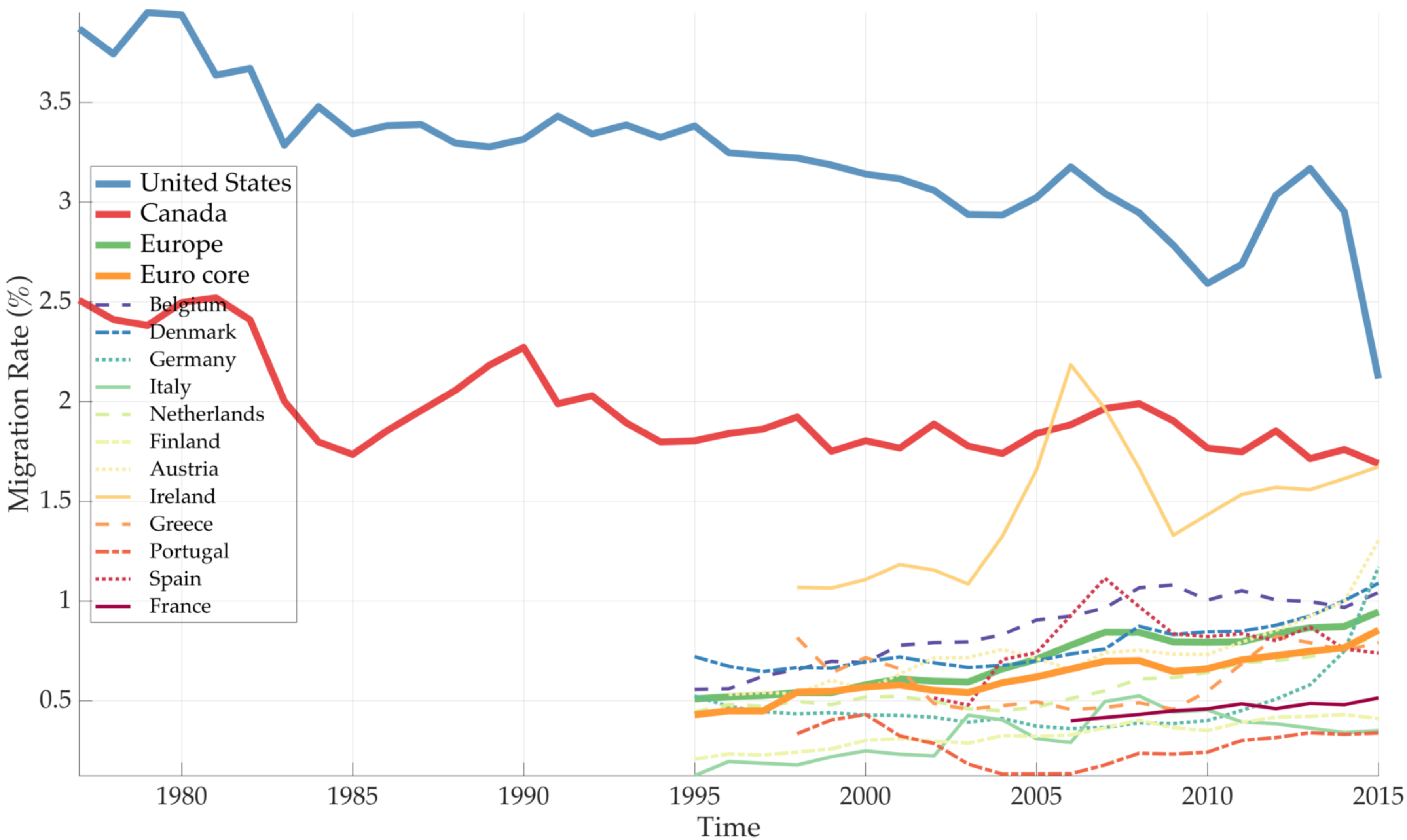
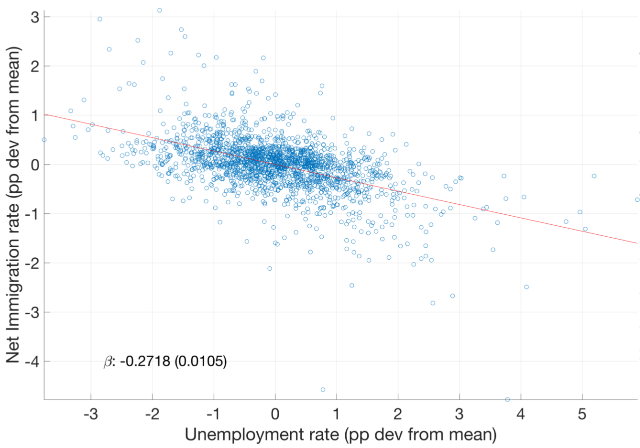
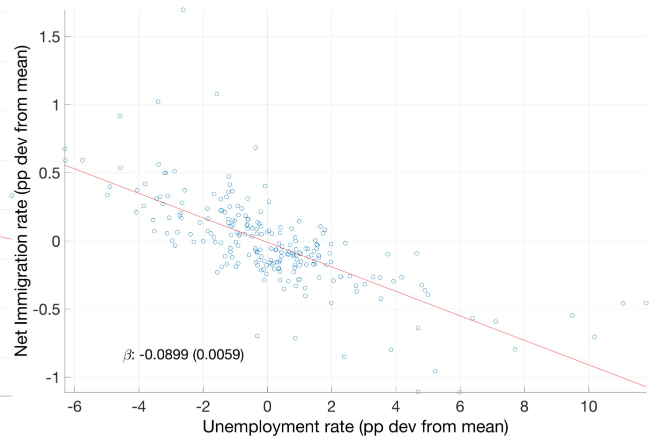


Figure 5: Migration Rates over Time

Note: The figure plots the migration-to-population ratio over time for the average of US States, the average of Canadian Provincesn the average of Western European countries, and individual Western European countries. The average of Western European countries averages over all countries with available data in any given year.



(a) U.S.: 1977 - 2014



(b) Euro area: 1995 - 2015

Figure 6: Net Migration Rate vs. Unemployment Rate

Note: The first panel plots the demeaned state net migration rates $netm_{i,t}$ for the U.S. against the demeaned state unemployment rates $u_{i,t}$ over 1977 - 2015. The second panel plots the corresponding data for the euro area countries, 1995 - 2015.

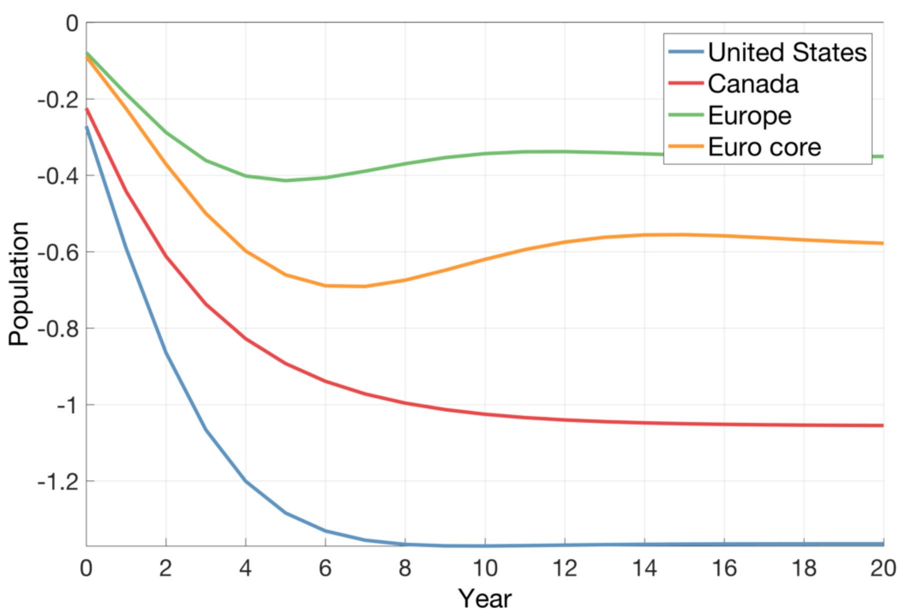


Figure 7: Population Response to a 1 percentage point Innovation in the Unemployment Rate

Note: Impulse response for population is calculated based on the estimated persistence process for the unemployment rate (see Figure 3) and the estimated relationship between net migration and unemployment rates (see Table 3).

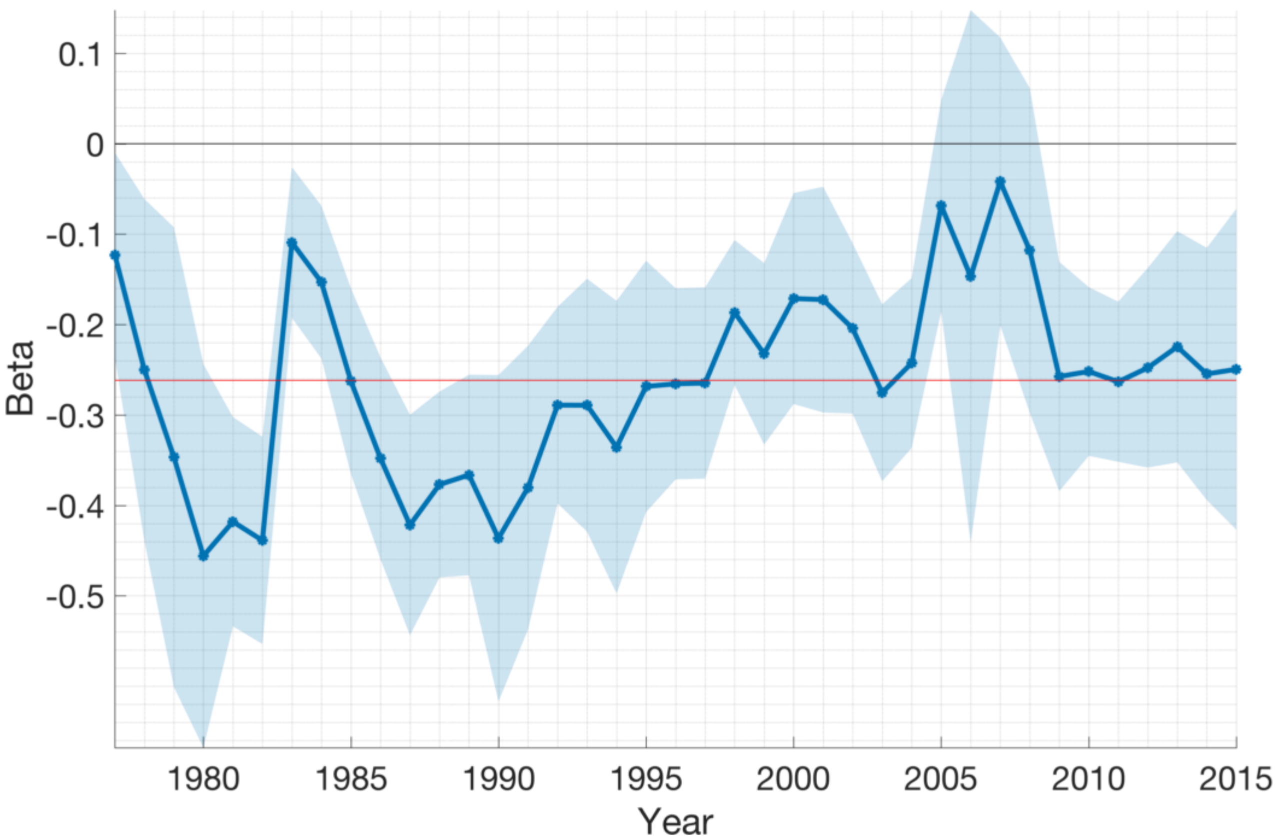
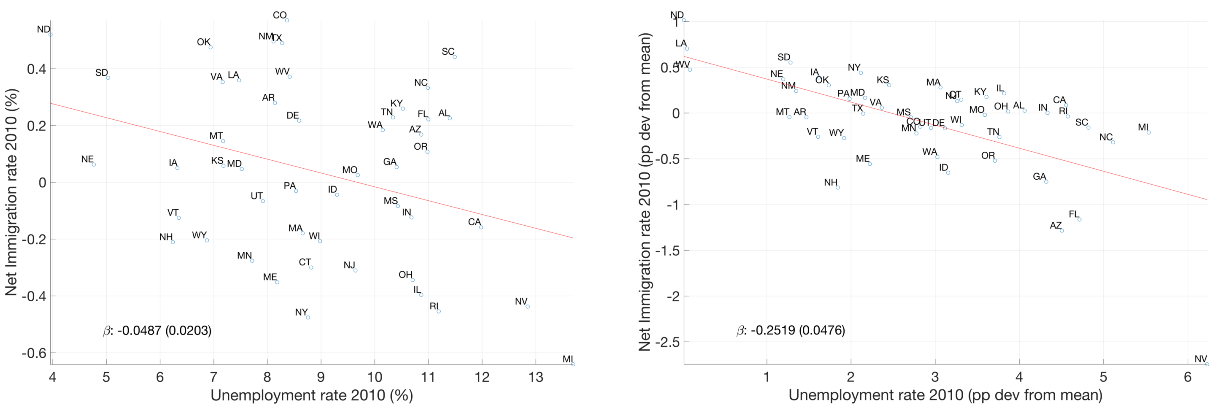


Figure 8: U.S. State Net Migration Rate vs. State Unemployment Rate: Repeated Cross Sections

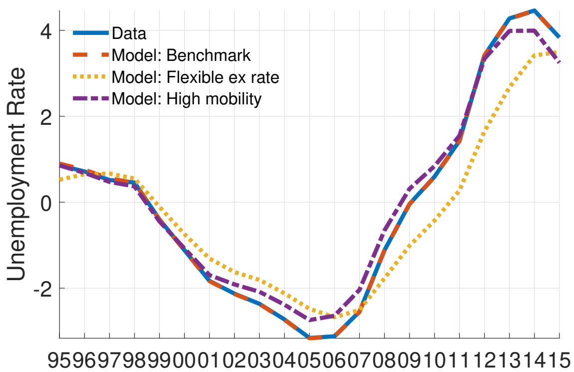
Note: The figure displays the coefficients from regressions of demeaned state net migration rates vs. demeaned state unemployment rates (see equation (2.3)). Every coefficient corresponds to a single year. Confidence intervals are $\hat{\beta} \pm 1.96\widehat{stderr}$.



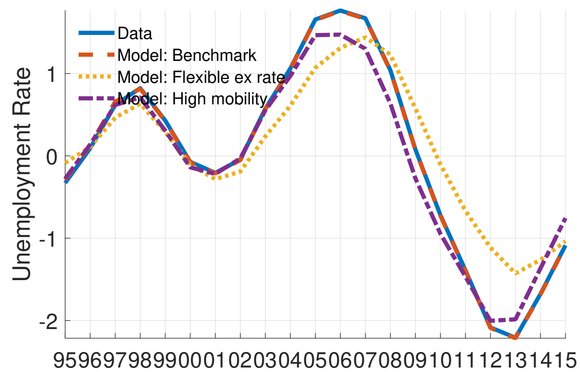
(a) Raw Data (b) Demeaned Data

Figure 9: State Net Migration Rate '09-'10 vs. State Unemployment Rate Growth '07-'10

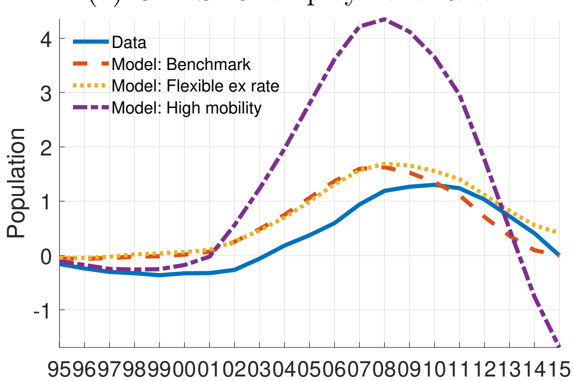
Notes: Panel (a) shows state net migration rates between 2009 and 2010 against the percentage point change in the unemployment rate during 2007-2010. Panel (b) displays state net migration rates between 2009-2010 demeaned by their state-specific average value 1977-2014, against the state unemployment rates between 2009 and 2010 demeaned by their state-specific average value 1977-2014. Unemployment rate data comes from the BLS. State net migration data comes from the IRS.



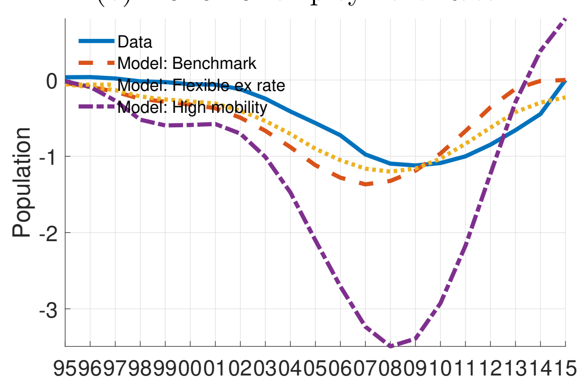
(a) GIIPS: Unemployment Rate



(b) EU10: Unemployment Rate



(c) GIIPS: Population



(d) EU10: Population

Figure 10: Unemployment Rate and Population in Data and Model

Notes: Panels display unemployment rates and cumulative net migration ("population") both in the data and the model, for GIIPS and EU10.

A Appendix

A.1 Database US States

Data sources:

- *Population*: Mid-year population estimates, provided by BEA; data is based on US Census data and smoothes out jumps in census years, 1958 - 2016
- *Unemployment rate*: BLS, 1976 - 2015
- *Bilateral migration*: IRS Statistics of Income Division, 1975 - 2015

A.1.1 Migration Data

We use data from the Internal Revenue Service (IRS) to calculate state-to-state migration flows. The IRS has calculated migration rates based on the universe of tax filers. It compares mailing addresses on tax returns and then classifies tax returns as 'migrant' whenever the geographic code changes, and 'non-migrant' otherwise. The IRS then reports the number of tax returns that flow between any two geographical areas (counties or States), including the number of non-migrants. Combining this information allows us to calculate migration rates. The IRS reports numbers for both the number of returns (approximating households) and the number of exemptions claimed (approximating people). We focus on the number of exemptions claimed. The IRS data does not allow us to directly observe migration flows, but we only observe locations of tax filers at certain points in time, e.g. a tax filer lived at some point in 1999 in Ohio and at some point in 2000 in Michigan. Our best guess is that the move between the two states took place between July 1st 1999 and June 30th 2000. So migration in year t refers to migration between July 1st of calendar year $t-1$ and June 30th of calendar year t.

Another popular source for migration data is the American Community Survey (ACS) (see e.g. Yagan, 2014) and the Annual Social and Economic Supplement of the Current Population Survey (CPS). Both surveys ask individuals whether their residence in the previous year was in the same state as their current residence, which allows the researcher to calculate migration rates. The ACS survey also includes information on the State of previous residence so that even bilateral migration rates can be calculated. The panel structure of the ACS is a main advantage of this data set, but the small sample size leads to imprecise estimates of net migration rates (the CPS' sample size is even smaller, roughly one third of that of the ACS), especially for small states. This is also illustrated in Figure A1, which display internal net (in)migration rates for six US States based on IRS data and ACS data. The measures are calculated as follows:

$$netmigr_{i,t}^{IRS} = \frac{\sum_{j \in US} \left(v_{i,j,t}^{IRS} - v_{j,i,t}^{IRS} \right)}{\sum_j v_{j,i,t}^{IRS}}$$
$$netmigr_{i,t}^{ACS} = \frac{\sum_{j \in US} \left(v_{i,j,t}^{ACS} - v_{j,i,t}^{ACS} \right)}{pop_{i,t-1}}$$

where $v_{i,j,t}^{IRS}$ is the number of exemptions claimed for individuals that lived in State j in $t-1$ and in State i in t, as reported by the IRS. Summation is over all US States, that is we ignore international migration. We divide by the total number of exemptions claimed for individuals that lived in i in $t-1$. ACS estimates of state-to-state flows are directly expressed in people, so we divide by the mid-year population as of $t-1$. One difference between the two measures is that the IRS figures refer to tax returns, and the population of tax filers is not necessarily representative of nonfilers.

We compare these two figures to data provided by the US Census. The Census provides intercensal estimates of the resident population for all US States, including year-to-year components of change. Starting in 1991 these components of change specifically include net migration (both internal and international). The Census partially sources its net migration estimates on IRS data and has calculated, up to 2011, IRS migration rates. The Census complements the IRS data with data on social security payments to better estimate migration patterns of e.g. people above 65. Despite these adjustments, the Census estimates of net migration rates are quite similar to the "raw" IRS data. Importantly, ACS time series display larger volatilities, especially for smaller states. These volatilities are even higher when only looking at bilateral migration flows.

A more detailed description on the various data sets on internal migration in the US can be found in Molloy, Smith and Wozniak (2011).

A.2 Database Canada

- Statistics Canada

A.3 Database Europe

Our goal is to create a database of bilateral migration flows within Europe that uses a consistent definition of migration across countries. Doing so, we face two challenges:

1. Definitions of 'Migrant' differ across countries.

2. 'Mirror' flows of migrants are inconsistent and have to be reconciled

To overcome the first challenge, we adjust data using an adjustment factor based on time periods where data according to both 'national' and 'harmonized' definitions of migrants exist. The second challenge has been tackled in the trade literature and we therefore apply the methodology proposed by one of the most used trade databases (BACI).

'Europe' encompasses, for our purpose, all countries in EU28 + EFTA, excluding Luxembourg, Liechtenstein and Croatia.

A.3.1 Different Definitions of 'Migrant' across Countries

The UN defines a migrant as any person moving in or out of a country for at least 12 months. Eurostat has asked member states to provide data according to this definition starting in 2008 (regulation No. 862/2007), and most countries had updated their migration data accordingly by 2015. Previously, countries had used national definitions. In Germany, the Netherlands, Austria and Switzerland, for example, these national definitions include migrants that move for less than 12 months (e.g. seasonal workers, exchange students), and numbers of migrants according to these definitions produce higher numbers. In many Eastern European countries (such as Poland, Slovak Republic, Bulgaria), migrants only refer to those changing their permanent residence, which leads to substantially smaller numbers of migrants compared to the UN definition. The five Scandinavian countries have national definitions that are close to the UN definition.

Adjusting data for different definitions Tables A4 and A5 display data availability for all 29 countries in our dataset, for both unilateral (i.e. overall immigration and emigration) and bilateral data (i.e. including information on country of previous residence / next residence). For unilateral data, there are two countries that do not report any data on Eurostat (Estonia and Slovak Republic)[40] Twelve countries either only report through Eurostat or do not have

[40] They report some data on Eurostat, but not according to the UN definition.

longer time series based on a national definition (Ireland, Greece, France, Cyprus, Latvia, Lithuania, Hungary, Malta, Poland, Portugal, Romania and United Kingdom)) and for the remaining thirteen countries, national data sources display longer time series than the time frame reported on Eurostat.

Let $\tilde{v}^i_{i,j,t}$ denote the migration flow from j to i at time t reported by country i according to the national definition of country i. The corresponding value using the harmonized definition proposed by the UN and enacted by Eurostat is denoted by $v^i_{i,j,t}$. For time periods with missing values for $v^i_{i,j,t}$, we replace these missing values by $adj^i_{i,j}\tilde{v}^i_{i,j,t}$, where we calculate the adjustment factor $adj^i_{i,j}$ as

$$adj^i_{i,j} = \frac{1}{S}\sum_s \left(\frac{\tilde{v}^i_{i,j,s}}{v^i_{i,j,s}}\right).$$

Here, s indexes all periods for which data according to both 'national' and 'harmonized' definitions of migrants exist, and S is the number of those periods. We apply this factor to both unilateral and bilateral migration data. For some countries bilateral migration data is not reported on Eurostat (in particular, Germany, and to a lesser extent, Spain and Italy), but migration data is available for country groups. In those cases, we calculate the adjustment factor based on either data reported for the EU15 or the EFTA aggregate.

A.3.2 Reconciling Bilateral Flows

Whenever two countries report numbers on the same flow of migrants, we face the challenge of reconciling these two reported numbers because these so-called *mirror flows* rarely coincide across reporting countries. Reconciliation methods used in the literature are the following:

- Only take inflows (immigration is easier to measure than emigration)
- Use BACI method for trade flows: reconciled value is a weighted average of the two reported numbers, with weights corresponding to the 'quality' of a country's reports. Quality is measured as the discrepancy in mirror flows averaged across all partner countries.

Bilateral flows among Scandinavian countries that are fairly consistent among each other, e.g. the number of migrants from Denmark to Norway is almost the same as reported by Denmark and Norway. We opt for the BACI method, as explained in the following paragraph.

Overview BACI method Suppose the true value v for migration from j to i at time t is unobservable. Reported values contain an error e. We assume

$$v_i = ve_i \qquad \text{with} \qquad lne_i \sim N(0, \sigma_i^2),$$

where v_i is the migration value reported by i. We would like to choose weights w to minimize the variance of the reconciled value, $wv_i + (1-w)v_j$, relative to the true value:

$$\min_w Var\left(we_i + (1-w)e_j\right).$$

The solution is[41]

$$w = \frac{Var(e_i)}{Var(e_i) + Var(e_j)} = \frac{e^{\sigma_i^2}(e^{\sigma_i^2} - 1)}{e^{\sigma_i^2}(e^{\sigma_i^2} - 1) + e^{\sigma_j^2}(e^{\sigma_j^2} - 1)}.$$

We estimate σ_i^2 by first regressing the relative distance between reported values, $|\ln v_i - \ln v_j|$, on a set of dummies:

$$|\ln v_{i,j,t}^i - \ln v_{i,j,t}^j| = \alpha_i + \beta_j + \lambda_t + \epsilon_{i,j,t} \qquad \text{with} \quad \sum_i \alpha_i = \sum_j \beta_j = \sum_t \lambda_t = 0. \tag{A.1}$$

Given the assumptions on the error term e_i, we have $\ln e_i - \ln e_j \sim N(0, \sigma_i^2 + \sigma_j^2)$ because the variance of the sum (or difference) of two normal distributions is the sum of their variances. The absolute value of the difference of two normal distributions, $|\ln e_i - \ln e_j|$, is a folded normal distribution with a mean equal to $\sqrt{\frac{2}{\pi}}\sqrt{\sigma_i^2 + \sigma_j^2}$. Denote this mean by $\mu_{i,j}$. Then, the average mean of values reported by i is a weighted average of all bilateral means, with some

[41]Note that the minimization problem can be rewritten as

$$\min_w \left(w^2 Var(e_i) + (1-w)^2 Var(e_j)\right).$$

Also, the variance of the log-normally distributed e_i is $e^{\sigma_i^2}(e^{\sigma_i^2} - 1)$.

weights s_j that sum up to 1:[42]

$$\begin{aligned}\mu_i &= \sum_j s_j \mu_{i,j} \\ &= \sum_j \left(s_j \sqrt{\frac{2}{\pi}} \sqrt{\sigma_i^2 + \sigma_j^2} \right) \\ &\approx \sqrt{\frac{2}{\pi}} \sum_j \left(s_j(\sigma_i + \sigma_j) \sqrt{\frac{2}{\pi}} \right) \\ &= \frac{2}{\pi}\sigma_i + K_i,\end{aligned}$$

where K_i is some constant. Our estimate of μ_i is $\hat{\alpha}_i$. Then, our estimate of σ_i is

$$\hat{\sigma}_i = \frac{\pi}{2}\left(\hat{\alpha}_i - \min_j \hat{\alpha}_j + 2stderr(\hat{\alpha}_i) \right),$$

and similarly for $\hat{\sigma}_j$. Here, $stderr(\hat{\alpha}_i)$ is the estimated standard error of $\hat{\alpha}_i$. The ad-hoc transformation sets $K_i = \min_j \hat{\alpha}_j - 2stderr(\hat{\alpha}_i)$ and is a normalization plus it gives an (arbitrary) penalty term to imprecisely estimated values of α_i.

Intuitively, σ_i is estimated to be large for countries that on average, i) report different values than their partners (either underreport or overreport), i.e. a large $\hat{\alpha}_i$, and ii) are inconsistent in their reports in the sense that some of their reports closely match values reported by their partners and others do not, i.e. a large $stderr(\hat{\alpha}_i)$. The regression (A.1) *cleans* the quality of country i's reports from the quality of its partners, j, and the quality of reports associated with certain time periods.

For some bilateral pairs, we have two reported values for a subset of all years, whereas only one value is reported in all other years. In that case, we calculate an adjustment factor. For example, if j does not report values for all years, but i does, our estimate of v is

$$v_{i,j,t} = w_{i,j} v_{i,j,t}^i + (1 - w_{i,j}) v_{i,j,t}^i \frac{1}{S} \sum_s \left(\frac{v_{i,j,s}^j}{v_{i,j,s}^i} \right),$$

where s indexes all periods for which both i and j report, and S is the number of those periods.

[42]The approximation seems to work, but not sure where it comes from.

A.4 Bilateral Regressions

We run the following regression:

$$100 * \log v_{i,t}^{j} = \beta_{ij} + \beta^{dest} u_{i,t} + \beta^{orig} u_{j,t} + \beta^{trend} t + \epsilon_{ij,t} \quad \text{(A.2)}$$

where, $v_{i,t}^{j}$ denotes migration from j to i at time t and $u_{i,t}$ is the unemployment rate in i at time t, demeaned over time. We include pairwise fixed effects β_{ij} and a time trend t. As before, the time period for the North American samples is 1977-2014, and 1991-2014 for the European samples.

Table A7 reports the estimated coefficients with their standard errors clustered at the pair level.[43] For the US, the estimated coefficients for β^{orig} and β^{dest} are around -4.5 and 4.5, implying that a one percentage point increase (decrease) in the unemployment rate of the destination (origin), lowers migration by 4.5 percent. The coefficient on the time trend is statistically insignificant, meaning that the *absolute number* of migrants has not changed over time. This reflects the combined effect of a decrease in migration rates (discussed above) and the counterbalancing population growth. For the Canadian sample, the point estimates on the unemployment rates are not symmetric, with movements in unemployment rates in the destination playing a larger role ($\hat{\beta}^{dest} = 6.9$) than movements in unemployment rates in the origin ($\hat{\beta}^{orig} = 3.5$). Migration in Western Europe displays the lowest sensitivity to movements in unemployment rates, with coefficients around -3.2 and 3.2. Migration in absolute terms has been downward trending in Canada, but substantially increasing in Western Europe, rising by about 3 percent by year.

[43] We cluster standard errors at the pair level to account for possible correlations in $\epsilon_{ij,t}$ over time.

Table A1: MIGRATION STATISTICS: UNITED STATES

State	pop	migr	dom	sd(netm)	State	pop	migr	dom	sd(netm)
Alabama	4.3	2.8	96.1	0.24	Nebraska	1.7	3.1	96.7	0.32
Arizona	4.6	5.0	96.8	0.85	Nevada	1.7	6.6	97.7	1.38
Arkansas	2.6	3.4	97.7	0.36	New Hampshire	1.2	4.1	97.9	0.76
California	31.4	2.0	93.3	0.45	New Jersey	8.1	2.4	96.0	0.20
Colorado	3.9	4.7	96.0	0.68	New Mexico	1.7	4.9	95.9	0.55
Connecticut	3.4	2.7	95.9	0.25	New York	18.5	1.9	94.5	0.25
Delaware	0.7	3.8	97.0	0.47	North Carolina	7.6	3.3	95.3	0.34
Florida	14.6	4.0	95.6	0.86	North Dakota	0.7	3.8	94.8	0.88
Georgia	7.5	3.6	94.3	0.41	Ohio	11.2	1.9	96.7	0.26
Idaho	1.2	4.6	97.5	0.85	Oklahoma	3.4	3.6	95.6	0.82
Illinois	12.1	2.1	96.3	0.21	Oregon	3.2	3.5	97.8	0.62
Indiana	5.9	2.3	97.6	0.33	Pennsylvania	12.2	1.8	96.5	0.21
Iowa	2.9	2.5	97.7	0.46	Rhode Island	1.0	3.0	96.3	0.41
Kansas	2.6	3.8	95.7	0.22	South Carolina	3.8	3.4	95.9	0.26
Kentucky	3.9	2.9	96.2	0.27	South Dakota	0.7	3.6	96.9	0.49
Louisiana	4.4	2.7	96.0	0.95	Tennessee	5.4	3.2	97.5	0.31
Maine	1.2	2.8	96.3	0.37	Texas	19.6	2.7	93.9	0.54
Maryland	5.1	3.1	94.7	0.32	Utah	2.1	3.5	97.0	0.58
Massachusetts	6.2	2.3	94.8	0.30	Vermont	0.6	3.4	97.5	0.30
Michigan	9.6	1.7	95.9	0.34	Virginia	6.7	4.0	92.2	0.26
Minnesota	4.7	2.0	97.1	0.22	Washington	5.4	3.5	94.1	0.53
Mississippi	2.7	3.1	96.8	0.23	West Virginia	1.9	2.7	98.4	0.48
Missouri	5.4	2.8	97.1	0.23	Wisconsin	5.2	1.8	97.5	0.26
Montana	0.9	4.1	97.3	0.74	Wyoming	0.5	6.2	97.6	1.63

Notes: Table displays average population (in millions), the average migration rate, the share of internal migration in total migration, and the standard deviation across time of the net-migration rate. Time period: 1977-2014

Table A2: MIGRATION STATISTICS: CANADA

Province	pop	migr	dom	sd(netm)	Province	pop	migr	dom	sd(netm)
N'foundland & Labr	0.6	1.9	94.0	0.55	Ontario	11.0	1.3	44.6	0.33
P Edward Island	0.1	2.4	87.0	0.49	Manitoba	1.1	2.0	73.2	0.44
Nova Scotia	0.9	2.1	87.7	0.20	Saskatchewan	1.0	2.2	86.2	0.73
New Brunswick	0.7	1.9	90.1	0.22	Alberta	2.9	2.9	77.5	0.94
Quebec	7.2	0.8	47.8	0.28	Brit Columb	3.7	2.2	61.1	0.61

Notes: Table displays average population (in millions), the average migration rate, the share of internal migration in total migration, and the standard deviation across time of the net-migration rate. Time period: 1977-2014

Table A3: MIGRATION STATISTICS: EUROPE

Country	pop	migr	dom	sd(netm)	Country	pop	migr	dom	sd(netm)
Belgium	10.5	0.8	0.6	0.18	Malta	0.4	1.3	–	0.29
Bulgaria	7.8	0.2	0.7	0.01	Netherlands	16.0	0.5	0.3	0.06
Czech Republic	10.3	0.4	–	0.26	Austria	8.1	0.7	0.4	0.19
Denmark	5.4	0.7	0.4	0.09	Poland	38.4	0.6	–	0.06
Germany	81.8	0.5	0.3	0.23	Portugal	10.3	0.3	–	0.31
Estonia	1.4	–	–	–	Romania	21.4	0.9	–	0.28
Ireland	4.0	1.4	0.9	0.93	Slovenia	2.0	0.5	0.2	0.37
Greece	10.9	0.6	–	0.36	Slovak Republic	5.4	–	–	–
Spain	42.4	0.8	0.4	0.38	Finland	5.2	0.3	0.2	0.10
France	60.1	0.5	–	0.04	Sweden	9.0	0.6	0.3	0.19
Italy	57.8	0.3	0.2	0.20	United Kingdom	60.0	0.7	0.3	0.09
Cyprus	0.7	1.4	–	1.31	Iceland	0.3	1.3	1.1	0.58
Latvia	2.3	0.6	0.1	0.43	Norway	4.6	0.6	0.4	0.10
Lithuania	3.3	0.7	0.5	0.52	Switzerland	7.4	1.4	0.9	0.06
Hungary	10.2	0.3	–	0.07					

Notes: Table displays average population (in millions), the average migration rate, the share of internal migration in total migration, and the standard deviation across time of the net-migration rate. Time period: 1991-2014

Table A4: AVAILABILITY OF MIGRATION DATA: UNILATERAL

	Inflow			Outflow		
Country	NSO	Eurostat	Adj	NSO	Eurostat	Adj
Belgium	1960	2011	1.18	1960	2011	1.15
Bulgaria	2007	2007	1.00	2007	2012	1.00
Czech Republic	1991	2008	0.85	1991	2008	0.43
Denmark	1960	2008	1.31	1960	2008	1.29
Germany	1991	2009	1.88	1991	2009	2.80
Estonia	2004	-	-	2004	-	-
Ireland	-	1998	-	-	1998	-
Greece	-	1998	-	-	1998	-
Spain	1998	2008	1.25	1998	2008	0.92
France	-	2006	-	-	2006	-
Italy	1988	1998	0.99	1988	1998	0.97
Cyprus	-	1998	-	-	2002	-
Latvia	-	1998	-	-	1998	-
Lithuania	-	1998	-	-	1998	-
Hungary	-	2008	-	-	2008	-
Malta	-	2005	-	-	2006	-
Netherlands	1987	2009	1.24	1987	2012	1.04
Austria	1996	2007	1.51	1996	2007	1.76
Poland	-	2009	-	-	2009	-
Portugal	-	1998	-	-	1998	-
Romania	-	2008	-	-	2008	-
Slovenia	1961	2008	1.00	1961	2008	1.00
Slovak Republic	2004	-	-	2004	-	-
Finland	1980	1998	1.00	1980	1998	1.00
Sweden	1960	1998	1.00	1960	1998	1.00
United Kingdom	2000	1998	0.96	2000	1998	0.96
Iceland	1986	2009	1.31	1986	2009	1.41
Norway	1967	2008	1.11	1967	2008	1.44
Switzerland	1991	2011	1.17	1991	2011	1.00

Notes: Table displays the starting year for the unilateral migration data based on either the national definition (NSO) or the Eurostat definition (Eurostat). The adjustment factor, $adj^i_{i,j}$, is used to transform migration data based on national definitions into migration data based on the Eurostat definition. It is calculated as the ratio of migration data based on the national definition to migration data based on the Eurostat definition, averaged over all time periods where data from both sources overlap.

Table A5: AVAILABILITY OF MIGRATION DATA: BILATERAL

	Inflow			Outflow		
Country	NSO	Eurostat	Adj	NSO	Eurostat	Adj
Belgium	-	2011	1.18 (0.07)	-	2011	1.15 (0.05)
Bulgaria	-	2007	1.00 (0.00)	-	2012	1.00 (0.00)
Czech Republic	-	-	-	-	-	-
Denmark	1960	2008	1.38 (0.07)	1960	2008	1.21 (0.15)
Germany	1991	-	1.79 (0.11)	1991	-	2.46 (0.17)
Estonia	-	-	-	-	-	-
Ireland	-	2006	-	-	2006	-
Greece	-	-	-	-	-	-
Spain	1998	2008	0.97 (0.04)	1998	2008	0.32 (0.05)
France	-	-	-	-	-	-
Italy	1998	2008	0.97 (0.05)	1998	2008	0.92 (0.12)
Cyprus	-	-	-	-	-	-
Latvia	-	1998	-	-	1998	-
Lithuania	-	1998	-	-	2001	-
Hungary	-	-	-	-	-	-
Malta	-	-	-	-	-	-
Netherlands	1987	2009	1.35 (0.07)	1987	2012	1.22 (0.09)
Austria	1996	2007	1.49 (0.11)	1996	2007	1.85 (0.19)
Poland	-	-	-	-	-	-
Portugal	-	-	-	-	-	-
Romania	-	-	-	-	-	-
Slovenia	-	2008	1.00 (0.00)	-	2008	1.00 (0.00)
Slovak Republic	-	-	-	-	-	-
Finland	1980	1998	1.00 (0.00)	1980	1998	1.00 (0.00)
Sweden	1960	1998	1.00 (0.00)	1960	1998	1.00 (0.00)
United Kingdom	2000	1998	0.95 (0.14)	2000	1998	0.97 (0.04)
Iceland	1986	2009	1.34 (0.27)	1986	2009	1.72 (0.42)
Norway	1967	2008	1.12 (0.07)	1967	2008	1.29 (0.45)
Switzerland	-	2011	1.17 (0.05)	-	2011	1.00 (0.00)

Notes: See Notes to Table A4. The adjustment factor reported in the table is a simple average of adjustment factors across partner countries. The value in the parentheses is the standard deviation of the adjustment factor, $std\left(\frac{\tilde{v}^i_{i,j,s}}{v^i_{i,j,s}}\right)$, calculated over time for each partner country. It is then averaged across all partner countries. Germany: No bilateral data available in Eurostat. Italy: Bilateral data available in Eurostat starting in 2008. Spain: Bilateral data available in Eurostat for only some countries.

Table A6: ADDITIONAL MIGRATION STATISTICS EUROPE 2012

Country	Western Europe			Europe		
	Ave	In	Out	Ave	In	Out
Belgium	0.43	0.40	0.47	0.64	0.64	0.65
Denmark	0.36	0.33	0.40	0.59	0.59	0.59
Germany	0.29	0.24	0.42	0.56	0.65	0.47[a]
Ireland	0.28	0.32	0.25	0.56	0.57	0.54
Greece	–	–	–	0.63	0.63	0.63[a]
Spain	0.24	0.23	0.24	0.39	0.38	0.39
France	–	–	–	0.38	0.48	0.29[a]
Italy	0.23	0.09	0.70	0.48	0.35	0.62
Netherlands	0.38	0.35	0.42	0.60	0.60	0.61
Austria	0.30	0.27	0.36	0.63	0.66	0.60[a]
Portugal	–	–	–	0.64	0.61	0.66[a]
Finland	0.38	0.27	0.62	0.63	0.56	0.70
Sweden	0.36	0.29	0.50	0.51	0.44	0.58
United Kingdom	0.24	0.23	0.26	0.37	0.38	0.36[a]
Iceland	0.64	0.60	0.69	0.82	0.78	0.86
Norway	0.37	0.29	0.64	0.61	0.62	0.60
Switzerland	0.48	0.52	0.42	0.60	0.67	0.54
Average	0.36	0.32	0.46	0.57	0.57	0.57

Notes: Tables displays the shares of Western Europe and Europe in overall immigration (In) and emigration in 2012 by country. Western Europe encompasses EU15+EFTA less Luxembourg and Liechtenstein. Europe refers to EU27+EFTA+4 candidate countries in 2010 (Croatia, Turkey, Montenegro and Macedonia. For countries marked with [a], Europe refers to EU27 only. Values as reported by the country.

Table A7: REGRESSION: GROSS FLOWS

	United States		Canada		Western Europe	
β^{dest}	-4.45	-5.17	-6.89	-8.02	-3.19	-3.46
	(0.13)	(0.11)	(0.84)	(0.89)	(0.40)	(0.48)
β^{orig}	4.49	4.70	3.54	4.53	3.16	2.77
	(0.13)	(0.11)	(0.73)	(0.74)	(0.42)	(0.43)
β^{trend}	-0.04		-1.25		3.18	
	(0.03)		(0.13)		(0.23)	
State trend	No	Yes	No	Yes	No	Yes
$R^2_{partial}$	0.08	0.11	0.12	0.16	0.07	0.06
No. Obs.	85,700	85,700	3,420	3,420	5,537	5,537

Notes: Table displays the regression coefficient of the regression $100 * \log v^j_{i,t} = \beta_{ij} + \beta^{dest} u_{i,t} + \beta^{orig} u_{j,t} + \beta^{trend} t + \epsilon_{ij,t}$ (columns (1), (3) and (5). For columns (2), (4) and (6), we use state-specific time trends for both origin and destination: $100 * \log v^j_{i,t} = \beta_{ij} + \beta^{dest} u_{i,t} + \beta^{orig} u_{j,t} + \beta^{trend}_i t + \beta^{trend}_j t + \epsilon_{ij,t}$. Dependent variable: Log of gross migration (times 100). Independent variables: Unemployment rates (in percent). Time period: 1977 - 2014 for US and Canada, 1991 - 2014 for Western Europe. Standard errors are clustered at the pair level. Partial R^2 is calculated as one minus the ratio of the residual sum of square of the full model to the residual sum of square of the model without $u_{i,t}$ and $u_{j,t}$. It gives the share of the variation explained by $u_{i,t}$ and $u_{j,t}$ that cannot be explained by the fixed effects and the time trend.

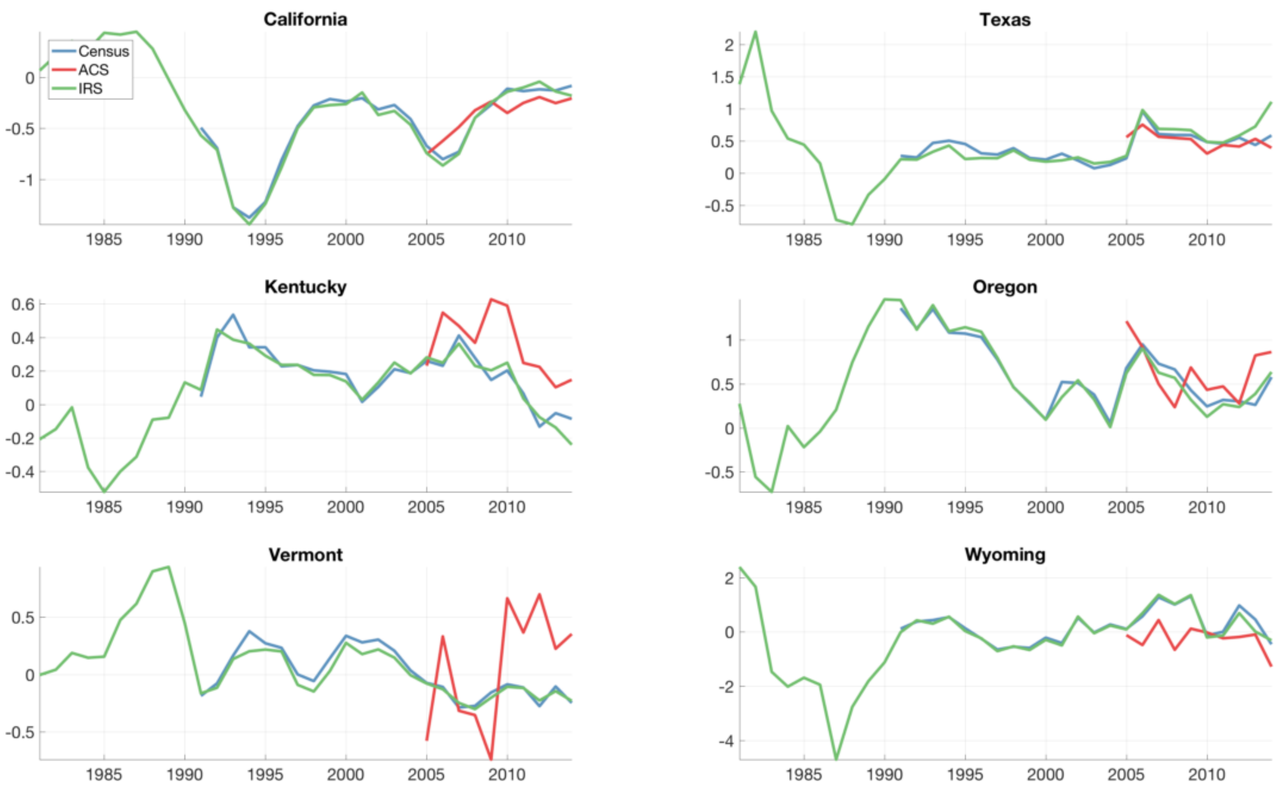


Figure A1: Internal Net Migration Rates in US States: Different Sources

Note: The figure displays internal net migration rates for six US States based on different data sources. Net migration rates are total immigration less total emigration divided by population.

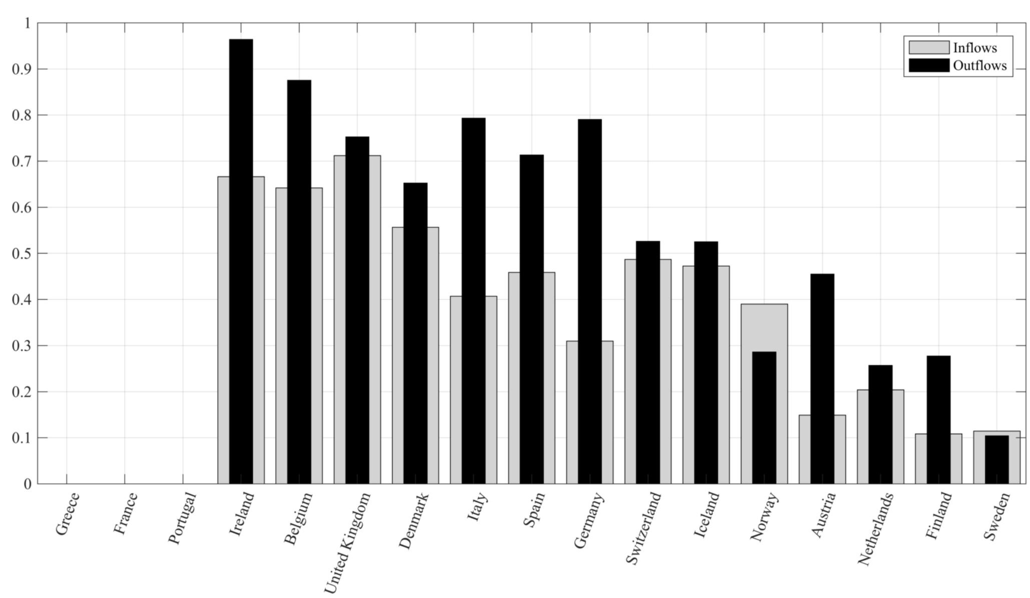


Figure A2: Estimated Standard Deviation of Reporting Error

Note: The figure plots estimates of the standard deviation of the reporting errors, σ_i and σ_j. Estimation of these standard deviations are explained in the Appendix section on reconciling bilateral data flows.

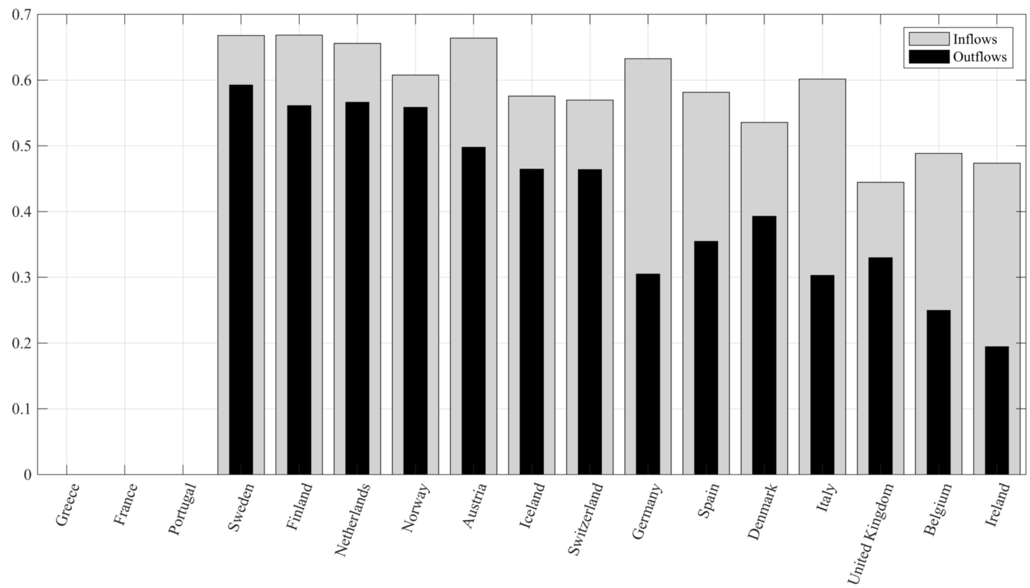


Figure A3: Average Weights for Reconciling Bilateral Migration Data

Note: The figure plots estimates of the weights $w_{i,j}$ used to reconcile bilateral data. The weights are simple averages across partner countries, $\frac{1}{N}\sum_j w_{i,j}$ for inflows of country i and $1 - \frac{1}{N}\sum_i w_{i,j}$ for outflows of country j. See the Appendix section on reconciling bilateral data flows for more information on how these weights are estimated.