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

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February 11, 2019

Abstract

Unemployment differentials between European countries are much greater than unemployment differentials between U.S. states. In both regions, net migration responds to unemployment differentials, though the response is smaller in Europe compared to the United States. Mundell (1961) argued that factor mobility is an important precondition for a successful currency union. This paper explores to what extent the relative lack of labor mobility in Europe makes macroeconomic stabilization more difficult in the euro area. We develop a multi-country DSGE model with cross-border migration and search frictions in the labor market. We use European migration data to estimate the model's structural parameters. The model allows us to quantify the benefits of increased labor mobility in Europe and to compare this outcome with a case of fully flexible exchange rates. Labor mobility and flexible exchange rates both work to reduce unemployment and per capita GDP differentials across countries provided that monetary policy is sufficiently responsive to national output.

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

JEL Codes: F22, F41, F45

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†We thank seminar participants at the University of Texas, the University of Lausanne, the University of Michigan, UCLA, UCSB, the Ohio State University, the Federal Reserve Bank of Dallas, the Department of the Treasury Australia in Canberra, the 2018 CEF conference in Milan, the 2018 SED conference in Mexico City, the 2018 NBER Summer Institute, the 2018 EEA conference in Cologne, the 2018 ABFER conference in Singapore, the 2018 ASSA conference in Atlanta. We thank Daniela Hauser, John Leahy, Matthew Shapiro, Andrei Levchenko, Loukas Karabarbounis, Helen Popper, Martin Berka and Bent Sorensen for their comments. We gratefully acknowledge financial support from the Michigan Institute for Teaching and Research in Economics (MITRE).

[The case] for flexible exchange rates [is] best if each nation (and currency) has internal factor mobility but external factor immobility. [If] factors are mobile across national boundaries then a flexible exchange system becomes unnecessary.'

– Mundell, Robert A. 1961. *A Theory of Optimum Currency Areas.*

1 Introduction

Unemployment differentials are much larger between countries in the euro area than they are between U.S. states. Figure 1 plots unemployment rates in 12 Western European euro area economies and 48 U.S. states between 1995 and 2015, together with the euro area and U.S. averages (the dark lines). Average unemployment in both the United States and Europe declined prior to the Great Recession and then increased by roughly 5 percentage points during the crisis. This similarity at the aggregate level, however, masks a tremendous amount of variation across countries in the euro area that is not observed across U.S. states. The cross-sectional standard deviation of unemployment, averaged over 1995-2015, is more than three times greater in the euro area (3.8 percent) than the United States (1.2 percent).

Large and persistent unemployment differentials within the euro area pose a significant risk to the currency union because a common monetary policy cannot be tailored to country-specific economic conditions. Mundell (1961) famously argued that factor mobility was a necessary pre-condition for an optimum currency area; in the face of a country-specific shock, factor inputs must adjust if relative prices cannot. Despite concerns about the extent of labor market integration in Europe, member states moved ahead with the adoption of the euro. In 2008, the global financial crisis and its asymmetric effects across Europe presented a challenge to the currency union. While the Euro survived, the question remains: are European labor markets flexible enough to adjust to macroeconomic shocks in the absence of independent, national monetary policies? If they are not sufficiently flexible, what is the cost of maintaining the currency union? Our main empirical finding is that net migration responds more to unemployment differentials in the United States compared to Europe. 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-country DSGE model that incorporates both a search and matching framework giving rise to unemployment, and a migration decision

that generates cross-border labor flows. We calibrate the model to the multi-country economy of Europe. The model reflects country size, migration patterns, trade, unemployment and currency regimes. We estimate the structural parameters of the model to match the empirical elasticity of net migration to unemployment in Europe.

The model allows us to evaluate Mundell's conjecture that factor mobility serves as a substitute for independent monetary policy in a realistic setting that reflects the actual economic conditions in Europe. In the spirit of Mundell (1961), we examine the responses to country-specific demand shocks that generate changes in the demand for labor. Our analysis suggests that, if the euro area had the same degree of labor mobility as the United States, the cross-sectional standard deviation in unemployment differentials across countries would fall by a quarter and would be accompanied by substantial increases in migration. Conversely, if the euro area had flexible exchange rates, there would also be a reduction in unemployment differentials though this would entail large changes in inflation rates across countries that may be difficult to tolerate in an integrated economy.

While the counterfactual unemployment rates are somewhat similar under high labor mobility and under flexible exchange rates, the mechanisms that achieve these outcomes are very different. In the first case – an environment with greater labor mobility – countries with high unemployment would experience labor outflows, which reduce unemployment and also reduce total production. In the GIIPS economies, the required outflow between 2008 and 2015 would have been more than 5 percent of the population, instead of the 1 percent outflow observed in the data. In the second case – flexible exchange rates – countries with high unemployment would cut interest rates and devalue their currency to stimulate the economy. Again the domestic unemployment rate would fall but this time would be accompanied by an increase in total production. As Mundell suggested, labor mobility and flexible exchange rates are substitutes along some dimensions – both reduce unemployment and wage differentials – but they differ along other dimensions – notably output and inflation.

Our model highlights the relative effectiveness of migration and monetary policy in response to shocks. Migration is most effective when wages are slow to respond to shocks and when the demand for a country's goods is inelastic. Monetary policy on the other hand, is most effective when the trade elasticity is high, consumers readily respond to changes in the real exchange rate and real wages adjust more quickly. Given the heterogeneity across European countries in their openness to trade and the flexibility of labor markets, national policy makers are likely to have conflicting views about the relative benefits of increased labor

mobility and adherence to a common monetary policy.

2 Related Literature

Our research relates to the classic literature on "optimal currency areas", dating back 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 on this topic. 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. Complementary to our work is Hauser and Seneca (2018) who show that a mobile labor force reduces the welfare costs of joining a monetary union. Relatedly, Mandelman and Zlate (2012) study the insurance role of remittances for consumption smoothing in an international business cycle model calibrated to the U.S. and Mexico. Their model abstracts from nominal rigidities, which play a key role in our analysis, and consequently does not address the issue of optimal currency areas. Our contribution to this literature is two-fold: First, our model clarifies settings that make labor mobility particularly powerful in reducing unemployment rate differentials, such as labor market frictions and low trade elasticities. Second, we provide a quantitative assessment of the benefits of labor mobility over the business cycle in a rich DSGE model.

Our work also relates to studies investigating different mechanisms in which trade and migration are interrelated (Davis and Weinstein, 2002; Burstein et al., 2017; Di Giovanni, Levchenko and Ortega, 2015; Caliendo, Dvorkin and Parro, 2015). For example, building on the quantitative trade literature for policy analysis, Caliendo et al. (2017) add migration to an Eaton-Kortum framework to study the welfare effects of the EU enlargement in 2004 for both low-skilled and high-skilled workers. They find large welfare gains for the new member countries, while the welfare gains are small for the old member countries, and even negative if the enlargement had not reduced trade barriers as well. While sharing some features with their model, our approach differs in that we focus on the interplay of migration and unemployment rates at business cycle frequency, as opposed to the effect of a permanent reduction in migration costs. Consequently, our model includes nominal rigidities, search and matching frictions in the labor market and international bond markets, which are all features that are

missing in Caliendo et al. (2017).

Our paper is not the first to empirically analyze the response of migration to labor market conditions. The seminal paper in this literature is Blanchard and Katz (1992) who estimate the joint behavior of employment growth, the employment rate and the participation rate in response to a positive region-specific labor demand shock in the United States. Using a VAR approach 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. Subsequent studies have documented a slight decline of interstate mobility since the early 90s in response to local labor demand shocks (Molloy, Smith and Wozniak, 2011; Dao, Furceri and Loungani, 2017; Kaplan and Schulhofer-Wohl, 2017; Yagan, 2014), similar to our results. Applying the Blanchard and Katz (1992) method to European data, Beyer and Smets (2015) report that in response to labor market shocks, migration reacts less than half as much in Europe, although the role of migration as an adjustment mechanism has become more important over time. See also Jauer et al. (2014). The low migration response in Europe has been confirmed by several studies (Decressin and Fatas, 1995; Huart and Tchakpalla, 2015) and is in line with our results. Our contribution to this literature is two-fold: First, we substantially increase the sample of European countries and gather new data on observed migration flows (as opposed to migration flows deduced from population movements). Our data indicate that the difference between the U.S. and Europe is even larger than estimated in Beyer and Smets (2015). Second, while the cited literature is mostly empirical, we use the estimated cyclical relationship between migration and unemployment as moments for the calibration and estimation of our DSGE model to quantify the effects of migration on economic outcomes under fixed and flexible exchange rates.

3 Empirical Analysis

3.1 Data

Geographical Coverage We analyze migration flows within three geographical areas: the United States, Canada and Europe. The sample for the United States consists of 48 states (excluding Alaska and Hawaii due to their geographical isolation). The Canadian sample includes all ten provinces. We consider two samples of European countries. Our first sample is a "narrow" set that includes only the twelve core euro area countries of Western Europe

(including Denmark whose currency is pegged to the euro during our sample period). These countries are a fairly homogenous group in terms of economic development and moreover they removed restrictions on labor mobility in the late 1980's to early 1990's.[1] Our second sample is a "wide" set which includes an additional 17 European countries. These additional countries are either part of the European Union or part of the European Free Trade Association, and liberalized cross-border labor flows somewhat later.[2]

Sample Period For the United States and Canada, our sample period is 1977-2015. The sample choice is governed by the lack of unemployment and migration data at the subnational level prior to the mid 1970's. For the European sample, we focus on 1995-2015. Before 1995, migration data is available only for a handful of countries and restrictions on labor mobility were still prevalent in a number of euro area countries.

Data Sources We collect data on population, unemployment rates and migration by state and by country. We follow the United Nations in defining a migrant as any person moving into or out of a country or state irrespective of their nationality or their country/state of birth. Data on annual, bilateral migration flows at the U.S. state level are provided by the Internal Revenue Service (IRS) and begin in 1975. Migration data are based on the the mailing addresses of tax returns and encompass all U.S. tax filers. Migration rates between states are measured as returns with changes of address from one state to another. We use the IRS data - as opposed to alternative sources used in the literature, such as the American Community Survey and the Current Population Survey - because the IRS data do not suffer from small sample sizes that could be problematic for measuring migration flows of small states.[3] Data on state population and unemployment rates are provided by the Bureau of Economic Analysis and the Bureau of Labor Statistics.

Data for Canadian provinces come from Statistics Canada. Migration data start in 1972 and unemployment data start in 1977.

[1]The "narrow" sample includes 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 Statistics Luxembourg.

[2]The "wide" sample includes all of the countries in the "narrow" sample plus Bulgaria, Czech Republic, Estonia, Cyprus, Latvia, Lithuania, Hungary, Malta, Poland, Romania, Slovenia, Slovak Republic, Sweden, United Kingdom, Iceland, Norway, and Switzerland.

[3]The IRS data are used by the U.S. Census to calculate state-level net migration rates since 1981. The U.S. Census adjusts the raw IRS data to account for households that do not file taxes. As discussed in the Appendix, these adjustments are rather small.

Data on migration in Europe are provided by both Eurostat and national statistical agencies. The underlying data sources vary across countries. Administrative data are used in countries where registration is mandatory (e.g., all Scandinavian countries); otherwise, survey data is used (e.g. in the UK). There are two complications associated with the European data. First, there are discrepancies in the definition of what constitutes a migrant prior to 2008. Second, for each country pair, we have two measures of in- and out-migration. We adjust the data to account for both features. Details on these adjustments are in Appendix A. Again, a migrant is defined by a change in residency. For instance, both a German and French citizen moving from France to Germany are counted as emigrants from France and immigrants to Germany. Our panel data for Europe are unbalanced, as displayed in Appendix Table A4. We have complete data for twelve countries. For another nine countries, data begin in 1998.[4] Data on unemployment rates are collected through national labor force surveys and reported by Eurostat.[5] The Appendix provides more details on data sources and the construction of the migration database for Europe.

Migration We begin by examining migration patterns in North America and Europe. As we will show, migration rates have been declining in the United States and have been gradually increasing in Europe. Despite these trends, there remains substantially more migration in the United States and Canada relative to Europe.

We define the gross migration rate as the average of inflows and outflows over one year divided by the population at the beginning of the year.[6] That is, the gross migration rate of country or state i at time t is

$$\text{Gross migration}_{i,t} = \frac{1}{2}\frac{\text{In-migration}_{i,t} + \text{Out-migration}_{i,t}}{\text{Population}_{i,t}}$$

where $\text{Population}_{i,t}$ is country or state i's population at the beginning of year t.

Table 1 reports migration rates for the the United States, Canada and the two European samples. In the table, migration rates are first averaged over time, and then averaged across countries (or states), using simple averages. The table shows that migration rates are sub-

[4]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

[5]Labor force surveys are harmonized across Europe and use the same definition of unemployment as in the United States.

[6]For the United States, 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 U.S. Census.

stantially higher in North America than in Europe. The U.S. gross migration rate is more than 3 percent while it is less than 1 percent in both European samples. Canadian migration is in between with a gross migration rate of 2 percent. These differences in migration rates could be due to geographical differences between the three regions. One might think that larger, more populous regions would have less cross-border migration than smaller regions. Table 1 shows that U.S. states are, on average, smaller in terms of population than European countries, which could explain the relatively low migration rates in Europe. Figure 2 shows that while countries or states with greater populations do have less migration, the U.S. rate remains substantially greater than the European rate even after controlling for population. In addition to country size, there are many additional possible explanations for the difference in migration rates between North America and Europe. Language, culture, institutional differences, and so forth, all present barriers to labor flows that could be greater in Europe relative to the United States and Canada. For instance, Beine, Bricongne and Bourgeon (2013) show that migration flows are by about 85 percent larger between countries that share the same language. In our analysis in Section 4 we are agnostic about the specific frictions that impede labor mobility. The purpose of the model is to capture the consequences of lower mobility in Europe abstracting from the underlying cause.

Figure 3 displays average gross migration rates for the United States, Canada and the two European samples plotted over time. Migration rates have been trending down in the United States and Canada (see Molloy, Smith and Wozniak, 2011). Since the mid-70s migration rates have fallen from 3.75 percent to 3 percent in the United States, and from 3.2 percent to 1.75 percent in Canada. In contrast, migration has gradually increased in Europe though the rate is still well below the U.S. rate. See Jauer et al. (2014) for a thorough analysis of migration patterns before and after the financial crisis.

Not all migrants moving to a U.S. state come from another U.S. state. We define the *internal* migration rate as the number of migrants from state i that come from or leave for another U.S. state, as a share of state i's total population. That is, internal migration for U.S. states excludes migration flows from or to areas outside the United States. Similar calculations are made for Canada and Europe.[7] Table 1 shows that almost all of the migrants in U.S. states come from other U.S. states; i.e., the difference between the gross migration rate

[7]For calculating internal migration we include migration to and from Alaska, Hawaii and Washington D.C. as internal to the United States. Similarly, we include all 29 European countries as internal migration in both the 'Europe' and 'Core euro area' cases.

and the internal migration rate is relatively small. In Europe (and Canada), the difference is larger reflecting the greater importance of external migration in those regions.

The last row in Table 1 reports the standard deviation of the *net* migration rate over time. The net migration rate is the difference between a state's total inflows and total outflows as a share of its population

$$\text{Net migration}_{i,t} = \frac{\text{In-migration}_{i,t} - \text{Out-migration}_{i,t}}{\text{Population}_{i,t}}.$$

Net migration includes all migratory flows (both internal and external to the region). Because, on average, overall net migration in the United States will be close to zero (each incoming migrant is another state's outgoing migrant), we report the standard deviation of net migration over time. The bottom row of Table 1 reports the standard deviation of net migration for the United States, Canada and Europe. Unlike the gross migration rates and the internal migration rates, which were substantially different between the United States and Europe, net migration rates are more comparable. The average across all states is 0.48 in North America, and about 0.3 in Europe. Net flows in Europe are therefore more than half as large as in North America, despite substantially lower gross flows. Countries in Europe therefore tend to experience either inflows or outflows of migrants, while these flows tend to cancel out in North America.

Unemployment Rates We now turn our attention to the difference in unemployment rates in the United States, Canada and Europe. As described below, we first de-mean unemployment rates in both the cross-sectional and the time dimension. This removes long-run average differences as well as common cyclical variations in unemployment rates. We apply a similar "double demeaning" procedure to the other variables below. We do this because many regions have persistently high (or low) unemployment rates and persistently high (or low) migration rates that are not related to the short-run business cycle adjustments that are the focus of our analysis. Double demeaning the data removes both the state average unemployment rate and the yearly national average unemployment rate. The double-demeaning procedure is similar to applying country and time fixed effects though there are small differences because our panel is not balanced and because we use a country-weighted average for the time fixed effect.[8] We use the same statistical procedure with the model generated data.

[8]Repeating our analysis with conventional state and time fixed effects yields virtually the same results.

Consider the unemployment rate for country i in Europe. A similar construction applies for a U.S. state or for a Canadian province. Let country i's unemployment rate at time t be $ur_{i,t}$ and let the long-run average unemployment rate in country i be $ur_i = \frac{1}{T}\sum_{t=1}^{T} ur_{i,t}$. The aggregate unemployment rate for Europe at time t is the population-weighted sum of countries' unemployment rates, $ur_t = \frac{1}{N}\sum_{i=1}^{N} \frac{pop_i}{pop} ur_{i,t}$, where N is the number of countries in the European sample, pop_i/pop is the share of country i's population in Europe. The average unemployment rate $\overline{ur}$ is simply the time series average $\overline{ur} = \frac{1}{T}\sum_{t=1}^{T} ur_t$. Then, the double-demeaned unemployment rate for country i is

$$\widehat{ur}_{i,t} = ur_{i,t} - ur_i - (ur_t - \overline{ur}). \tag{3.1}$$

Our empirical analysis centers on the properties of the unemployment rates $\widehat{ur}_{i,t}$. The rate $\widehat{ur}_{i,t}$ is an indication of whether country i's unemployment is high relative to its own long-run rate and relative to other countries' rates at a given point in time. In effect this captures the country-specific, cyclical component of a country's unemployment rate.

Figure 4 plots the standard deviations of the demeaned unemployment rates, together with their average over time, $\sum_t std\,(\widehat{ur}_{i,t})$. For the United States and Canada the standard deviation of unemployment rates is about 1. For the two European samples, the standard deviation is roughly 2.5. The earlier observation of greater unemployment rate dispersion in Europe relative to the United States (see Figure 1) is not driven by long-run differences across countries (or states), but remains even after removing country averages and common cyclical changes in unemployment. Unemployment rates were somewhat more dispersed in the U.S. during the early 1980's and in the Great Recession. Unemployment rates in Europe diverge particularly 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 persistence of unemployment differentials. Following Jordà (2005), we estimate a local projection of unemployment rates on their own lags. For each horizon h we estimate the following regression

$$\widehat{ur}_{i,t+h} = \beta_0^h \widehat{ur}_{i,t} + \beta_1^h \widehat{ur}_{i,t-1} + \beta_2^h \widehat{ur}_{i,t-2} + \epsilon_{i,t}^h \qquad \forall h = 0, 1, .., H \tag{3.2}$$

up to a nine year horizon $H = 9$. $\hat{\beta}_0^h$ is an estimate of the impulse response of unemployment rates to its own innovation at horizon h. The upper part of Figure 5 displays the estimated

coefficients $\hat{\beta}^h$ for the United States (a), Canada (b), Europe (c) and the euro area (d). The estimates show that unemployment rate differentials are persistent in all cases, but particularly so in Europe and the euro area. In response to an innovation of 1 percentage point, unemployment differentials initially rise by 0.5 to 0.8 percentage points in Europe and stay above 1 percent for 3 to 4 years.[9]

To summarize, this section has shown that (demeaned) unemployment rates are more dispersed across European countries than U.S. states and that this dispersion is quite persistent, especially in the euro area.

3.2 Unemployment Rates and Net Migration

We are particularly interested in the relationship between net migration flows and unemployment differentials and how this relationship differs across regions. To study this relationship we regress net migration on the unemployment rate as follows:

$$\widehat{nm}_{i,t} = \beta \widehat{ur}_{i,t} + \epsilon_{i,t}, \tag{3.3}$$

where $\widehat{ur}_{i,t}$ is the double-demeaned unemployment rate as defined in (3.1) and $\widehat{nm}_{i,t}$ is the double-demeaned net migration rate (calculated analogously). This specification, which focuses on demeaned variables, implicitly assumes that what matters for migration choices is a country's unemployment rate relative to the regional unemployment rate at a particular point in time.[10]

Table 2 displays the results of this regression and Figure 6a shows the scatterplot of the data. As before, the time period for the North American samples is 1977-2014, and 1995-2015 for the European samples. The U.S. coefficient is -0.27 with a standard error of 0.03 (Driscoll and Kraay (1998) standard errors are reported). Thus in years when a state has a 1 percentage point higher de-meaned unemployment rate, net migration falls by 0.27 percentage points. In other words, an increase of 100 unemployed workers in a state coincides with outmigration of 27 people from that state. These regressions are not meant to be interpreted

[9] In an earlier version of this paper, we estimated the AR(2) specification

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

The comparison of the Jorda projections with the parametric AR(2) representation is very similar.

[10] The relevance of *relative* unemployment rates is consistent with the DSGE model presented in the next section and the "gravity approach" that has been successfully used to describe trade flows (Anderson, 2011).

causally. Rather, we are simply documenting that periods with relatively high unemployment are associated with periods of net outmigration.

Panel (a) of Figure 7 displays the estimated β coefficients for the United States when we run regression (3.3) separately for all years in our sample. While there are year-to-year differences in the estimated slope coefficient, the yearly estimates are close to the estimate of -0.27 found for the full sample. Some papers have argued that migration played a minor role during the Great Recession compared to other recessions.[11] The estimated coefficients in Figure 7 suggest otherwise. In 2010 the estimated coefficient is $\hat{\beta} = -0.25$ (0.05), close to the coefficient estimated on the entire sample. One explanation for why we find an important role for migration 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 were also the most negatively affected states during the Great Recession. Their rise in unemployment coincided with reduced inflows of workers and therefore pushed their migration rates down to those observed in other states, flattening out the relationship between unemployment and net migration. Failure to control for long-run trends yields a coefficient of $\hat{\beta} = -0.05$ in 2009-2010 (see Figure 8).[12]

The relationship between unemployment rates and net migration is much smaller in Europe. 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)). Canada's coefficient ($\hat{\beta} = -0.23$ (0.02)) is closer to that of the United States.

So far, we have focused on the *contemporaneous* relationship between unemployment rates and net migration at an annual frequency. As we described above, unemployment rate differentials tend to persist over time. This is particularly true for Europe. One would therefore expect migration flows to persist as well, potentially resulting in substantial changes in regional populations. To quantify these population changes, we perform a local projection analysis by estimating the horizon-specific regressions

$$\widehat{nm}_{i,t+h} = \beta_0^h \widehat{ur}_{i,t} + \beta_1^h \widehat{ur}_{i,t-1} + \beta_2^h \widehat{ur}_{i,t-2} + \epsilon_{i,t}^h \qquad \forall h = 0, 1, .., H$$

[11] 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.

[12] Beraja, Hurst and Ospina (2016) find a slope of 0 rather than -0.05. This difference can be attributed to our use of IRS data instead of ACS data and that we focus on the unemployment rate instead of the employment rate.

with $H = 9$. The estimated coefficient β_0^h provides us with an estimate of the response of net migration to changes in unemployment rates at horizon h. Based on the estimated coefficients β_0^h, we can also calculate the implied cumulative population response at each horizon. The cumulative response is the change in population associated with the estimated migration flows (ignoring population changes due to birth and death).

The middle panels in Figure 5 show the estimated response of net migration over time to a 1 percentage point unemployment differential (i.e., the panels report the estimated coefficients $\hat{\beta}_0^h$ for each h). For the United States (column a), the net migration rate falls by a bit more than 0.25 percent. In the following year, net migration falls more, to roughly -0.3 percent. It takes 5 to 6 years to return to its mean, slightly before the unemployment rate differential dissipates. The lower row of panels in Figure 5 show the cumulative change in population implied by the net migration estimates. Following an increase in unemployment of 1 percentage point above its mean, a state's population falls by roughly 1.3 percent after five years, and remains below average for several years afterwards. This reduction in population is substantial and even exceeds the initial increase in the unemployment rate. It is conceivable that these migration flows have significant feedback effects and alter the response of macroeconomic variables over the business cycle.

Columns (c) and (d) of Figure 5 repeat the local projections for the European samples. The overall dynamics of migration flows are similar, but are clearly smaller than the U.S. reactions. The fall in population is only about one third of the response in the U.S. (-0.47 vs. -0.3). While the population response is somewhat stronger for the euro core area (-0.95), it is even more delayed (nine years) and its magnitude has to be interpreted against the backdrop of more persistent (the upper panel) and larger unemployment rate differentials (see Figure 4).

To summarize, we find that (i) Labor is less mobile in Europe relative to the United States. (ii) Unemployment differentials are larger and more persistent in Europe relative to the United States. (iii) Net migration reacts to regional differences in unemployment rates in both the United States and in Europe though the relationship is notably weaker in Europe. (iv) The implied changes in population are economically significant in both regions.

4 A DSGE Model with Cross-Country Labor Mobility

In this section, we develop a multi-country model with cross-border migration to analyze the tradeoff between labor mobility and exchange rate adjustment emphasized by Mundell. The distinctive features of the model are labor mobility across countries, unemployment, and 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 real economic activity. We introduce labor mobility in a tractable way which exploits 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).

4.1 Households

The world is populated by $i = 1, ..., \mathcal{N}$ countries. The number of households 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. 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 country of origin and subscripts to denote the current living and working place of members of a household.

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. Due to migration, the population of country i, denoted by $\mathbb{N}_{i,t}$, might differ from the number of household members who originate from country i, $\mathbb{N}^i$, and can be calculated as

$$\mathbb{N}_{i,t} = \sum_j n^j_{i,t} \mathbb{N}^j. \tag{4.1}$$

Household members supply a fixed amount of labor l_i in the country of their current residence, so that total labor supply in country i is simply equal to country i's population times l_i. Household members born in country i but who live in j consume country j's final good (their consumption is denoted $c^i_{j,t}$). These country-specific final goods cannot be traded. As described later, firms in every country produce the final good using combinations of tradable intermediate goods sourced from different countries. That is, production of the final

consumption good features home bias, so that the law of one price does not hold.

We implicitly assume that labor supplied by migrants and natives are perfect substitutes, similar to Mandelman and Zlate (2012). We think this is a reasonable assumption given the relative homogeneity of labor across Europe. The degree of substitutability of natives and immigrants is a subject of ongoing debate and varies depending on the region and time period under consideration (see e.g. Peri, Ottaviano et al., 2006; Borjas, Grogger and Hanson, 2008; Furlanetto and Robstad, 2017).

In addition to receiving utility from consumption, 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. Kaplan and Schulhofer-Wohl (2017), Sterk (2015) and the literature review in Redding and Rossi-Hansberg (2017)). 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 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 than for a Spanish one. We denote the utility gain from living in j for a household member from country i by A_j^i 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. 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. As the share of "expats" increases, less cosmopolitan household members move abroad decreasing the average utility gain per migrant. We formalize this idea by assuming that the average utility gain from living abroad—beyond utility differences due to different consumption levels—is $A_j^i - \frac{\ln(n_{j,t}^i)}{\gamma}$, which is decreasing in $n_{j,t}^i$ for $\gamma > 0$. (See the Appendix for a discussion of how one could micro-found this term.) 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 γ to match our empirical results on the relationship between migration flows and unemployment.

Taken together, the expected discounted sum of future household utility, as of date 0, is given by

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \sum_j n_{j,t}^i U(c_{j,t}^i) + \sum_{j \neq i} n_{j,t}^i \left(A_j^i - \frac{\ln(n_{j,t}^i)}{\gamma} \right) \right\}.$$

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

$$U(c^i_{j,t}) = \frac{\left(c^i_{j,t}\right)^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}},$$

where σ is the intertemporal elasticity of substitution.

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. We assume 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 originating from 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 origin 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, independent of their country of origin, whereas lump-sum taxes are levied on a country's household, independent of its members' current residence.[13]

Because wages and the returns to capital may be earned in different locations, the exchange rate will affect the real value of income and the cost of consumption. Let $S_{i,t}$ be the nominal exchange rate that converts country i's currency into a reserve currency, and define $S^j_{i,t} = \frac{S_{j,t}}{S_{i,t}}$ 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 $\sum_j S^j_{i,t} W^h_{j,t} n^i_{j,t} l_j$. Here, $n^i_{j,t} l_j$ describes the household's labor supplied in country j at time t. Labor is supplied inelastically by each household member. We allow for country-specific variation in labor force participation rates so the per capita labor supply l_i differs for each country. We calibrate these differences to match observed labor force participation rates.[14] Since labor is assumed to be uniform across countries, each worker is paid the same nominal wage $W^h_{j,t}$ irrespective of their country of origin.

In addition to labor income, households receive income from renting capital to firms.

[13] We discuss how these transfers and taxes are set in Section 4.3.

[14] Notice that we assume that when a worker moves, he or she adopts the labor force participation rate in the destination country.

Let $K_{i,t-1}$ denote the capital in country i at the beginning of period t, divided by country i's population in period $t-1$. Households can adjust the rate at which this capital stock is utilized, $u_{i,t}$, 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 $u_{i,t}K_{i,t}$ effective units of capital to intermediate-good-producing firms and earn a rental price of $R^k_{i,t}$ per effective unit of capital.

Households receive nominal profits $\mathbb{N}_{i,t}\Pi_{i,t}$ from firms as well as lump-sum nominal taxes or transfers $T_{i,t}$. In addition to $T_{i,t}$ we also include a set of constant location specific lump-sum transfers $\tau^j_i = c^j_i - w^h_i l^j_i$ to residents living abroad. These additional transfers are included to eliminate steady state income flows across countries in the steady state. We discuss this technical adjustment in greater detail in the Appendix. Households receive income from nominal bonds purchased in the previous period B^i_{t-1}. These bonds are denominated in the reserve currency; thus the income from bond holdings is $\frac{B^i_{t-1}}{S_{i,t}}$.

Households use the receipts to pay for consumption, $\sum_j S^j_{i,t}P_{j,t}n^i_{j,t}c^i_{j,t}$, invest in the capital stock of their country of origin, $\mathbb{N}_{i,t}P_{i,t}X_{i,t}$, purchase state-noncontingent bonds, $\frac{B^i_t}{(1+i_t)S_{i,t}}$, pay for utilization costs, $\mathbb{N}_{i,t-1}K_{i,t-1}P_{i,t}a(u_{i,t})$, and pay for any moving cost for members that migrate. Total moving costs for household i are $\sum_{j\neq i} S^j_{i,t}P_{j,t}n^i_{j,t}\frac{1}{1-\beta}\Phi\left(\frac{n^i_{j,t}}{n^i_{j,t-1}}\right)$. (Moving costs are in units of the final good of a migrant's destination country.) Similar to the restrictions on the investment adjustment cost function, Φ is convex with $\Phi(1) = \Phi'(1) = 0$, and $\Phi''(1) > 0$. Moving occurs within the period, so that migrants are immediately available for work in their new country of residence.

Households choose their members' locations $n^i_{j,t}$, consumption in each location $c^i_{j,t}$, 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 budget constraints[15]

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

[15]Because models with incomplete markets often have non-stationary equilibria, we impose a small quadratic penalty cost of holding claims on other countries. This cost implies that the equilibria is always stationary. For our purposes, we set the cost sufficiently low that its effect on the equilibrium is negligible. See Schmitt-Grohé and Uribe (2003) for a discussion of "closing" models in environments with incomplete markets. For clarity purposes, we abstract from these standard quadratic adjustment costs in the budget constraint.

the capital accumulation constraint[16]

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

and the constraint on total labor supply from country i

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

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 first-order condition for the location choice $n^i_{j,t}$ is[17]

$$\begin{aligned} U(c^i_{j,t}) - U(c^i_{i,t}) + A^i_j - \frac{1}{\gamma}\left(\ln(n^i_{j,t})+1\right) &= \left(c^i_{j,t} - w^h_{j,t}l_j - \tau^i_j\right)U^i_{1,j,t} - \left(c^i_{i,t} - w^h_{i,t}l_i - \tau^i_i\right)U^i_{1,i,t} \\ + \frac{1}{1-\beta}\left(\frac{n^i_{j,t}}{n^i_{j,t-1}}\left(\Phi^i_{j,t}\right)' + \Phi^i_{j,t}\right)U^i_{1,j,t} &- \frac{\beta}{1-\beta}\mathbb{E}_t\left\{\left(\frac{n^i_{j,t+1}}{n^i_{j,t}}\right)^2\left(\Phi^i_{j,t+1}\right)'U^i_{1,j,t+1}\right\}, \end{aligned} \tag{4.2}$$

where we have written $\Phi^i_{j,t}$ for $\Phi\left(\frac{n^i_{j,t}}{n^i_{j,t-1}}\right)$ and 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 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 spending and labor income. In addition, the move generates moving costs, captured by the Φ^i_j terms in period t and $t+1$.

The remaining first-order conditions are standard. The Euler equations associated with

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

[17] 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 lump-sum transfers, τ^i_j, as given.

the non-contingent bonds, B_t^i, require

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

The utilization choice requires the first order condition

$$r_{i,t}^k = a'(u_{i,t}),$$

where $r_{i,t}^k = \frac{R_{i,t}^k}{P_{i,t}}$ is the real rental price of capital. We assume that $a(1) = 0$ and $a'(1) = r_i^k$, so that $u = 1$ in steady state. The curvature parameter $a''(1) > 0$ governs the cost of changing utilization. The optimal choice for investment requires

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

where $\mu_{i,t}$ denotes the 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, the first order condition for $K_{i,t}$ implies that the shadow values $\mu_{i,t}$ satisfy

$$\mu_{i,t} = \beta\mathbb{E}_t\left\{\frac{U_{1,i,t+1}^i}{U_{1,i,t}^i}\left[u_{i,t+1}r_{i,t+1}^k + \mu_{i,t+1}(1-\delta) - a(u_{i,t+1})\right]\right\}.$$

4.2 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.

4.2.1 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

$$q_{i,t}(\xi) = Q_{i,t}\left(\frac{p_{i,t}(\xi)}{p_{i,t}}\right)^{-\psi_q}, \tag{4.3}$$

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,

$$p_{i,t} = \left[\int_0^1 \left(p_{i,t}(\xi)\right)^{1-\psi_q} d\xi\right]^{\frac{1}{1-\psi_q}}. \tag{4.4}$$

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 $W_{i,t}^f$ 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 (4.3) as given. These firms have a Cobb-Douglas production function

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

First-stage producers charge a markup for their products. The desired price naturally depends on the demand curve (4.3). 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,

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

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

$$MC_{i,t} = \frac{\left(W_{i,t}^f\right)^{1-\alpha} R_{i,t}^{\alpha}}{Z_{i,t}} \left(\frac{1}{1-\alpha}\right)^{1-\alpha} \left(\frac{1}{\alpha}\right)^{\alpha}.$$

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 (4.4), the nominal price of the tradable intermediate good evolves according to

$$p_{i,t} = \left[\theta^p p_{i,t-1}^{1-\psi_q} + (1-\theta^p)\left(p_{i,t}^*\right)^{1-\psi_q}\right]^{\frac{1}{1-\psi_q}}. \tag{4.5}$$

4.2.2 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

$$Y_{i,t} = \left(\sum_{j=1}^{\mathcal{N}} \left(\omega_{i,t}^{j}\right)^{\frac{1}{\psi_y}} \left(y_{i,t}^{j}\right)^{\frac{\psi_y - 1}{\psi_y}} \right)^{\frac{\psi_y}{\psi_y - 1}} \tag{4.6}$$

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. The weights $\omega_{i,t}^{j}$ for each country pair fluctuate around a long-run average $\bar{\omega}_i^j$. We require $\sum_j \bar{\omega}_i^j = \sum_j \omega_{i,t}^j = 1$. We calibrate the average values $\bar{\omega}_i^j$ to match average bilateral trade shares (see below). Demand for country-specific intermediate goods is given by

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

As we explain later, fluctuations in $\omega_{i,t}^{j}$ serve as the main forcing variables in our model.

4.3 Monetary Policy and Taxes

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 taxes and transfers. The lump-sum taxes and transfers ensure that the government budget constraint is balanced every period.

Monetary policy is conducted through a Taylor Rule of the form

$$i_{i,t} = \bar{\imath}_i + \phi_i i_{i,t-1} + (1 - \phi_i)\left(\phi_Q Q_{i,t} + \phi_\pi \pi_{i,t}\right), \tag{4.7}$$

where we assume the same reaction parameters ϕ_i, ϕ_Q and ϕ_π across all countries. In our setup, $Q_{i,t}$ corresponds to real GDP per capita and $\pi_{i,t}$ is the CPI-based inflation rate. 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 (4.7), with the exception that it reacts to GDP-weighted averages of innovations in GDP and inflation for the countries in the union.

4.4 Labor Market

The labor market is governed by a search-and-matching mechanism. For a worker to be employed by a sub-intermediate good firm they first have to be hired by an employment

agency. The employment agency hires unemployed workers at the real household wage $w^h_{i,t}$. The agency then uses the workers to search for vacancies. Vacancies are posted by human resource (HR) firms that pay a match wage $w_{i,t}$ for successful matches. The HR firms then supply matched labor services to the sub-intermediate good firms that pay the firm wage $w^f_{i,t}$. Below, we describe the labor market in greater detail, starting with the worker / employment agency side.

4.4.1 Value Functions

Workers: Workers can only find jobs through an employment agency. Employment agencies hire workers and try to match them with firms. At the beginning of every period t, the agencies pay workers the real wage $w^h_{i,t}$ regardless of whether they can match them or not. If the employment agency cannot immediately match the worker, the agency pays $w^h_{i,t}$, but it retains the unemployment benefit $b_i \geq 0$. If the employment agency matches the worker, the agency collects the real match wage $w_{i,t}$ paid by the HR firm. This match wage varies over time and is paid as long as the match survives. This setup guarantees that all workers receive the same wage, $w^h_{i,t}$, and therefore operates as an insurance mechanism against unemployment. Note that all 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

$$\mathcal{E}_{i,t} = w_{i,t} - w^h_{i,t} + (1-d)\beta \mathbb{E}_t \left\{ \Psi_{i,t+1} \mathcal{E}_{i,t+1} \right\}, \tag{4.8}$$

where $\Psi_{i,t+1} = \frac{u^i_{1,i,t+1}}{u^i_{1,i,t}}$ is household i's stochastic discount factor. With probability $1 - f_{i,t}$, the employment agency cannot match the job hunter. In that case, the employment agency receives only 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 the profit from hiring a job hunter, $\mathcal{H}_{i,t}$, must be zero in equilibrium. This implies

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

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.

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

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

We assume that HR firms have to incur a quadratic cost to adjust the number of posted vacancies, expressed in proportion to the per-period posting cost. HR firms choose the number of posted vacancies to maximize the discounted stream of expected net profits

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

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

$$\frac{\mathcal{V}_{i,t}}{\varsigma} = \Upsilon_{i,t} + \frac{V_{i,t}}{V_{i,t-1}}\Upsilon'_t - \beta\mathbb{E}_t\left\{\Psi_{i,t+1}\left(\frac{V_{i,t+1}}{V_{i,t}}\right)^2\Upsilon'_{t+1}\right\}, \tag{4.9}$$

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

4.4.2 Labor Flows and Matching

Every period, job hunters, $H_{i,t}$, are matched with vacancies, $V_{i,t}$. The number of unemployed at the end of the period is the labor force less the number of people employed. Recall that all variables in the model are in per capita terms so the number of job hunters in country i at time t is $\mathbb{N}_{i,t}H_{i,t}$ and the number of people unemployed is $\mathbb{N}_{i,t}\left[l_i - L_{i,t}\right]$. The total number of job hunters consists of three groups: (i) everyone who was unemployed at the end of the previous period, $\mathbb{N}_{i,t-1}\left[l_i - L_{i,t-1}\right]$, (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, $l_i\left[\mathbb{N}_{i,t} - \mathbb{N}_{i,t-1}\right]$. thus,

$$\mathbb{N}_{i,t}H_{i,t} = \mathbb{N}_{i,t-1}\left[l_i - L_{i,t-1}\right] + d\mathbb{N}_{i,t-1}L_{i,t-1} + l_i\left[\mathbb{N}_{i,t} - \mathbb{N}_{i,t-1}\right].$$

Note that a reduction in the labor force caused by out-migration, i.e. $l_i\left[\mathbb{N}_{i,t} - \mathbb{N}_{i,t-1}\right] < 0$, directly reduces the number of job hunters in country i. These workers enter their destination country as unemployed job hunters. That is, we assume that matched workers never directly exit the labor force.

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

$$M_{i,t} = \bar{m}H_{i,t}^{\zeta}V_{i,t}^{1-\zeta}$$

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

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

where $\lambda = \frac{V}{H}$ is the standard measure of labor market tightness. Similarly, the job filling rate is

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

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

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

Since the number of people unemployed at the end of the period is $\mathbb{N}_{i,t}\left[l_i - L_{i,t}\right]$ and the total labor force is $\mathbb{N}_{i,t}$, the unemployment rate is simply

$$ur_{i,t} = l_i - L_{i,t}. \tag{4.10}$$

4.4.3 Wage Rigidity

Following Shimer (2010), we introduce wage rigidity through backward-looking wage setting into the match wage $w_{i,t}$. Specifically, $w_{i,t}$, is a weighted average of the past match wage, $w_{i,t-1}$ and the current target match wage, denoted $w^*_{i,t}$.[18]

$$w_{i,t} = \theta^w w_{i,t-1} + (1-\theta^w) w^*_{i,t}. \tag{4.11}$$

The target wage, $w^*_{i,t}$, is determined through Nash bargaining. Given a match (indexed by ξ), the HR firm and the employment agency bargain over the target wage, say $w^*_{i,t}(\xi)$, taking the other variables in the economy as given. The target wage solves the Nash bargaining problem

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

where we write $\mathcal{E}_{i,t}\left(w(\xi)\right)$ and $\mathcal{J}_{i,t}\left(w(\xi)\right)$ to indicate that the value of this match (to both the HR firm and the employment agency) depends on the bargained wage. In what follows, we suppress the index ξ because in equilibrium, all matches result in the same wage. The worker's bargaining power is $\varrho \in (0,1)$. Differentiating the bargaining objective with respect to $w^*_{i,t}$ gives

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

Note that 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 (4.8). Similarly, $\mathcal{J}(w^*_{i,t}) = -w^*_{i,t} + w_{i,t} + \mathcal{J}(w_{i,t})$. Thus, the target wage satisfies

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

[18] See also Christoffel and Linzert (2005) for the same approach.

where we are writing $\mathcal{E}(w_{i,t}) = \mathcal{E}_{i,t}$ and $\mathcal{J}(w_{i,t}) = \mathcal{J}_{i,t}$. Combining this expression with 4.11 gives

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

4.5 Forcing Variables

To generate migration and unemployment as seen in the data, the model requires shocks that imply relative differences in cross-country labor demand. Purely aggregate shocks to the region as a whole will not have differential effects on wages and employment opportunities across countries. The forcing variables we consider are shocks to the preferences weights ($\omega^j_{i,t}$) in equation (4.6).[19] Specifically, we assume that, for each country-pair, $\omega^j_{i,t}$ is given by

$$\omega^j_{i,t} = \frac{\bar{\omega}^j_i \exp\left(\varepsilon^j_t\right)}{\sum_k \omega^k_{i,t}}.$$

The variables, ε^j_t, cause fluctuations in demand for country j's tradable intermediate good. These fluctuations can be interpreted either as changes in production technology or changes in consumer preference. This formulation ensures that even though preference weights fluctuate, they always sum to 1 for every final good producer, i.e. $\sum_j \omega^j_{i,t} = 1$ for all t. The shock ε^j_t is common to all countries that use goods from country j, including the country j itself.

These fluctuations formalize the idea of "terms-of-trade" shocks that Mundell (1961), McKinnon (1963) and Kenen (1969) considered in their early discussions of optimal currency areas.[20] The shocks follow an AR(1) process with persistence ρ,

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

4.6 Aggregation and Market Clearing

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

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

[19] See Itskhoki and Mukhin (2017) for a recent paper that uses similar shocks.

[20] Both Mundell (1961) and Kenen (1969) consider what they call a "productivity" shock. Their narrative emphasizes that this shock generates excess demand for the foreign product and excess supply of the domestically produced good and unemployment at home. Whether these follow from a productivity shock is debatable, but they are captured by a negative "terms-of-trade" shock in our model.

This is also equal to real aggregate GDP.[21] The market clearing condition for the tradable intermediate goods is

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

Final goods production is given by (4.6). The market clearing condition for the final good is

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

where

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

is aggregate consumption in country i. The labor market clearing condition is given by (4.10). Finally, the bond market clearing condition requires

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

4.7 Steady State

We solve the model by log-linearizing the equilibrium conditions around a non-stochastic steady state with zero inflation.[22] 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 real exchange rates, are unity in all countries. We then solve for the share of net exports in GDP, which depends on the trade preference weights, $\bar{\omega}_i^j$, and country size as 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. We recover the amenity values A_j^i by inverting the structural relationship describing the location choice, (4.2), which, in steady state, is given by

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

[21] This expression for aggregate production is accurate only to a first-order approximation. For additional discussion of this approximation see Galí (2008) and Woodford (2003).

[22] See the Technical Appendix for details on the calculation of the steady state.

Since steady-state values for c_j^i and l_j^i are independent of A_j^i, there is a direct one-to-one mapping of A_j^i to the migration shares n_j^i. We directly calibrate n_j^i to the data and adjust A_j^i accordingly. Given n_j^i and data on population, $\mathbb{N}_i$, we solve for the size of households, $\mathbb{N}^j$, from (4.1).

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

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

where we directly back out employment, L_i, from data on labor force participation, 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_i^h. Finally, we solve for the consumption values of migrants, c_i^j, by exploiting the risk-sharing condition, $c_i^j = c_j^j$, and solving the linear equation system

$$C_i\mathbb{N}_i = \sum_j n_i^j c_i^j \mathbb{N}^j = \sum_j n_i^j c_j^j \mathbb{N}^j.$$

4.8 Calibration and Estimation

The model is expressed at a quarterly frequency and calibrated to a European sample of 29 countries as well as a rest-of-the-world aggregate for the period 1995 - 2015. Appendix A 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 six parameters that are either new to our model or where we have little guidance from previous studies. Table 5 lists the parameter values used for our baseline calibration. We discuss the calibrated parameters below.

4.8.1 Calibrated Parameters

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 $\sigma = 0.5$.

Technology and Nominal Price Rigidity The elasticity of substitution between varieties is $\psi_q = 10$, implying a markup of roughly 11 percent, in line with studies by Basu and

Fernald (1995) and Basu and Kimball (1997) among others. We calibrate the curvature of the production function, α, to match the average labor income share, defined as $\frac{w^f L}{Q} = (1-\alpha)\frac{\psi_q - 1}{\psi_q}$.[23] Karabarbounis and Neiman (2013) report a labor income share for Germany of about 0.63 between 1975 and 2010. This corresponds to $\alpha = 0.30$. We set the depreciation rate to 0.021 for both samples, which implies an annual depreciation rate of 8 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.

We calibrate the Calvo parameter to roughly match observed frequencies of price adjustment in the micro data. Evidence on price adjustment in Europe suggests an average duration of prices of 13 months, which corresponds to $\theta_p = 0.77$ (Alvarez et al., 2006).

Trade and Country Size The trade elasticity ψ_y is set to 0.5. This is comparable to parameter values used in international business cycle models with trade. Using aggregate data Heathcote and Perri (2002) estimate an elasticity of $\psi_y = 0.90$ at quarterly frequency, whereas Backus, Kehoe and Kydland (1994) calibrate an elasticity of 1.5.[24] Firm-level estimates of short-run elasticities range from almost 0 in Boehm, Flaaen and Pandalai-Nayar (Forthcoming) to values closer to 1.5 in Cravino (2014) and Proebsting (2015). We consider a higher trade elasticity in the sensitivity analysis below.

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

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

To calibrate ω_i^j, we therefore rely on bilateral trade data. In particular, 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 $\mathbb{N}_i Y_i$. We adjust the weights to ensure that net exports are zero in steady state. The steady-state calibration is based on an average over the years 2000-2005. For the average European country in our sample, the import share is about 40 percent,

[23] Our model features several distinct wages. For the purposes of our calibration, we count any income generated by HR firms and employment agencies as labor income, so the relevant labor income is $w^f L$.

[24] Their model is calibrated to the U.S. They cite several studies that find lower elasticities for Europe.

Migration We back out the amenity values, A_j^i, from observed migration shares. To approximate the share of migrants in steady state, we use data from the U.N. database on migrant stocks (United Nations, 2017). The U.N. reports data on total migrant stocks by country of current residence and by country of origin at five-year intervals covering 1995 - 2015. From this data, we derive the share of people born in country i living in country j, n_j^i, for all European countries in our sample plus a rest-of-the-world aggregate. We then take an average across all reported time periods. The average share of people living abroad is 8 percent in our sample, substantially lower than the import share of goods and services (see Table 4). Given values for n_j^i and data on population, $\mathbb{N}_i$, we solve for the number of households originating in country j, $\mathbb{N}^j$, using (4.1).

Labor Market As discussed in the empirical section, data on unemployment rates in Europe are provided by Eurostat. Country-specific steady-state unemployment rates are measured as the sample averages, ur_i. The steady state unemployment rate is 8.5 percent for Europe. Similarly, we use sample averages to calibrate the labor supply l_i to observed ratios of labor force to population using data from Eurostat. The OECD publication "Benefits and Wages" reports official net replacement rates as a function of unemployment duration, previous income and a worker's famility situation. On average, the data suggest a replacement rate of about 0.59. That is, we set b_i to $0.59w_i$. We set the matching elasticity to 0.72. This value is the estimate reported by Shimer (2005), which he bases on U.S. data for 1951-2003 and is close to the estimates by Burda and Wyplosz (1994) for France, Germany and Spain. As is common in this literature, we set the household's bargaining power equal to the matching elasticity. For the job separation rate we follow Christoffel et al. (2009) who calibrate the quarterly separation rate in their search-and-matching DSGE model for the euro area to 6 percent. We set the vacancy cost to 0.004, which corresponds to the estimate by Shimer (2010) for the US and is only somewhat higher than the calibrated value for the euro area model in Christoffel et al. (2009). We impose a wage rigidity parameter of 0.9 per quarter, in accordance with Shimer (2010), but also consider lower degrees of wage rigidity in the sensitivity analysis. [25]

[25] 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). Christoffel and Linzert (2005) study values in the range of 0.90 to 0.97. Hall (2005) argues that a completely rigid real wage norm vastly increases the sensitivity of the standard search and matching model to shocks and can therefore help solving the "Shimer puzzle" (Shimer, 2005).

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. Countries changed monetary policy over the sample period, especially during the 1990s and with 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.[26] Some countries followed a peg with the euro over (most of) the data period.[27] The remaining countries follow an independent monetary policy. All monetary authorities follow a Taylor rule with $\phi_i = 0.75$, $\phi_{GDP} = 0.50$ and $\phi_\pi = 1.50$, which is in line with estimates reported by Galí and Gertler (1999).

4.8.2 Estimation

Given these parameter values, we estimate the remaining five parameters. These parameters describe 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 curvature of the investment adjustment cost function, Λ'', and the persistence of the shock process, ρ.

Our estimation procedure is as follows: Given a set of 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 (3.1) for every country.[28] We then calculate the following five moments from the model-implied data series and compare them to their counterparts in the data: (i) the OLS slope coefficient from regressing the net migration rate on the contemporaneous unemployment rate (see equation (3.3)), (ii) the OLS slope coefficient from a regression of net migration on the one-year-lag of the unemployment rate, (iii) the (annual) persistence of investment spending, (iv) the correlation between the date t net export to GDP ratio and date t GDP and (v) an autocorrelation of zero for the structural shocks ϵ_t^j.[29] We choose the five parameter values to minimize the squared difference between the model-implied moments and the actual moments taken from the data.

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

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

[28] 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.

[29] We double-demean our GDP and investment data by first linearly de-trending the log series and then removing a European-wide (weighted) average for every year. Net exports are calculated as real net exports over 2005 nominal GDP in the data and real net exports over steady-state GDP in the model.

Table 5 compares moments of the data with moments of the model. The second column of the table reports estimates for our baseline model specification as described in Table 5. The third column reports estimates for a high-trade-elasticity case and the fourth column reports estimates for a low-wage-rigidity case.

The migration propensity γ governs the long-run reaction of migration to labor income differentials across locations. The log-linearized first-order condition for migration (ignoring the short-run adjustment costs) from country i to country j is[30]

$$\tilde{n}^i_{j,t} = \gamma U^i_{1,i} \left[w^h_j l_j \tilde{w}^h_{j,t} - w^h_i l_i \tilde{w}^h_{i,t} \right]. \tag{4.12}$$

The term in brackets is the absolute difference in wage income in the two contries. The term $\gamma U^i_{1,i}$ is the semi-elasticity of migration to wage differentials. While the point estimate of γ is the same across countries, $U^i_{1,i}$ varies from one country to the next. Wealthy countries (e.g., Switzerland) have low values for the marginal utility of consumption while poor countries (e.g., Bulgaria) have much higher values. Thus, in the model, the migration elasticity varies across countries. In particular, people from poor countries should migrate much more than people from wealthy countries. (This seems to be borne out in the data.) The unweighted average value for $U^i_{1,i} w^h_i l_i$ is 1.6. Combining this average with our estimate for γ gives an average elasticity of approximately 8.1 meaning that a one percent change in wage income across two average countries implies roughly a 8.1 percent change in the migrant population in country j from country i.

The migration adjustment cost parameter Φ'' has a point estimate of 4.94 suggesting that migration reacts relatively slowly to changes in cross-country income differentials in the short-run. In contrast, the estimated vacancy adjustment cost Υ'' and the investment adjustment cost parameter Λ'' are both relatively low indicating that both the number of vacancies and the investment rate can react sharply to temporary changes in economic conditions. For the investment adjustment cost function, we estimate $\Lambda'' = 0.03$, which implies that a (permanent) one percent increase in Tobin's Q would cause current investment spending to increase by

[30] Up to a first order approximation, changes in consumption, c^i_j and c^i_i, drop out because consumption is chosen optimally in steady state. Similarly, since we assume that migrants are autonomous in steady state in the sense that they do not send income abroad / receive income from abroad, fluctuations in the marginal utility of consumption, $U^i_{1,i,t}$ and $U^i_{1,j,t}$, also drop out. Finally, notice that the Backus-Smith condition implies that the marginal utility of consumption is equalized across household members in steady state, $U^i_{1,i} = U^i_{1,j}$ (since all real exchange rates are set to 1 in steady state). See the Technical Appendix for more details on the derivation.

roughly 30 percent. This estimate is much lower than conventional estimates from closed-economy models for the United States (see e.g Christiano, Eichenbaum and Evans, 2005; Del Negro et al., 2013; Brave et al., 2012). The difference is likely due to the fact that our model features additional frictions to increasing production and investment and so does not rely on high adjustment costs to reduce investment fluctuations. To interpret the estimate of Υ'', notice that the log-linearized first-order condition for vacancy creation by the HR firms, (4.9), is

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

where $\mathcal{V}_t$ is the value of having an open vacancy. The term, $[\Upsilon'']^{-1}$ is the elasticity of vacancy creation to the value of having an open vacancy. Our estimate of $\Upsilon'' = 0.72$, implies that a temporary 1 percent increase in the value of a vacancy causes a $1/0.72 = 1.39$ percent increase in the number of posted vacancies. Finally, our estimate of the persistence of the shock process is $\rho = 0.983$ (quarterly). This estimate is close to the common calibration of productivity shocks in business cycle models.

The estimates in the baseline specification do not change dramatically in the High Trade Elasticity specification (column 3). The main difference arises with the estimation of the investment adjustment cost parameter (Λ'') which is somewhat greater when goods become more substitutable. If wages are assumed to be less rigid (column 4), the migration propensity (γ) is estimated to be smaller, meaning that migrants are less sensitive to wage differentials.

Model and Data Comparison The bottom sections of Table 5 report measures of model fit for both the targeted moments and selected non-targeted moments in the data, the baseline model and for two alternative specifications (high trade elasticity and low wage rigidity).

Since we have five parameters to estimate and five moments to match, we obtain a perfect fit for the targeted moments. The model does relatively well with the untargeted moments as well. The model matches the (annual) persistence of GDP ($\widehat{Q}_{i,t}$), but generates insufficient overall volatility in GDP in the cross section. One reason for this could be that our model does not include TFP shocks, which would generate additional fluctuations in GDP beyond movements in factor inputs. This could also explain why the (negative) correlation between the unemployment rate and GDP is stronger in the model than in the data. The model matches the persistence of GDP and consumption observed in the data almost perfectly. The degree of risk sharing, measured by the relative standard deviation of consumption to GDP,

is somewhat stronger in the model relative to the data, as is often observed in standard international business cycle models.[31]

5 Mundell's Tradeoff: Mobility vs. Flexible Exchange Rates

We next conduct a series of counterfactuals to evaluate Mundell's conjecture: that adjustment in the allocation of labor across countries can take the place of flexible exchange rates. To evaluate this issue we compare our benchmark model to two counterfactual simulations. The first simulation considers the effect of increased international labor mobility maintaining fixed exchange rates. The second simulation considers the effect replacing the common currency in the euro area with country-specific monetary policy and floating exchange rates. In each experiment, we hold the sequences of country-specific shocks (recovered in the estimation procedure) fixed while we change the model parameters. The country-specific shocks are essentially shocks to the demand for the local good, which in turn affect the demand for labor. The resulting changes in labor demand generate dispersion in unemployment rates and income across the currency union. As Mundell conjectured, one way to mitigate this dispersion is through the endogenous adjustment of labor supply, which entails the movement of workers across countries. Alternatively, central banks could use monetary policy and exchange rate adjustments to stimulate export demand.

We consider five measures of economic performance: the cross-sectional standard deviations of the unemployment rate, GDP (aggregate and per capita), net migration and inflation for the euro area. For each measure, we calculate the cross-sectional standard deviation in each year and then average across 1995-2015. Panel A of Table 6 reports results for the simulations with the baseline parameters. The table also reports the model-based slope coefficients from the regressions of the net migration rates on the unemployment differentials in the simulated data. The different counterfactual scenarios are listed in columns (2) through (5). Column (1) reports the empirical measures as observed in the actual data.

Because we recover country-specific shocks that perfectly reproduce the paths of unem-

[31] Our finding that the standard deviation of consumption exceeds the standard deviation of GDP in the data is partly driven by our sample composition that includes several emerging economies in Central and Eastern Europe. The standard deviation of consumption relative to output is often greater than 1 in less advanced economies (see e.g. Neumeyer and Perri, 2005).

ployment rates across countries, the standard deviation of unemployment differentials in the benchmark model is identical to the standard deviation in the data (2.38). While our estimation procedure matches the OLS slope coefficients of the net migration regressions for Europe, the estimated model does not produce as much variation in GDP, GDP per capita and inflation as observed in the data.

Column (3) shows the outcome when there is greater adjustment to local demand shocks through the reallocation of labor. For this simulation, we use the same shocks, but we set migration parameters to match U.S. migration rates. Specifically, we adjust the migration propensity parameter γ and the migration adjustment cost Φ'' to match the empirical values for the OLS slope coefficients from regressions of net migration on contemporaneous and one-year-lagged unemployment for the U.S. sample (-0.27 rather than -0.08 and -0.22 rather than -0.07). All other parameter values and the realizations of the underlying shocks, ϵ_t^j, are kept the same as in our benchmark.[32] Higher labor mobility reduces the cross-sectional standard deviation in unemployment rates from 2.38 to 1.79. Because labor now flows to economies where demand for the location-specific good is higher and out of countries where demand is low, output dispersion across countries increases. On the other hand, *per capita* output, which reflects both the change in local production and the change in the number of workers, is now more similar across countries (under the benchmark specification, the standard deviation of GDP per capita is 1.72 while in the high mobility scenario it is 1.33.) Not surprisingly, the cross-sectional variation in net migration rises substantially from 0.24 in the benchmark model to 0.64 in the high mobility case. Because the adjustment to demand shocks occurs through the adjustment in the supply of inputs, there is less variation in marginal costs and thus the dispersion in inflation rates across countries drops from 0.61 to 0.57.

Column (4) shows what would happen if labor were completely immobile in Europe. Had there been no migration in response to shocks, there would have been significantly more dispersion in unemployment and GDP relative to the benchmark. (Because workers stay in the same location, there is no distinction between GDP and GDP per capita.) This simulation suggests that although migration rates in Europe are low compared to the United States, the current degree of labor mobility in Europe *does* provide a significant mechanism for responding

[32]Higher labor mobility can also be modeled as a higher share of expats in the overall population in steady state, $\frac{\sum_{j \neq i} n_i^j}{\mathbb{N}_i}$. As discussed above, this share is substantially higher in the U.S. than in Europe. In our model, this share depends on both γ and the amenity values, A_j^i. We choose to keep the steady-state share of expats the same across experiments, i.e. as we change γ we implicitly adjust A_j^i. Conditional on matching the OLS slope coefficients for the U.S. it makes little difference whether A_j^i is adjusted or not.

to country-specific shocks.

We now consider a counter-factual under which migration in the euro area remains at its observed level but countries can respond to regional shocks by allowing the exchange rate to adjust. When countries pursue independent monetary policy, changes in the exchange rate mitigate the impact of local demand shocks. However, whether the monetary authority responds aggressively to such demand shocks depends on whether it is willing to tolerate inflation to achieve output stability. We consider two monetary policy rules. The first (column 5) is a standard Taylor rule. This rule places relatively more weight on inflation than output. The second rule (column 6), is a Taylor rule in which output and inflation are weighted equally by the monetary authority. Under the first rule (column 5), flexible exchange rates allow the central bank to reduce unemployment differentials relative to the benchmark model (from a standard deviation of 2.38 in the benchmark to 1.98). Similar to the high mobility case, flexible exchange rates result in a substantial reduction in cross-country deviations in GDP per capita (from 1.72 in the benchmark to 1.36). Because the monetary authority places a significant weight on inflation stabilization, this scenario actually features a substantial decline in the inflation differential across countries.

In the case where the monetary authority focuses equally on inflation and output (column 6), there is a greater reduction in unemployment differentials but there is more dispersion in inflation. Indeed, the dispersion in inflation increases nearly three-fold. Thus, many of the benefits of greater factor mobility (here captured by changes in labor migration) can be achieved by independent monetary policy but only at the cost of greater inflation variability.

The results from the counterfactual simulations demonstrate that migration can be as effective as independent monetary policy in reducing cross-sectional variation in unemployment. The relative effectiveness of exchange rate adjustment and labor mobility depends, however, on underlying parameter values that determine the responsiveness of labor demand and labor supply. A negative demand shock puts downward pressure on real wages, employment and output. Migration magnifies the drop in output and employment but limits the drop in wages as workers flow from areas of high unemployment to areas of low unemployment. An exchange rate devaluation also limits the decline in real wages by supporting demand for the home good but alters relative prices. The extent to which exchange rate adjustment is effective as a substitute for migration depends on the elasticity of demand for the home good and the degree of price and wage rigidity. Monetary policy is most effective if the trade elasticity is relatively high (so that consumers readily substitute between home and foreign goods) and if prices are

relatively sticky (so that the change in the exchange rate is not fully passed through to prices). Alternatively, migration is most effective if wages are sticky (so that migration does not lead to higher wages at home) and / or the trade elasticity is low (so that despite higher wages and hence prices, consumers do not switch towards foreign goods).

To see this point, Panel B in Table 6 repeats the simulations when the trade elasticity (ψ_y) is increased from 0.5 to 1.5. When we change the trade elasticity, we re-estimate the parameters of the model. The estimates for the high trade elasticity case are listed in Table 5. Turning to the results in Table 6, we see that with a higher trade elasticity, shifting from the benchmark specification to higher labor mobility yields a smaller reduction in unemployment dispersion (column (2) versus column (3)). On the other hand, flexible exchange rates result in a much greater reduction in unemployment dispersion (column (2) versus column (5)).[33] A similar finding can be observed in Panel C of Table 6, where we repeat the simulations for a lower wage rigidity ($\theta_w = 0.75$ instead of 0.90). Again, labor mobility is somewhat less effective in reducing unemployment differentials, whereas flexible exchange rates are somewhat more effective.

The intuition for these results is straightforward: In response to a negative demand shock, migration limits the drop in wages. This wage "increase" (relative to a no-migration benchmark) translates into higher prices and hence less demand for the domestically produced good. As a result, although migration directly reduces unemployment, lower demand partially offsets this effect. Sticky wages limit price increases and keep demand high. Similarly, a low trade elasticity prevents demand from falling by limiting the degree to which consumers switch away from the domestic good in response to higher prices. Conversely, exchange rate policy generates large changes in relative demand when the trade elasticity is high and consumers are more sensitive to changes in the real exchange rate.

Another way to compare flexible exchange rates with high labor mobility is to examine the actual paths of economic variables over time under different scenarios. Figure 9 shows time series plots of the unemployment rate differentials, population (i.e., cumulative net migration calculated as $\sum_{s=1}^{t} \widehat{nm}_{i,s}$), and inflation for two country subgroups. The left panels show the paths for the GIIPS countries while the right panels show the corresponding paths for the countries in the EU10.[34] Each pair of panels corresponds to a different variable and

[33] In results not reported here, we observe that the cross-sectional standard deviation of the unemployment rate increases to 2.06 if we assume a trade elasticity of $\psi_y = 5$ (compared to 2.00 for $\psi_y = 1.5$).

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

within each panel we report the actual data (the solid line), the benchmark model (the filled dotted line), the high mobility case (the dashed line) and the flexible exchange rate case (the light dotted line). All series are double demeaned. For this comparison, monetary policy is "aggressive" in the sense that the Taylor rule places equal weight on GDP and inflation.

The top panels show the unemployment rates. The paths of unemployment rates for the data and the baseline calibration perfectly overlap by construction. In the figure, prior to the onset of the Great Recession in 2007-08, unemployment was relatively low in the GIIPS countries and somewhat high in the EU10 countries. The situation reversed sharply following the recession. According to the model, if labor mobility in Europe were as high as it is in the United States, the unemployment rates would have been substantially less divergent both before and after the recession. Prior to the recession, workers would have stayed in the GIIPS countries but after the recession began, the worker outflow would have increased unemployment in the EU10 but reduced unemployment in GIIPS. The paths for these country groups is similar under flexible exchange rates. Both mechanisms – flexible exchange rates and labor mobility – serve to temper differential unemployment rates, partially vindicating Mundell's claim that labor mobility can operate as a substitute for floating exchange rates.

The middle panels show the change in population (cumulative net migration). In the baseline model and the model with flexible exchange rates, the population time series is similar to the path observed in the data. The similarity is particularly striking given that net migration in the model almost exclusively reacts to changes in average household wages, which reflect both the wage earned by employed workers and the probability of being unemployed. 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. The model matches quite well the timing of the reversal in 2009 about three years after the reversal in unemployment rates. (Key for this delayed response is the moving cost parameter Φ''.) With high labor mobility (the dark dashed line), the model predicts sizable changes in population in the two regions. The bottom panels show inflation. Under flexible exchange rates, the model generates sharp changes in inflation, particularly in the GIIPS subgroup.

To summarize, flexible exchange rates and labor mobility have similar implications for the paths of unemployment over time. However, greater labor mobility entails significant reallocation of population, much larger than has been experienced in Europe. On the other hand, flexible exchange rates entail greater dispersion in inflation rates.

As a final comparison of flexible exchange rates and labor mobility, Figure 10 shows how

the cross sectional standard deviations of unemployment, GDP, GDP per capita and inflation vary as we smoothly transition from our benchmark specification to higher labor mobility or more flexible exchange rates. Every dot or cross corresponds to a separate experiment. For the solid dots, we slowly adjust the migration parameters γ and Φ'' from their benchmark values to the high-labor-mobility values used in column (3) of Table 6. The horizontal axis is the weight set on the high-labor-mobility value, so the dot furthest to the left corresponds to the baseline case and the dot furthest to the right corresponds to the high-labor-mobility case. The crosses show outcomes as we smoothly transition from a completely fixed exchange rate to a purely floating exchange rate. For intermediate cases, we assume the central banks follow a hybrid monetary policy that puts some weight on a fixed nominal exchange rate as opposed to a country-specific Taylor rule.[35]

The left panels in the figure show that the cross-sectional dispersion in unemployment and GDP per capita both steadily drop as we gradually go from our baseline case (shown as the large black dot on the vertical axis) to either fully mobile labor (the "+" marks) or to a fully flexible exchange rate (the solid circles). For these two measures of economic activity, Mundell's conjecture is accurate – exchange rate flexibility and labor mobility serve as substitutes in the sense that they have the same effects. The right panels show the cross-sectional dispersion in aggregate GDP and inflation. For these measures, increases in labor mobility and increases in exchange rate flexibility are clearly not the same. As labor becomes more mobile, the dispersion in aggregate GDP rises. In contrast, as we shift towards more and more independent monetary policy dispersion in aggregate GDP falls. Again, this is to be expected. Allowing factors of production to flow across borders exaggerages regional demand shocks. Counter-cyclical monetary policy tempers such shocks. Inflation variability doesn't change as factors flow from one country to the next but it does change with independent monetary policy. Once a central bank is allowed to pursue its own domestic agenda, it can trade off inflation variability for stable output or vice versa.

[35]More precisely, let x denote the weight depicted on the x-axis, then for the blue dots, the migration parameters are

$$\gamma = (1-x)\gamma_{bench} + x\gamma_{hlm}$$
$$\Phi'' = (1-x)\Phi''_{bench} + x\Phi''_{hlm},$$

where *hlm* indicates the high-labor-mobility value. Similarly, for the red crosses, the monetary policy rule follows

$$(1-x)\Delta E_{i,t} + x\left[i_{i,t} - \bar{\imath}_i - \phi_i i_{i,t-1} - (1-\phi_i)\left(\phi_Q Q_{i,t} + \phi_\pi \pi_{i,t}\right)\right] = 0.$$

6 Conclusion

Euro area countries experienced vastly different paths of unemployment over the last ten years, raising concerns about whether sharing a common monetary policy is sustainable without further reforms. In this paper, we return to Mundell's claim that cross-country labor mobility can substitute for independent monetary policy. To evaluate his claim, we first empirically examine whether labor mobility is indeed low in Europe, using the U.S. as a benchmark. The data paint a very clear picture: Migration flows react to cyclical variations in unemployment rates in Europe and across U.S. states, but this reaction is faster and about three times larger in the United States.

Motivated by these facts we then quantify the benefits of higher labor mobility in Europe in a multi-country New Keynesian dynamic general equilibrium model that we augment to include cross-country migration and a search- and matching-framework in the labor market that gives rise to unemployment. The model is calibrated to match the main features of the European countries in our dataset including country size, trade flows and exchange rate regimes. As a driving force the model features shocks to the demand for countries' goods. We choose the realizations of these shocks so that the model-generated unemployment series matches observed unemployment rates. Our model replicates the low degree of labor mobiity in Europe and broadly matches the dynamic behavior of macro variables observed in the data.

We then use the model to simulate outcomes in Europe with higher labor mobility or with flexible exchange rates. In line with Mundell's conjecture, greater labor migration and exchange rate adjustment both reduce the cross-sectional dispersion in unemployment and per capita GDP. However, the two counterfactual scenarios differ along other dimensions. The movement of labor results in higher aggregate output in locations with high demand and further reduces output in locations with low demand, resulting in widening output disparities across Europe. In contrast, exchange rate flexibility works to offset fluctuations in demand and thereby reduces aggregate output differentials at the expense of greater inflation dispersion. While the theoretical arguments underpinning Mundell's tradeoff have been understood since its original publication, our analysis provides a quantitative assessment based on observed trade patterns, existing monetary policy and measured differences in labor mobility in Europe today. Based on our findings, Europe is still many steps away from meeting the conditions of an optimum currency area.

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Table 1: 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
Net migr rate (std dev)	%	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 2: UNEMPLOYMENT RATES AND NET MIGRATION

	US	CAN	Europe	Euro
β	-0.272	-0.231	-0.081	-0.090
	(0.029)	(0.019)	(0.009)	(0.009)
R^2	0.26	0.26	0.28	0.51
No. Obs.	1,872	390	460	224

Notes: Table displays the regression coefficient of the regression (3.3). Time period: '77-'15 for US and Canada, '95-'15 for Europe. Driscoll and Kraay (1998) standard errors in parentheses.

Table 3: Calibration

Parameter		Value	Target / Source
Preferences			
Discount factor	β	0.99	4% real interest rate
Coefficient of relative risk aversion	$\frac{1}{\sigma}$	2	Standard value
Technology & Nominal Rigidities			
Curvate of production function	α	0.30	Labor income share of 0.63 for Germany (Karabarbounis and Neiman (2013))
Depreciation rate	δ	0.021	Annual depreciation rate of 8 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)
Sticky price probability	θ_p	0.77	Price duration: 13 months (Alvarez et al., 2006)
Trade and Country Size			
Trade demand elasticity	ψ_y	0.5	e.g. Heathcote and Perri (2002), Boehm, Flaaen and Pandalai-Nayar (Forthcoming)
Trade preference weights	ω_i^j	x	Share of imports from j; OECD TiVA (2000, 2005)
Country's absorption	$\mathbb{N}_n Y_n$	x	Nominal GDP; Europe: Eurostat (2005)
Migration			
Population	$\mathbb{N}_i$	x	Europe: Eurostat ('95-'15)
Amenity value	A_i^j	x	Share of people from j living in i, United Nations (2017) ('95-'15)
Labor Markets			
Unemployment rate	ur	x	Eurostat ('95-'15)
Labor force	l	x	Eurostat ('95-'15)
Separation rate	d	0.06	Christoffel et al. (2009)
Matching elasticity to tightness	ζ	0.72	Shimer (2005), Burda and Wyplosz (1994)
Bargaining power of workers	ϱ	0.72	Same as matching elasticity
Unemployment benefits	b/w	0.59	Net replacement rate, OECD "Benefits and Wages" database
Vacancy cost	$\frac{\varsigma V_i}{Y_i}$	0.004	Shimer (2010)
Real wage rigidity	θ_w	0.90	Shimer (2010)
Fiscal and Monetary Policy			
Gov't purchases over final demand	$\frac{G_i}{Y_i}$	x	Eurostat ('95-'15)
Taylor rule persistence	ϕ_i	0.75	Clarida, Gali and Gertler (2000)
Taylor rule GDP coefficient	ϕ_Q	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. TiVA: Trade in Value Added Database.

Table 4: STEADY-STATE

Country	GDP	Import share	Population	Expat share	Unemployment	Country	GDP	Import share	Population	Expat share	Unemployment
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	319.1%	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 expat share is the share of nationals living abroad. The average import share and migration share are calculated based on the 29 European countries.

Table 5: Estimation

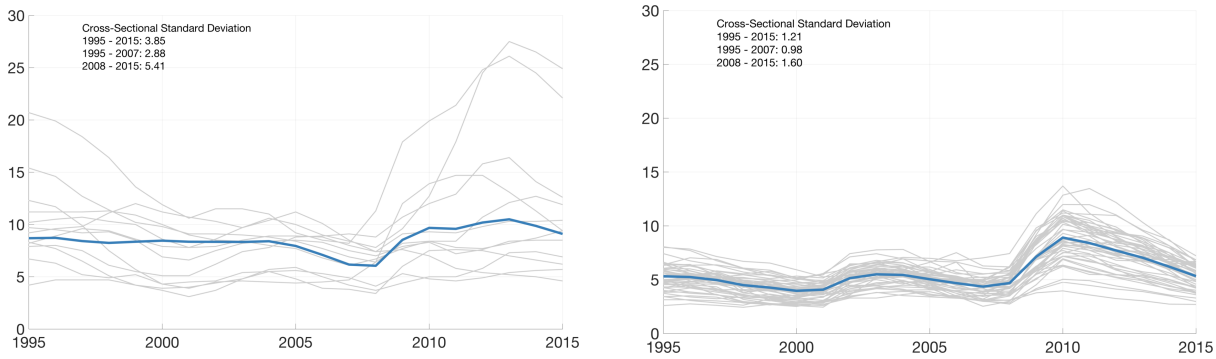
		(1) Data	(2) Base-line	(3) High trade elasticity	(3) Low wage rigidity
Calibrated Parameters					
Trade elasticity	ψ_y		0.500	1.500	0.500
Wage rigidity	θ_w		0.900	0.900	0.750
Estimated Parameters					
Migration propensity	γ		5.102	5.525	3.620
Migration adjustment cost	Φ''		4.637	4.995	4.406
Shock persistence	ρ		0.983	0.986	0.982
Vacancy adjustment cost	Υ''		0.724	0.715	0.862
Investment adjustment cost	Λ''		0.029	0.052	0.020
Targeted Moments					
Slope coefficient $\widehat{nm}_{i,t}$ on $\widehat{ur}_{i,t}$		−0.081	−0.081	−0.081	−0.081
Slope coefficient $\widehat{nm}_{i,t+1}$ on $\widehat{ur}_{i,t}$		−0.074	−0.074	−0.074	−0.074
Correlation $\frac{\widehat{nx_{i,t}}}{Qi,t}$ and $\widehat{Q}_{i,t}$		−0.303	−0.303	−0.303	−0.303
Persistence ϵ_t^j		0.000	−0.000	0.000	0.000
Persistence $\hat{X}_{i,t}$		0.671	0.671	0.671	0.671
Free Moments					
Std. dev. $\widehat{Q}_{i,t}$		3.540	1.752	1.789	1.790
Std. dev. $\widehat{C}_{i,t}$ rel. to std. dev. $\widehat{Q}_{i,t}$		1.365	0.784	0.744	0.811
Persistence $\widehat{Q}_{i,t}$		0.712	0.706	0.718	0.707
Persistence $\widehat{C}_{i,t}$		0.750	0.747	0.739	0.751
Correlation $\widehat{C}_{i,t}$ and $\widehat{Q}_{i,t}$		0.735	0.800	0.854	0.766
Correlation $\widehat{ur}_{i,t}$ and $\widehat{Q}_{i,t}$		−0.587	−0.861	−0.861	−0.861

Notes: Target refers to data moments for the European sample. $nm_{i,t}$ refers to net migration as percent of population, ur denotes the unemployment rate, $\frac{nx}{Q}$ is net exports over GDP, ϵ refers to the exogenous shocks, X is per capita real investment, C is per capita real consumption and Q is per capita real GDP.

Table 6: COUNTERFACTUAL EXPERIMENTS FOR THE EURO AREA

	(1) Data	(2) Estimated Model	(3) High labor mobility	(4) No labor mobility	(5) Flexible exch rate	(6) Aggr flex exch rate
Panel A: Simulations with Baseline Parameters						
Cross-Sectional Standard Deviation						
Unemployment rate	2.38	2.38	1.79	2.80	1.98	1.79
GDP	4.09	2.19	2.44	2.83	1.98	1.91
GDP per capita	3.74	1.72	1.33	2.83	1.36	1.24
Net migration	0.36	0.24	0.64	0.00	0.24	0.23
Inflation	1.66	0.61	0.57	0.66	0.29	1.06
Slope Coefficient on Unemployment Rate						
Net migration	−0.08	−0.08	−0.27	−0.00	−0.08	−0.08
Panel B: Simulations with High Trade Elasticity						
Cross-Sectional Standard Deviation						
Unemployment rate	2.38	2.38	2.00	2.52	1.83	1.57
GDP	4.09	2.23	2.83	2.58	1.93	1.82
GDP per capita	3.74	1.75	1.38	2.58	1.33	1.20
Net migration	0.36	0.24	0.70	0.00	0.23	0.21
Inflation	1.66	0.60	0.61	0.59	0.32	1.01
Slope Coefficient on Unemployment Rate						
Net migration	−0.08	−0.08	−0.27	−0.00	−0.08	−0.08
Panel C: Simulations with Low Wage Rigidity						
Cross-Sectional Standard Deviation						
Unemployment rate	2.38	2.38	1.86	2.74	1.86	1.67
GDP	4.09	2.22	2.53	2.85	1.99	1.95
GDP per capita	3.74	1.76	1.35	2.85	1.33	1.24
Net migration	0.36	0.24	0.65	0.00	0.24	0.23
Inflation	1.66	0.64	0.60	0.70	0.26	0.96
Slope Coefficient on Unemployment Rate						
Net migration	−0.08	−0.08	−0.27	−0.00	−0.08	−0.08

Notes: Table displays several statistics as observed in the data (1995 - 2015) and various model settings. Statistics are calculated for the euro area. For the High Labor Mobility case (column (3)) we adjust the migration parameters (γ and Φ'') to match the slope coefficients for the United States. For the Flexible Exchange Rate case (column (5)), countries follow a Taylor rule with $\phi_i = 0.75$, $\phi_\pi = 1.5$ and $\phi_Q = 0.5$. For the Aggressive Flexible Exchange Rate case (column (6)), we increase ϕ_Q to 1.5.



(a) Euro area (b) U.S.

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

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

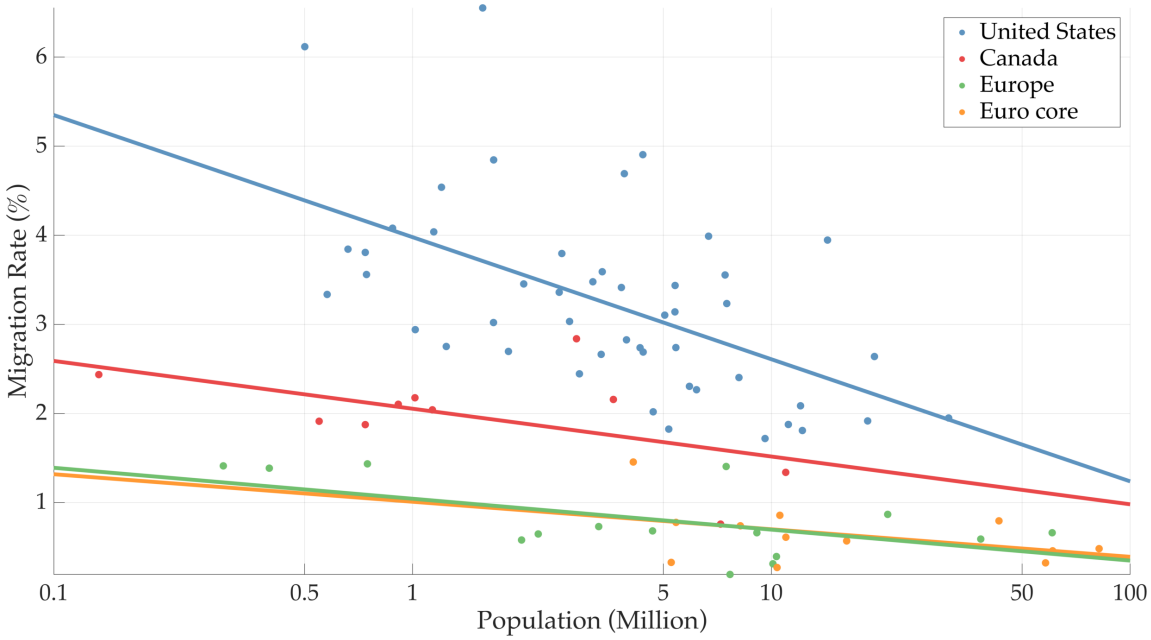


Figure 2: Migration Rates vs. Population

Note: The figure plots the migration-to-population ratio against population for US States, Canadian Provinces, European and core euro area countries. Migration is measured as the average of immigration and emigration. Values are averages over 1995 - 2015. The 'core euro area' sample is a subset of the 'Europe' sample.

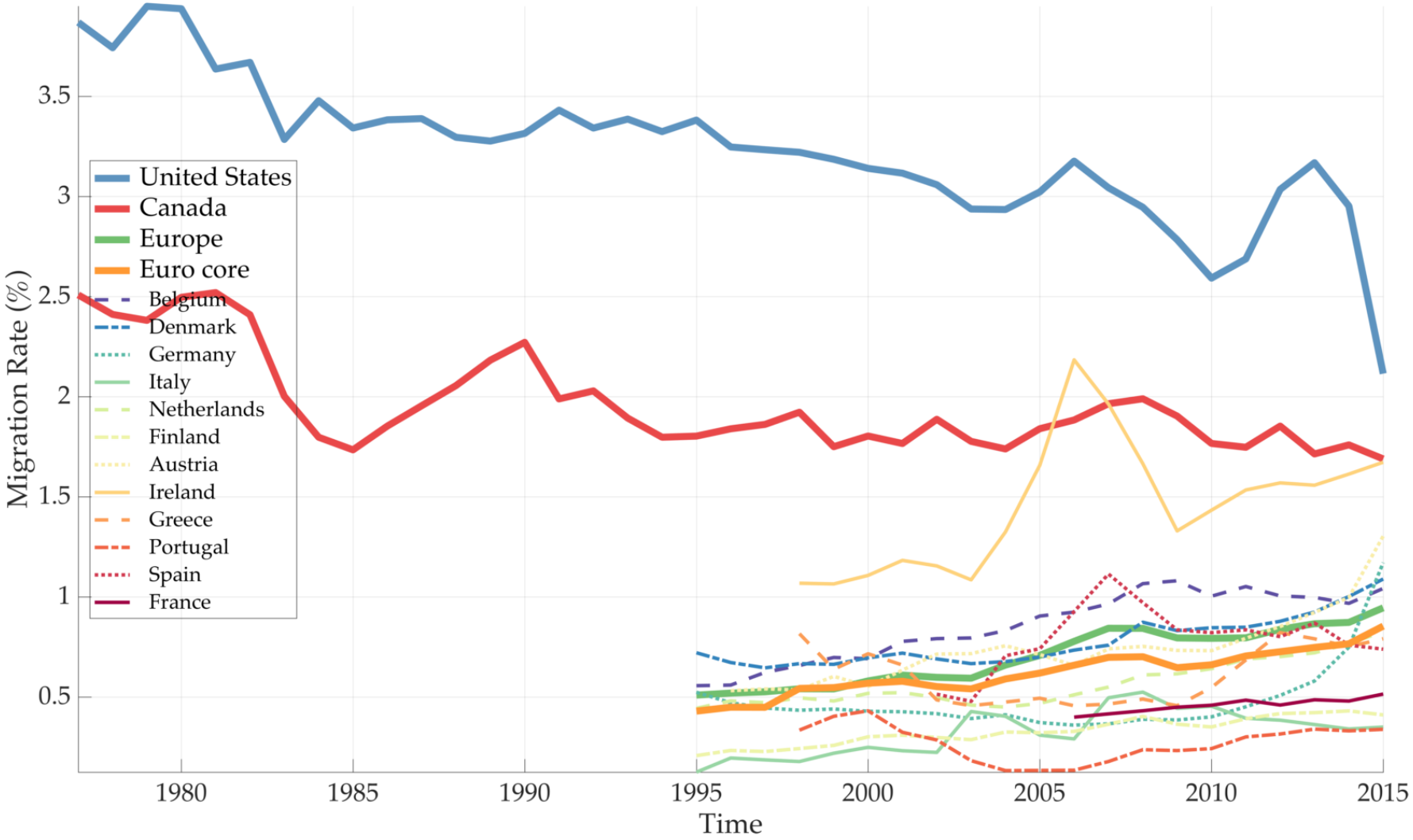


Figure 3: Migration Rates over Time

Note: The figure plots the migration-to-population ratio over time for the average of US States, the average of Canadian Provinces, the average of European countries, the average of core euro area countries and individual core euro area countries. The averages for the two European samples are averages over all countries with available data in any given year.

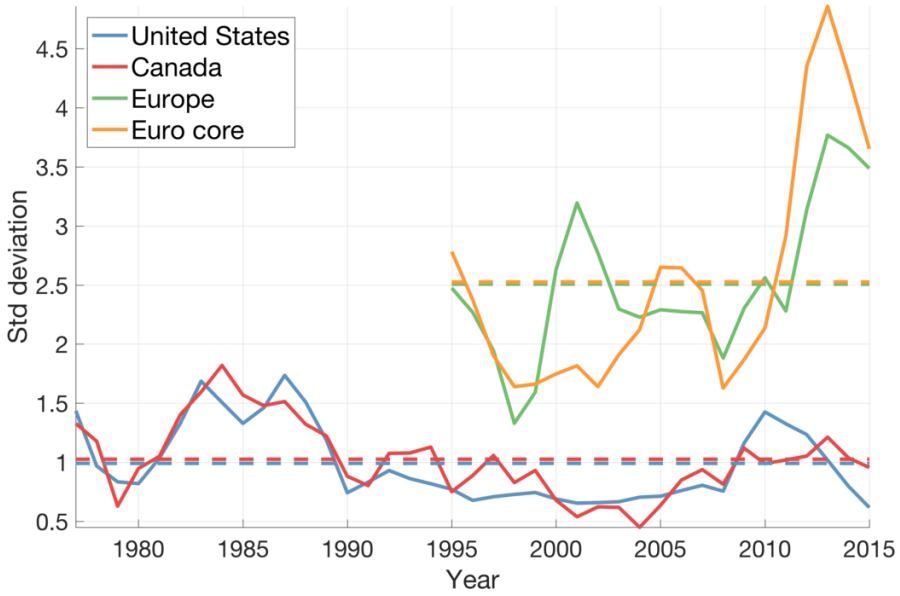
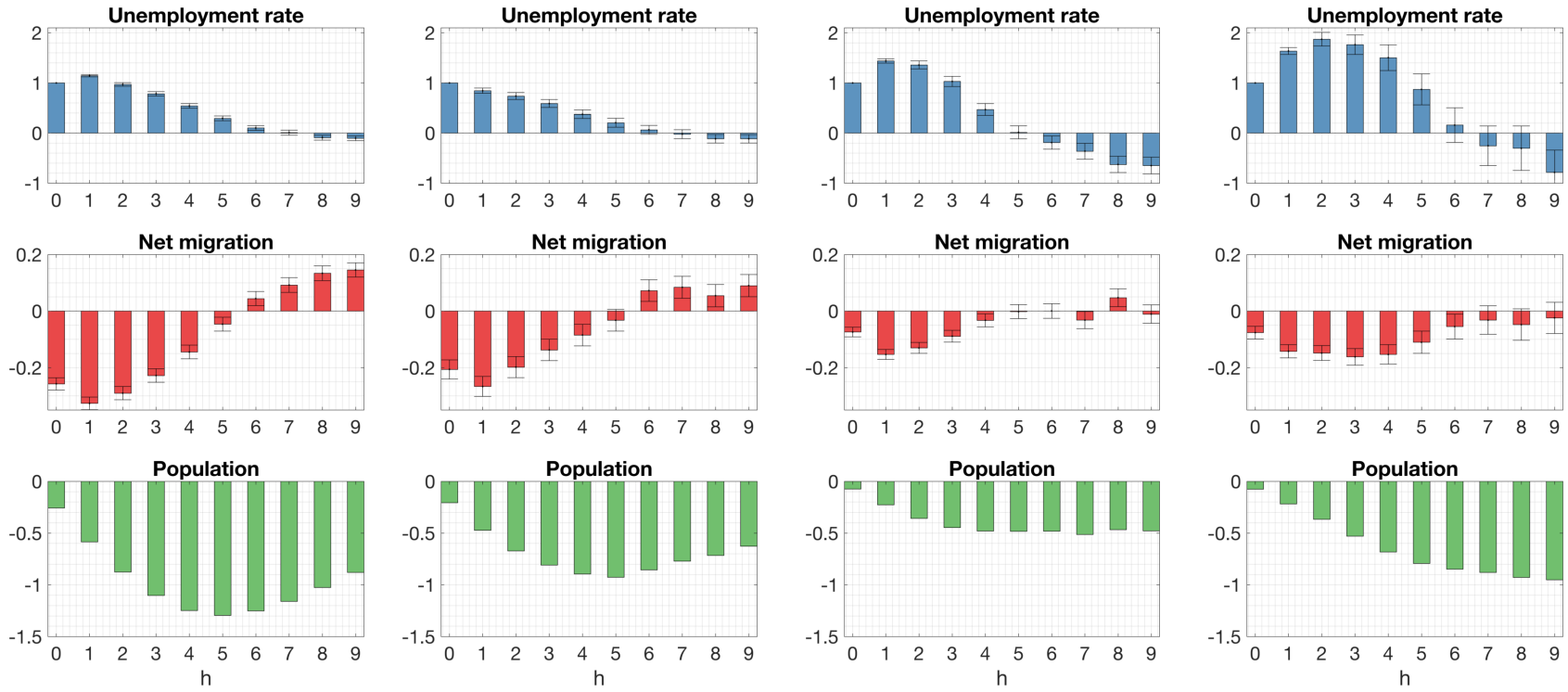


Figure 4: Cross-Sectional Standard Deviations in Unemployment Rates

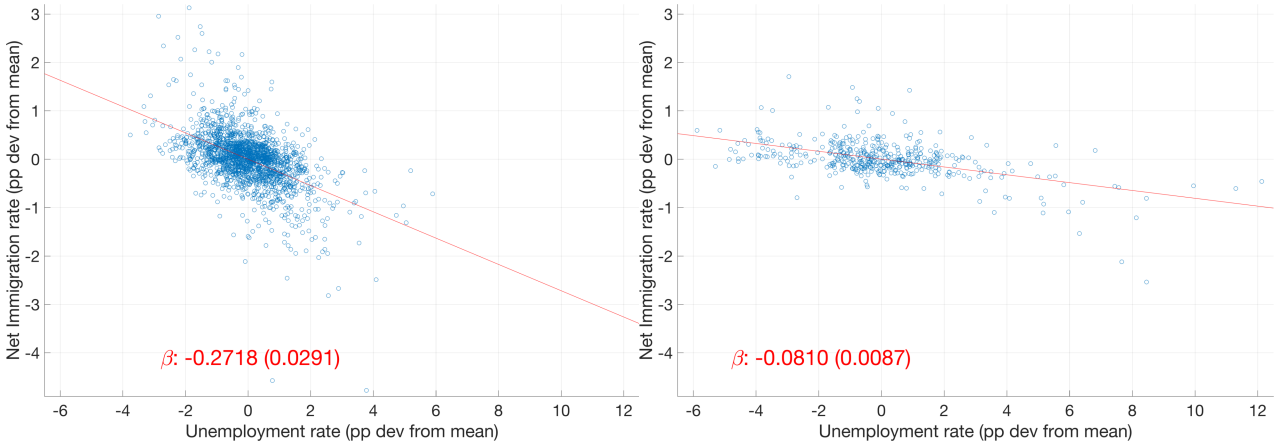
Note: The figure plots cross-sectional standard deviation in demeaned unemployment rates, $\widehat{ur}_{i,t}$, for four regions: US states, Canadian provinces, European countries and core euro countries. The dotted lines are the respective time averages. See the text for the definition of demeaned unemployment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



(a) U.S. (b) Canada (c) Europe (d) Euro core

Figure 5: Local Projections

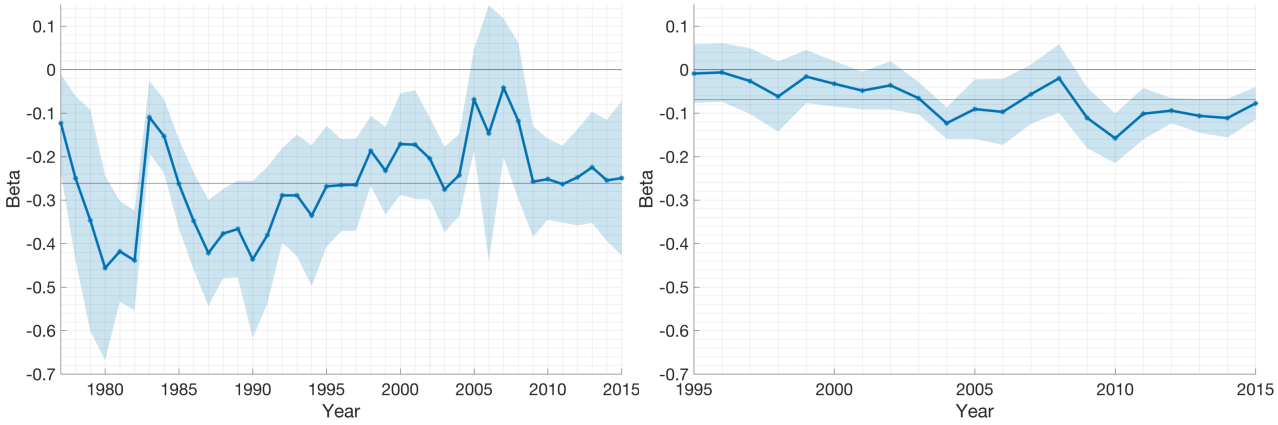
Notes: Figure displays the estimated coefficients (and standard errors) from local projection regressions (see equation (3.2)) for the U.S. (panel (a)), Canada (panel (b)), Europe (panel (c)) and the Euro core (panel (d)). The first set displays the coefficients from regressing the demeaned unemployment rate at time $t+h$, $\widehat{ur}_{i,t+h}$, on the demeaned unemployment rate at time t, $\widehat{ur}_{i,t}$ controling for two lags $\widehat{ur}_{i,t-1}$ and $\widehat{ur}_{i,t-2}$. The second set regresses the demeaned net migration rate at at time $t+h$, $\widehat{nm}_{i,t+h}$, on the demeaned unemployment rate at time t, $\widehat{ur}_{i,t}$ controling for two lags $\widehat{ur}_{i,t-1}$ and $\widehat{ur}_{i,t-2}$. The estimated population response at horizon h is calculated from the estimated coefficients as $\left(\sum_{k=0}^{h}(1+\beta_0^k)\right)-1$ of the net migration regression.



(a) U.S.: 1977 - 2015 (b) Europe: 1995 - 2015

Figure 6: Net Migration Rate vs. Unemployment Rate

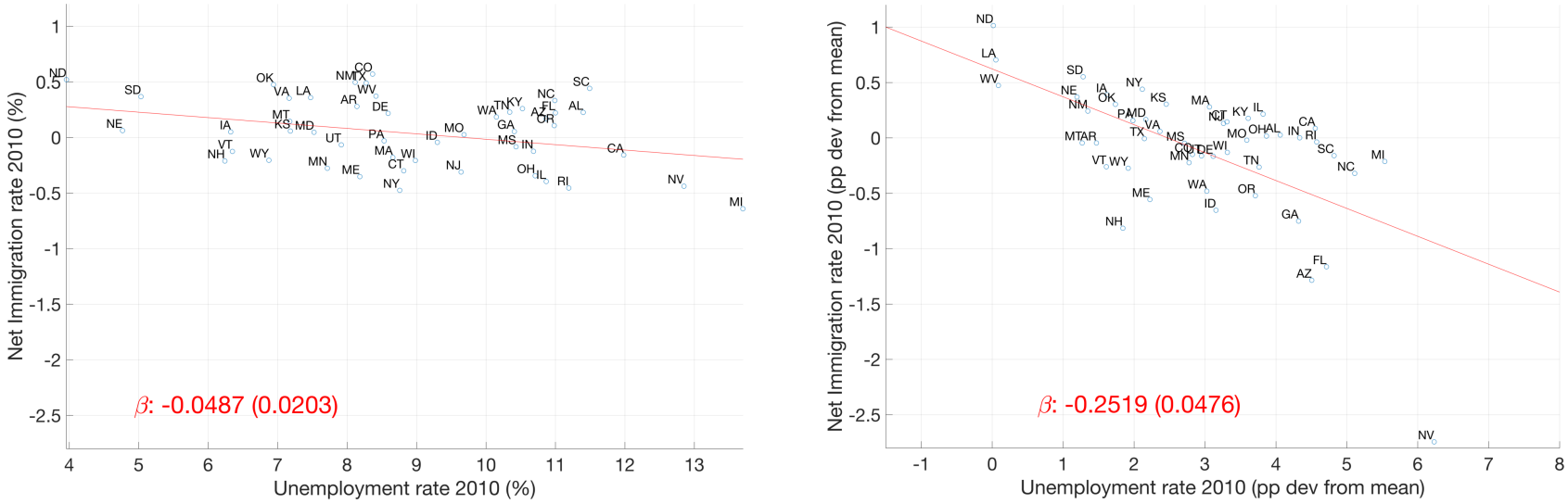
Note: The first panel plots the demeaned state net migration rates $\widehat{nm}_{i,t}$ for the U.S. against the demeaned state unemployment rates $\widehat{ur}_{i,t}$ over 1977 - 2015. The second panel plots the corresponding data for the European countries, 1995 - 2015. Driscoll and Kraay (1998) standard errors in parentheses.



(a) U.S.: 1977 - 2015 (b) Europe: 1995 - 2015

Figure 7: Net Migration Rate vs. Unemployment Rate: Repeated Cross Sections

Note: The figure displays the coefficients from regressions of demeaned state / country net migration rates vs. demeaned state / country unemployment rates (see equation (3.3)). Every coefficient corresponds to a single year. Confidence intervals are $\hat{\beta} \pm 1.96\widehat{stderr}$, where standard errors are regular standard errors.

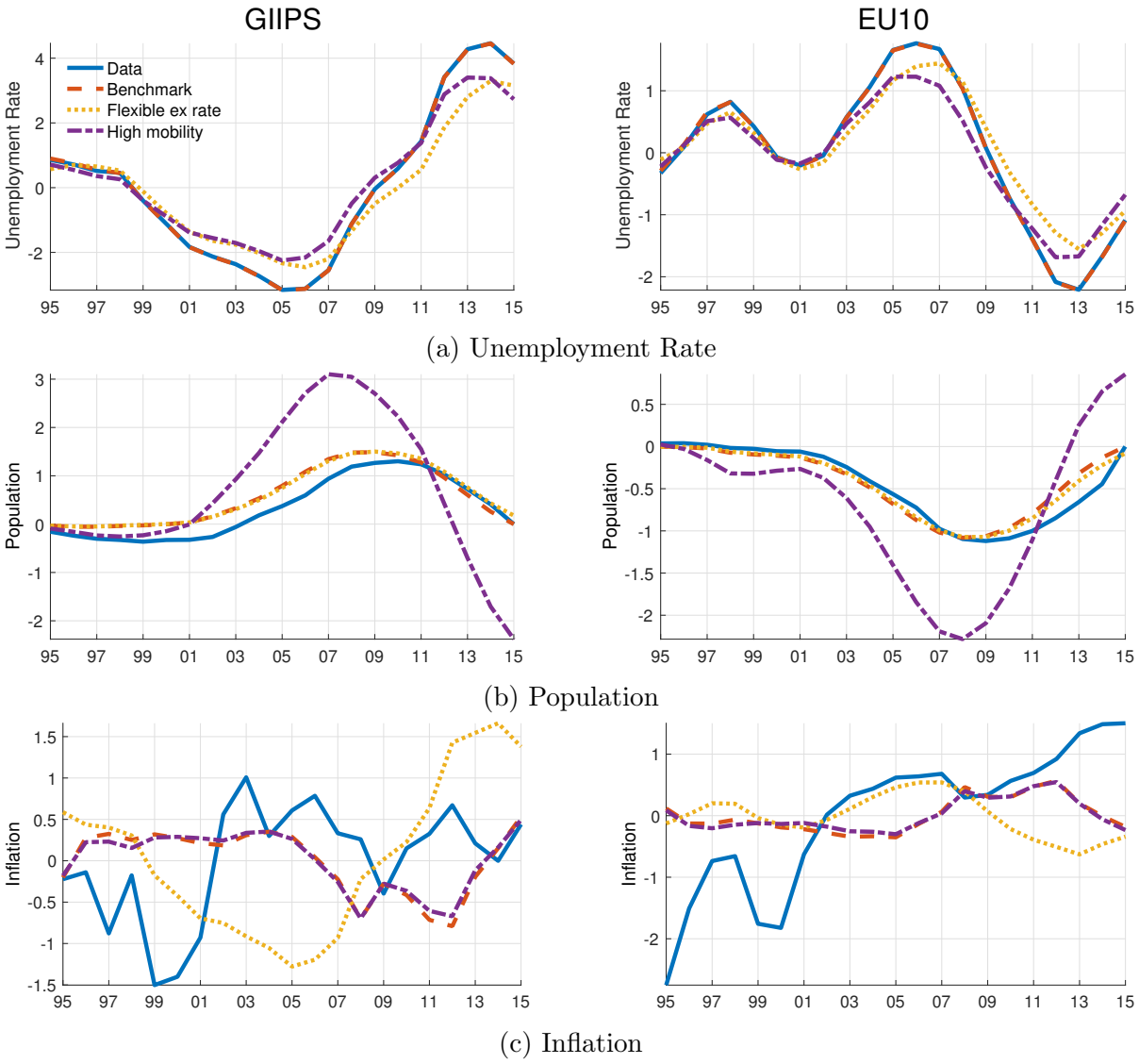


(a) Raw Data

(b) Demeaned Data

Figure 8: 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. Regular standard errors in parentheses.



(a) Unemployment Rate

(b) Population

(c) Inflation

Figure 9: Unemployment Rate, Population and Inflation in Data and Model

Notes: Panels display unemployment rates, cumulative net migration ("population") and inflation both in the data and the model, for GIIPS (left) and EU10 (right). All variables are double-demeaned.

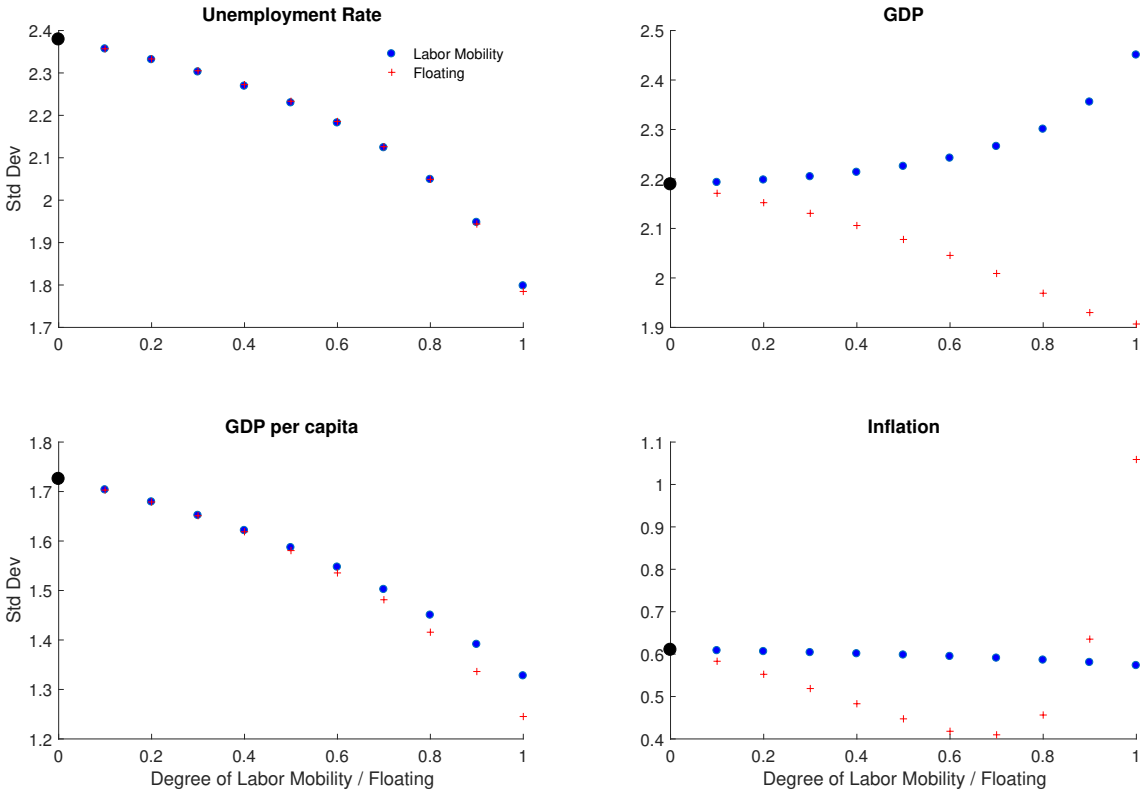


Figure 10: Cross-Sectional Standard Deviations in Counterfactuals

Notes: Panels display the cross-sectional standard deviations of the unemployment rate, GDP per capita, GDP and inflation for the euro area implied by model, as a function of the degree of labor mobility and the degree of floating. Degree of labor mobility ranges from 0 (corresponding to Benchmark case ('Estimated Model') in Table 6) to 1 (corresponding to case 'High labor mobility' in Table 6. A degree of 0.3 means that the labor mobility parameters γ and Φ'' are set as a weighted average assigning a 0.3 weight to the parameter combination to match labor mobility in Europe and a 0.7 weight to parameter combination to match labor mobility in the U.S. Degree of floating ranges from 0 (corresponding to Benchmark case ('Estimated Model') in Table 6) to 1 (corresponding to case with flexible exchange rates ('Aggr flex exch rate') in Table 6). In intermediate cases, we assume that every country in the euro area sets its interest rate as a weighted average of interest rates implied by a euro-area-wide Taylor rule and a country-specific Taylor rule.