

# QUANTIFYING THE BENEFITS OF LABOR MOBILITY IN A CURRENCY UNION<sup>\*†</sup>

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## Abstract

Unemployment differentials are greater between countries in the euro area than between U.S. states. In both regions, net migration responds to unemployment differentials, though the response is smaller in the euro area compared to the United States. We use a multi-country DSGE model with cross-border migration to quantify Mundell's hypothesis that labor mobility could substitute for independent monetary policy in a currency union. If, however, European migration rates were higher (at U.S. levels), then unemployment differentials would be 25 percent lower, and the welfare cost of the currency union would fall by one half. While mobility reduces the cost of the currency union on average, Mundell's conjecture does not hold uniformly throughout the euro area. For countries that primarily face demand shocks, labor mobility stabilizes inflation and unemployment and improves welfare. For countries that face relatively more supply shocks however, labor mobility increases the cost of being in a currency union by magnifying inflation volatility.

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

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*[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 18 euro area economies and 48 U.S. states between 1995 and 2018, together with the averages for the United States and the euro area (the dark lines). Average unemployment in both the United States and euro area 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 1995-2018, is almost three times greater in the euro area (3.8%) than the United States (1.4%).

Large 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 precondition for an optimal currency area. Despite concerns about the extent of labor market integration in Europe, member states moved ahead with the adoption of the euro. The global financial crisis of 2008, and its asymmetric effects across the euro area, presented a challenge to the currency union. While the euro survived, the difficulties of macroeconomic adjustment at the national level imposed large costs on members of the currency union. Our paper quantifies the cost of membership in the euro area and asks how that cost depends on labor mobility.

We begin by establishing some basic facts about cyclical labor mobility in the euro area relative to the United States. Empirically, migration rates are substantially lower in the euro area relative to the United States. In both regions, there is a clear relationship between migration and unemployment though the relationship is much stronger in the United States. In the data, workers in the United States are three times more likely to relocate for a given unemployment differential than in the euro area.

We then develop a multi-country DSGE model that incorporates frictions in the labor market giving rise to unemployment and endogenous migration. The model matches country size, migration patterns, trade flows, and unemployment. In the model, each country

experiences productivity shocks and shocks to demand for its export good. In equilibrium, price and wage rigidities cause inefficient variations in production and employment and generate country-specific variations in unemployment. If a country were to have flexible exchange rates, it could use monetary policy to stabilize these country-specific fluctuations. In a currency union, the response works through migration.

While it might seem obvious that both migration and monetary policy work to mitigate business cycle fluctuations, there are circumstances under which greater migration can exacerbate the cycle. This is particularly true for the volatility of inflation. Consider first a shock that increases the demand for a country's exports. Monetary policy would respond by raising interest rates, letting the exchange rate appreciate to offset the upward pressure on prices. Similarly, in-migration would raise labor supply, expand output and again offset the upward pressure on prices. The responses to a productivity shock, however, have sharply different implications for prices. As productivity increases, the price level falls. Optimal monetary policy implies a decrease in the interest rate and an exchange rate depreciation to stabilize the price level. Labor mobility, however, would push prices down even more – attracted by higher wages, workers enter from abroad, increasing the supply of labor, putting further downward pressure on wages and prices. Depending on the composition of the shocks, it is possible that labor mobility and monetary policy could be complements rather than substitutes.

The quantitative 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 the euro area. We estimate the structural parameters of the model to match the empirical elasticity of net migration to unemployment in the euro area. We then consider a counterfactual that matches the elasticity observed in the United States. In that scenario, unemployment differentials would fall by 25 percent. A shift to flexible exchange rates, on the other hand, eliminates unemployment differentials entirely. Increased labor mobility reduces the volatility of per capita GDP and consumption, but increases the volatility of aggregate GDP and consumption. In contrast, the shift to flexible exchange rates reduces volatility of both per capita and aggregate variables. The consequences of labor mobility for inflation are mixed – some countries in the euro area experience a reduction of inflation volatility while others experience an increase.

Following the New Keynesian literature (see Woodford, 2003; Galí, 2008) we calculate a second-order accurate approximation to household utility in the neighborhood of a (constrained) efficient equilibrium. The welfare measure reflects both the benefits of eliminating inefficient variations in output as well as inefficiencies from excessive price and wage variability. In the baseline model, calibrated to the euro area, the welfare costs of business cycle

inefficiencies for the average country in the euro area are significant—more than 273 euros per capita per year. If countries had independent monetary policy and floating exchange rates, this cost would fall by 65 percent to only 93 euros. The difference, 180 euros, is the per capita cost of being in the currency union for an average country. This cost would fall by almost half if migration rates in the euro area were comparable to migration rates in the United States.

Not all countries benefit from greater labor mobility however. While the cost of the currency union falls on average, most of these benefits accrue to only a few large countries. Many other countries in the euro area are actually worse off with higher labor mobility. The mixed results for Mundell’s conjecture can be traced to two sources: the emphasis on inflation stabilization in New Keynesian welfare metrics and the prevalence of productivity shocks for many countries in the euro area. For countries that are more exposed to productivity shocks, greater labor mobility actually increases inflation volatility and increases the cost of being in the currency union.

## 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 led to a resurgence of research on this topic. Our contribution to this literature is two-fold: First, we provide a quantitative assessment of the benefits of labor mobility over the business cycle in a DSGE model that matches the countries in the euro area. Second, our model clarifies settings in which labor mobility reduces unemployment rate differentials and welfare costs and settings where monetary policy is a more powerful tool for reducing volatility and stabilizing inflation. 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 outflow. 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 study optimal monetary policy in a currency union with labor mobility. Cook, Fan and Xu (2013) show that the optimal-currency-area logic can be reversed if economies face supply shocks.

Our work also relates to studies on the link between trade and migration (Davis and Weinstein, 2002; Burstein et al., 2020; Di Giovanni, Levchenko and Ortega, 2015; Caliendo et al., 2021). For example, Caliendo et al. (2021) add migration to a quantitative trade model for policy analysis 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 long-run effects of a permanent reduction in migration costs.

Several researchers have embedded migration channels into DSGE models of the business cycle. Hart and Clemens (2019) study a two region model to evaluate the consequences of labor flows for business cycle volatility. Using a model calibrated to Spain, Bentolila, Dolado and Jimeno (2008) argue that immigration flattens empirical Phillips curve relationships. Bandeira et al. (2019) study how immigration amplifies the reaction to austerity policies in Greece following the debt crisis. Lozej (2019) uses a small open economy model to analyze the role of migration in alleviating country-specific shocks using a model calibrated to Ireland with search and matching frictions. The key distinguishing feature of our paper is that our aim is to quantitatively evaluate the tradeoff between monetary policy and labor mobility (i.e., Mundell's tradeoff) for the euro area as a whole.

The seminal paper on the response of migration to labor market conditions is Blanchard and Katz (1992). They 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 of 100 workers leads to an out-migration of 65 workers in the first year, together with an increase in unemployment of 30 workers.<sup>1,2</sup> 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. We apply the methods in Blanchard and Katz (1992) to a larger sample of European countries and with new data on observed migration flows (as opposed to migration flows inferred from changes in population). Our data indicate that the difference between the U.S. and Europe is even larger than estimated in Beyer and Smets (2015). We use the estimated cyclical relationship between migration and unemployment as moments for the calibration and estimation of a DSGE model to quantify

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<sup>1</sup>In a recent paper, Furlanetto and Robstad (2019), using data on Norway, provide evidence that an exogenous inflow of migrants can actually lower unemployment.

<sup>2</sup>Molloy, Smith and Wozniak (2011); Dao, Furceri and Loungani (2017); Kaplan and Schulhofer-Wohl (2017); Yagan (2014) document a slight decline in U.S. mobility since the early 1990s.

the effects of migration on economic outcomes under fixed and flexible exchange rates.

### 3 Empirical Analysis

In this section we present evidence on migration and unemployment across U.S. states and across countries in the euro area. This analysis shows that labor migration rates are substantially lower in the the euro area relative to the United States. At the same time, unemployment differentials in the euro area countries are consistently greater than across U.S. states. In both regions, there is a clear relationship between labor migration and unemployment differentials though the relationship is much stronger in the United States compared to the euro area. We use these findings when we calibrate our multi-country model in Section 5.

#### 3.1 Data

**Geographical Coverage and Sample Period** We analyze migration flows in the United States and the euro area. The sample for the United States consists of 48 states (excluding Alaska and Hawaii due to their geographical isolation). Our set of euro area countries includes 18 members as of 2018 (we exclude Luxembourg, due to its high share of cross-border commuters and its paucity of migration data).<sup>3</sup> Our sample for the United States, covers 1977-2018. The time span is dictated by the lack of state-level unemployment and migration data prior to the mid-1970s. Our sample for the euro area covers 1995-2018 because prior to 1995, migration data is available only for a handful of countries and restrictions on labor mobility were still prevalent.

**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. This distinguishes us from most of the migration literature that focuses on migration of foreigners.<sup>4</sup> Definitions of migrants based on foreign citizenship would miss important labor flows that are the core of the adjustment mechanism in currency unions. For example, migration figures

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<sup>3</sup>Our sample includes Belgium, Germany, Estonia, Ireland, Greece, Spain, France, Italy, Cyprus, Latvia, Lithuania, Malta, Netherlands, Austria, Portugal, Slovenia, Slovakia and Finland. Belgium, Germany, Ireland, Spain, France, Italy, Netherlands, Austria, Portugal and Finland adopted the euro in 1999. The remaining countries adopted the euro in the following years: Greece (2001), Slovenia (2007, pegged since 2004), Cyprus (2008, pegged since 1999), Malta (2008, pegged since 2003), Slovakia (2009), Estonia (2011, pegged since 1999), Latvia (2014, pegged since 2005), Lithuania (2015, pegged since 2002).

<sup>4</sup>See e.g. Mayda (2010) or Beine, Bourgeon and Bricongne (2019) who rely on data from the International Migration Database hosted by the OECD that only captures movements by non-nationals.

reported by Spain would not include the large exodus of Spaniards attracted by better labor market conditions in Germany in the early 2010s. Missing flows of nationals in the euro area would also bias downward our estimates of migration flows and therefore undermine our comparison with U.S. data that records flows of people across states irrespective of their state of birth.

Data on migration in the euro area is provided primarily by Eurostat. Eurostat records migration flows of both nationals and non-nationals.<sup>5</sup> We complement this data using information provided by national statistical agencies whenever we are sure that the national data captures migration of both foreigners and nationals. While our main analysis focuses on in- and out-migration for each country, we also create a database of bilateral migration flows that is used to calibrate our multi-country model. Data on unemployment rates are collected through national labor force surveys and are reported by Eurostat.<sup>6</sup>

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 mailing addresses of tax returns and encompass all U.S. tax filers. Data on state population and unemployment rates are provided by the Bureau of Economic Analysis and the Bureau of Labor Statistics.

**Migration** This section shows that migration rates have been declining in the United States and have been gradually increasing in the euro area. Despite these trends, there remains substantially more migration in the United States relative to the euro area.

We define the gross migration rate as the average of inflows and outflows over one year divided by the population.<sup>7</sup> 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  $t$ .

The gross migration rate for the United States is 3.24 percent (averaged across states and time periods). For the euro area, the gross migration rate is only 0.75 percent. Figure 2 displays average gross migration rates for the United States and the euro area sample over

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<sup>5</sup>Despite this harmonized definition, 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 Ireland). In line with our data for the United States, we do not distinguish between national and foreign migrants. Appendix A.2 provides more details on data sources and the construction of our database for Europe.

<sup>6</sup>Labor force surveys are harmonized across European countries and use the same definition of unemployment as in the United States.

<sup>7</sup>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.

time. Migration rates have been trending down slightly in the United States while they have increased in the euro area. The increase in mobility in the euro area could reflect the liberalization of labor markets over our sample period. Free movement of labor between original member states and member states that entered since 2004 was only established over a seven-year transition period.

There are many possible reasons for the differences in migration rates. Language, culture, and institutional differences all present barriers to labor flows that could be greater in the euro area relative to the United States (see for instance Beine, Bourgeon and Bricongne, 2019). In the model in Section 4 we are agnostic about the specific frictions that impede labor mobility. For whatever reason, labor mobility is lower in the euro area than in the United States and Mundell’s conjecture suggests that maintaining a currency union will therefore be more costly for the euro area.

For purposes of macroeconomic stabilization, it is the *net* migration rate that matters. The net migration rate is the difference between a state’s total inflows and total outflows as a share of its population

$$\text{Net migration}_{i,t} = \frac{\text{In-migration}_{i,t} - \text{Out-migration}_{i,t}}{\text{Population}_{i,t}}. \quad (3.1)$$

Net migration rates fluctuate over time as relatively more people enter or exit countries or states. Unlike gross migration rates which are substantially different between the United States and the euro area, fluctuations in net migration rates are quite comparable. The average standard deviation of net migration across all U.S. states is 0.48 and is about 0.39 in the euro area.

**Unemployment Rates** We now turn our attention to the difference in unemployment rates in the United States and the euro area. 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 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. This 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.<sup>8</sup>

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<sup>8</sup>Repeating our analysis with conventional state and time fixed effects yields virtually the same results.



Consider the unemployment rate for country  $i$  in the euro area. 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 the euro area 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 the euro area. The average unemployment rate  $\overline{ur}$  is 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

$$\widehat{ur}_{i,t} = ur_{i,t} - ur_i - (ur_t - \overline{ur}). \quad (3.2)$$

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 3 plots the cross-sectional standard deviations of the demeaned unemployment rates together with their average over time. The standard deviation of U.S. unemployment is about 1. The standard deviation is higher in the euro area at 2.8. The earlier observation of greater unemployment rate dispersion in the euro area 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 (state) 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 the euro area diverge particularly during the debt crisis in 2011 - 2013, with a standard deviation of roughly 4 percentage points.

An important factor in considering whether a region is an optimal currency area is the extent to which macroeconomic fluctuations are due to a common business cycle or are country specific. To get a sense of whether common factors explain variation in unemployment rates, we decompose the variance for each state or country  $i$  as

$$var(ur_{i,t} - ur_i) = var(\widehat{ur}_{i,t}) + var(ur_t) + 2cov(\widehat{ur}_{i,t}, ur_t) \quad (3.3)$$

This decomposes fluctuations in a country's unemployment rate (relative to its average) into the variance of the idiosyncratic (double-demeaned) unemployment rate ( $var(\widehat{ur}_{i,t})$ ), the variance of the unemployment rate in the euro area ( $var(ur_t)$ ) and the covariance between the two terms. This covariance is positive if the idiosyncratic component comoves with the euro-area-wide component, that is if a country experiences the same business cycles as the average, but to a stronger extent. This is the case for countries like Spain and Greece. In contrast, Germany has a negative covariance, which indicates that its business cycles tend to be of a

smaller amplitude than those of the average country in the euro area. By construction the covariance term is zero on average.

Figure 4 shows the decomposition for the countries in the euro area and for U.S. states. The most striking feature is the difference between the variance of the idiosyncratic unemployment fluctuations in the euro area compared to the United States. For U.S. states, the average variance of state unemployment is 3.4 while for countries in the euro area it is 9.3. The idiosyncratic component accounts for only 29 percent of total variance for U.S. states while it accounts for 81 percent of the variance in the euro area. This suggests that the cost of a currency union in the euro area, where country-specific fluctuations are relatively large, is greater than the costs of the common currency in the United States. We later use the model to ask how higher labor mobility in the euro area can reduce the country-specific fluctuations in the unemployment rate.

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

$$\widehat{ur}_{i,t+h} = \beta_0^h \widehat{ur}_{i,t} + \beta_1^h \widehat{ur}_{i,t-1} + \beta_2^h \widehat{ur}_{i,t-2} + \epsilon_{i,t}^h \quad \forall h = 0, 1, \dots, H \quad (3.4)$$

up to a nine year horizon  $H = 9$ . The coefficients provide us with estimates of unemployment at horizon  $h$  given an initial unemployment differential. The upper part of Figure 6 displays the estimated coefficients  $\hat{\beta}_0^h$  for the United States (a), and the euro area (b). Unemployment differentials are persistent in all cases, but particularly so in the euro area. Following an innovation of 1 percentage point, unemployment differentials initially rise by 0.5 to 0.8 percentage points in the euro area and stay above 1% for 3 to 4 years.

To summarize, unemployment rates are more disperse across the euro area than across U.S. states, and they reflect greater idiosyncratic variation. In both regions, dispersion in unemployment is quite persistent.

## 3.2 Unemployment Rates and Net Migration

We are interested in the relationship between net migration flows and unemployment differentials and how this relationship differs between the euro area and the United States. To study this relationship we regress net migration on the unemployment rate

$$\widehat{nm}_{i,t} = \beta \widehat{ur}_{i,t} + \epsilon_{i,t}, \quad (3.5)$$

where  $\widehat{ur}_{i,t}$  is the double-demeaned unemployment rate as defined in (3.2) and  $\widehat{nm}_{i,t}$  is the double-demeaned net migration rate.<sup>9</sup> This specification 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.<sup>10</sup>

Figure 5a shows the scatterplot of the data and the estimated coefficients for  $\beta$ . The U.S. coefficient is  $-0.26$  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 0.26 percentage points. To put this in context, if the labor force participation rate were 0.65, an increase of 100 unemployed workers in a state coincides with an out-migration of 40 ( $26/0.65$ ) people from that state. These regressions are not meant to be interpreted causally. Rather, we are simply documenting that periods with relatively high unemployment are associated with periods of net out-migration.

The estimated coefficient for regression (3.5) is smaller in the euro area than in the United States. For the time period as a whole, the estimated coefficient for the euro area is  $\hat{\beta} = -0.08$  ( $0.01$ ). Consistent with the finding that migration flows have become smaller in the United States and larger in the euro area, there is a slight time trend in the estimated  $\beta$  coefficient in both regions: The relationship between net migration and unemployment rates is somewhat weakening in the United States, while it has slightly increased in the euro area

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 the euro area. 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

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

with  $H = 9$ . The estimated coefficient  $\beta_0^h$  provides us with an estimate of the response of net migration to changes in unemployment rates at horizon  $h$ . Based on the estimated coefficients  $\beta_0^h$ , 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).

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<sup>9</sup>We have also estimated versions of (3.5) including measures of regional wage differentials. While the wage coefficients have the “correct” sign, they are not statistically significant and including them does not change the coefficient on  $\widehat{ur}_{i,t}$ . See the Appendix for details.

<sup>10</sup>The relevance of *relative* labor market conditions is consistent with the DSGE model presented in the next section and “gravity” approaches to study migration flows (Anderson, 2011).

The middle panels in Figure 6 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 6 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% 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. Column (b) of Figure 6 repeats the local projections for the euro area samples. The overall dynamics of migration flows are similar, but are clearly smaller than the U.S. reactions. The cumulative reduction in population is less than half of the response in the U.S. ( $-0.55$  vs.  $-1.30$ ) and is more delayed.

To summarize our empirical findings, (i) Labor is less mobile in the euro area relative to the United States. (ii) Unemployment differentials persistent and are larger in the euro area relative to the United States. (iii) Net migration reacts to regional differences in unemployment rates though the relationship is notably weaker in the euro area. (iv) The implied long-run changes in population are economically significant in both regions.

## 4 A DSGE Model with Cross-Country Labor Mobility

We now analyze the tradeoff between labor mobility and exchange rate adjustment using a multi-country model of a currency union with cross-border migration. The model is parameterized to match observed migration rates in the euro area and the empirical relationship between unemployment differentials and migration flows documented in Section 3.1.

The model has four major components. First, and most importantly, the model features cross-country labor mobility. We introduce labor mobility by adapting the setup in Artuğ, Chaudhuri and McLaren (2010) and Caliendo, Dvorkin and Parro (2019) to our framework. Second, we allow for unemployment. Our unemployment specification builds on work by Erceg, Henderson and Levin (2000) and Galí (2011). Third, to allow for exchange rates and monetary policy to influence economic activity, we introduce price and wage rigidity through a Calvo mechanism (Woodford, 2003; Galí, 2008). Finally, the model includes a trade network (based on Eaton and Kortum, 2002) that reflects trade patterns in the euro area.

## 4.1 Households and Population

The model consists of  $i = 1, \dots, N - 1$  euro area countries plus a rest of the world (RoW) aggregate. In each country, there are capital owners and workers. Capital owners are immobile. The number of capital owners in country  $i$  is  $\mathbb{N}_i^k$ . Workers are mobile and move from one country to the next if they find it optimal to do so. The number of workers in country  $i$  at time  $t$  is given by  $\mathbb{N}_{i,t}^w$ . The total population for country  $i$  at time  $t$  is

$$\mathbb{N}_{i,t} = \mathbb{N}_i^k + \mathbb{N}_{i,t}^w.$$

The net migration rate in the model – the counterpart to (3.1) – is  $\mathbb{N}_{i,t}/\mathbb{N}_{i,t-1} - 1$ . Unless otherwise indicated, variables in the model are expressed in per capita terms. For instance,  $c_{i,t}^w$  is consumption of a single worker while total consumption for workers is  $\mathbb{N}_{i,t}^w c_{i,t}^w$ .

**Capital Owners** Capital owners receive utility from the consumption of the final good produced in their country of residence. At each date  $t$ , capital owners in country  $i$  act to maximize expected utility

$$\mathbb{E}_t \left[ \sum_{j=0}^{\infty} \beta^j \frac{(c_{i,t+j}^k)^{1-\frac{1}{\sigma}}}{1 - \frac{1}{\sigma}} \right] \quad (4.1)$$

subject to the nominal budget constraints

$$P_{i,t} c_{i,t}^k + P_{i,t} I_{i,t} + \frac{B_{i,t}}{(1 + i_{\in,t}) E_{i,t}} - \frac{B_{i,t-1}}{E_{i,t}} = W_{i,t} L_{i,t} + K_{i,t-1} (R_{i,t} u_{i,t} - P_{i,t} a(u_{i,t})) + \Pi_{i,t} - T_{i,t}^k,$$

and the capital accumulation constraint

$$K_{i,t} = K_{i,t-1} (1 - \delta) + \left[ 1 - f \left( \frac{I_{i,t}}{I_{i,t-1}} \right) \right] I_{i,t}.$$

Nominal expenditure on consumption and investment is  $P_{i,t} c_{i,t}^k$  and  $P_{i,t} I_{i,t}$  where  $c_{i,t}^k$  and  $I_{i,t}$  are consumption and investment for the capital owner and  $P_{i,t}$  is the nominal price of the final good.  $B_{i,t}$  is the face value of nominal bonds denominated in euros held by capital owners of country  $i$  and maturing at date  $t + 1$ . These bonds pay the nominal interest rate  $i_{\in,t}$ .<sup>11</sup> Finally,  $E_{i,t}$  is the nominal exchange that converts euros into country  $i$ 's currency.<sup>12</sup>

Capital owners earn nominal labor income,  $W_{i,t} L_{i,t}$ , earn nominal rental income  $R_{i,t} K_{i,t-1} u_{i,t}$ ,

<sup>11</sup>To ensure that the stochastic equilibrium is stationary, we impose a small quadratic penalty on bond holdings. We set the cost sufficiently low that its effect on the equilibrium is negligible. See Schmitt-Grohé and Uribe (2003) for additional discussion.

<sup>12</sup>For countries in the euro area,  $E_{i,t} = 1$ .

receive nominal profits  $\Pi_{i,t}$  and pay lump-sum nominal taxes  $T_{i,t}^k$ . Effective labor  $L_{i,t}$  is determined by labor unions and is taken as exogenous by the capital owners (see Section 4.2). Capital available for production in period  $t$  is  $K_{i,t-1}$ . Capital owners can adjust its utilization rate,  $u_{i,t}$ , at the nominal cost  $K_{i,t-1}P_{i,t}a(u_{i,t})$  with  $a(1) = a'(1) = 0$  and  $a''(1) > 0$  governing the cost of changing utilization. The investment adjustment cost function  $f$  satisfies  $f(1) = f'(1) = 0$  and  $f''(1) \geq 0$  (see Christiano, Eichenbaum and Evans, 2005).

**Workers** Workers are mobile and earn only labor income. Any workers in country  $i$  receive nominal labor income  $W_{i,t}L_{i,t}$  and pay lump-sum taxes  $T_{i,t}^w$ . Workers are assumed to be “hand-to-mouth”, so their consumption satisfies<sup>13</sup>

$$P_{i,t}c_{i,t}^w = W_{i,t}L_{i,t} - T_{i,t}^w. \quad (4.2)$$

At the level of the individual, labor supply is inelastic and thus the only meaningful choice workers make is where to work. At the beginning of each period, workers choose to migrate or remain in their current country. Migration takes place within a period and migrants immediately work and consume in their new location.

A worker moving from country  $i$  to country  $j$  incurs a migration cost  $\tau_j^i$  (with  $\tau_i^i = 0$ ). In addition to migration costs, workers receive idiosyncratic (i.e. worker-specific) shocks for each destination  $j$ , denoted by  $\epsilon_{j,t}$ .<sup>14</sup> Define  $v_{i,t}(\epsilon_t)$  as the value of a worker living in country  $i$  at time  $t$  conditional on the aggregate state and the worker’s vector of idiosyncratic shocks,  $\epsilon_t = [\epsilon_{1,t}, \epsilon_{2,t}, \dots, \epsilon_{N,t}]$  drawn at that date. The value to a worker of living in country  $i$  at time  $t$  is

$$v_{i,t}(\epsilon_t) = \max_j \left\{ \varphi_j U(c_{j,t}^w) + \frac{1}{\gamma} \epsilon_{j,t} - \tau_j^i + \beta \mathbb{E}_t(V_{j,t+1}) \right\}. \quad (4.3)$$

The flow utility function  $U(c)$  is  $\frac{c^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}}$ , and  $\varphi_j > 0$  are location specific constants. The value  $V_{i,t}$  is the expected value of  $v_{i,t}(\epsilon_t)$  prior to the realization of the vector  $\epsilon_t$  and thus,  $V_{i,t}$  is the average expected utility of any worker in country  $i$  at the start of time  $t$ . The parameter  $\gamma$  governs how strongly idiosyncratic location shocks affect migration decisions.

We follow Artu, Chaudhuri and McLaren (2010) and assume that the idiosyncratic shocks are i.i.d. over time and across individuals and are distributed according to a Type-I extreme

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<sup>13</sup>This specification follows Caliendo, Dvorkin and Parro (2019) and simplifies the solution to the model by allowing us to abstract from changes in worker-specific asset holdings as they change location. Allowing migrants to hold assets would result in propagating ex post heterogeneity among migrants.

<sup>14</sup>Since every worker draws his or her own shock  $\epsilon_{j,t}$ , we could add a subscript to denote the individual worker. We suppress this index for ease of notation.

value distribution with zero mean. Given these assumptions, the expected value  $V_{i,t}$  – the average utility of a worker in country  $i$  at time  $t$  – is

$$V_{i,t} = \frac{1}{\gamma} \ln \left\{ \sum_j \exp \left\{ \gamma \left( \varphi_j U(c_{j,t}^w) - \tau_j^i + \beta \mathbb{E}_t(V_{j,t+1}) \right) \right\} \right\}. \quad (4.4)$$

Migration decisions depend on this average utility. The share of workers that relocate from  $i$  to  $j$ , denoted by  $n_{j,t}^i$ , is then<sup>15</sup>

$$n_{j,t}^i = \frac{\exp \left\{ \gamma \left( \varphi_j U(c_{j,t}^w) - \tau_j^i + \beta \mathbb{E}_t(V_{j,t+1}) \right) \right\}}{\sum_k \exp \left\{ \gamma \left( \varphi_k U(c_{k,t}^w) - \tau_k^i + \beta \mathbb{E}_t(V_{k,t+1}) \right) \right\}}. \quad (4.5)$$

Naturally, markets with higher expected utility attract more workers. The number of mobile workers living in country  $i$  at time  $t$  is

$$\mathbb{N}_{i,t}^w = \sum_j n_{i,t}^j \mathbb{N}_{j,t-1}^w.$$

As the difference in the value of working in country  $i$  rises relative to country  $j$ ,  $n_{j,t}^i$  rises and more workers flow from  $i$  to  $j$ . Rewriting the migration rate in equation (4.5) gives

$$\ln \left( \frac{n_{j,t}^i}{n_{i,t}^i} \right) = \gamma \left( \left\{ \varphi_j U(c_{j,t}^w) - \tau_j^i + \beta \mathbb{E}_t(V_{j,t+1}) \right\} - \left\{ \varphi_i U(c_{i,t}^w) + \beta \mathbb{E}_t(V_{i,t+1}) \right\} \right). \quad (4.6)$$

The parameter  $\gamma$  is critical for our analysis because it governs the sensitivity of migration rates to utility differentials. The greater is  $\gamma$ , the more responsive migration is to differences in utility. Utility differences reflect differences in real labor incomes that are either driven by cross-country fluctuations in the real wage,  $\frac{W}{P}$ , or the level of (un)employment,  $L$ . Below, we choose  $\gamma$  so that the data generated by the model produces an elasticity of net migration to unemployment differentials that matches the empirical regression coefficient from (3.5). In Section 6, when we simulate counterfactual experiments with greater labor mobility, we adjust  $\gamma$  so that the model-implied regression coefficient matches that of the United States.

## 4.2 Labor Markets

To generate time-varying unemployment rates, we add wage rigidity as in Erceg, Henderson and Levin (2000). We follow Galí (2011) by adding indivisible labor and we assume a linear

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<sup>15</sup>The model predicts bi-directional migration flows across countries. Consistent with the empirical evidence, gross migration rates in the model generally exceed net migration rates.

demand specification as in Melitz and Ottaviano (2008).

As described above, workers and capital owners supply fixed amounts of labor,  $L_i^S$ , in their country of residence.<sup>16</sup> If labor supply exceeds labor demand at the equilibrium wage, some households will be unemployed. As in Hansen (1985) and Rogerson (1988), workers agree to a risk-sharing contract that guarantees each worker the same average wage at date  $t$  though in equilibrium not all workers are employed. Workers are then randomly assigned a type  $\iota \in [0, 1]$  according to a uniform distribution. As in Erceg, Henderson and Levin (2000), for each type  $\iota$ , and each country, there is a labor union with market power that acts in the interest of its workers in setting a wage rate and choosing who works.

Type-specific labor  $l_{i,t}(\iota)$  is employed by competitive labor-aggregating firms who, in turn, sell aggregate effective labor to goods-producing firms. Labor-aggregating firms behave competitively and choose labor types  $l_{i,t}(\iota)$  to maximize their profits

$$W_{i,t}L_{i,t} - \int_0^1 W_{i,t}(\iota)l_{i,t}(\iota)d\iota.$$

Here  $W_{i,t}$  is the nominal wage charged for a unit of effective labor while  $W_{i,t}(\iota)$  is the nominal wage paid for a unit of type  $\iota$  labor. Labor-aggregating firms take  $W_{i,t}$  and  $W_{i,t}(\iota)$  as given. Effective labor  $L_{i,t}$  is produced from the following combination of labor types  $l_{i,t}(\iota)$ :

$$L_{i,t} = \int_0^1 l_{i,t}(\iota)d\iota - \frac{1}{2} \frac{1}{\zeta_i} \left[ \int_0^1 (l_{i,t}(\iota))^2 d\iota - \left( \int_0^1 l_{i,t}(\iota)d\iota \right)^2 \right]. \quad (4.7)$$

This specification is a variation of the one used in Melitz and Ottaviano (2008).<sup>17</sup> We allow  $\zeta_i$  to vary across regions but we require  $\zeta_i < L_i^S$ .

Given the specification (4.7) above, demand for each labor type satisfies

$$l_{i,t}(\iota) = \zeta_i \left( \frac{W_{i,t} - W_{i,t}(\iota)}{W_{i,t}} \right) + L_{i,t}^D \quad (4.8)$$

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<sup>16</sup>Below, we calibrate cross-country differences in labor supply to match observed labor force participation rates. We assume that when a worker moves, he or she adopts the labor force participation rate in the destination country. Also, similar to Mandelman and Zlate (2012), Borjas, Grogger and Hanson (2008) and Lozej (2019) we treat labor supplied by workers as perfect substitutes regardless of the country of origin. The degree of substitutability of native workers and immigrant workers is a subject of active research (see e.g. Ottaviano and Peri, 2012; Borjas, Grogger and Hanson, 2008; Furlanetto and Robstad, 2019; Bentolila, Dolado and Jimeno, 2008; Brücker et al., 2014; Prean and Mayr, 2016; Dustmann, Glitz and Vogel, 2010). See Dustmann, Schönberg and Stuhler (2016) for additional discussion.

<sup>17</sup>We depart from the CES-specification in Erceg, Henderson and Levin (2000) because of our assumption that labor is supplied inelastically. A CES-specification would imply that the optimal wage set by trade unions is the cost of supplying labor times a gross markup. Since this cost is zero in our setup, the optimal wage would be zero.



where the labor aggregating firms take total labor demand,  $L_{i,t}^D \equiv \int_0^1 l_{i,t}(\iota) d\iota$  as given.

Labor unions set wages  $W_{i,t}(\iota)$  to maximize the total amount paid to their workforce taking the demand curve (4.8) as given. Wages are set according to a Calvo mechanism with a wage reset probability given by  $1 - \theta_w$ . Thus, a union that gets to reset their wage at time  $t$  chooses a reset wage  $W_{i,t}^*(\iota)$  to maximize their real wage payments over the life of the wage contract,

$$\mathbb{E}_t \left[ \sum_{j=0}^{\infty} (\theta_w \beta)^j \frac{W_{i,t}^*(\iota)}{P_{i,t+j}} \left( \zeta_i \left( \frac{W_{i,t+j} - W_{i,t}^*(\iota)}{W_{i,t+j}} \right) + L_{i,t+j}^D \right) \right].$$

All labor unions that can adjust at time  $t$  optimally choose the same reset wage so  $W_{i,t}^*(\iota) = W_{i,t}^*$ . This reset wage is given by

$$W_{i,t}^* = \frac{1}{2} \frac{\mathbb{E}_t \left[ \sum_{j=0}^{\infty} (\theta_w \beta)^j (\zeta_i + L_{i,t+j}^D) P_{i,t+j}^{-1} \right]}{\mathbb{E}_t \left[ \sum_{j=0}^{\infty} (\theta_w \beta)^j \zeta_i (W_{i,t+j} P_{i,t+j})^{-1} \right]}. \quad (4.9)$$

Notice that integrating (4.8) over  $\iota$  and using the definition of  $L_{i,t}^D$  implies that  $W_{i,t} = \int_0^1 W_{i,t}(\iota) d\iota$ . Wages for effective labor adjust according to

$$W_{i,t} = (1 - \theta_w) W_{i,t}^* + \theta_w W_{i,t-1}. \quad (4.10)$$

In the non-stochastic steady state, wages are equal across types so  $W_i(\iota) = W_i$  and employment is  $l_i(\iota) = L_i^D = \zeta_i$ . Since  $\zeta_i < L_i^S$ , the model implies unemployment in steady state.

Log-linearizing (4.9) and (4.10) and using the fact that, to a first-order (log) approximation,  $L_{i,t}^D = L_{i,t}$  we get the wage Phillips curve,

$$\pi_{i,t}^w = -\frac{(1 - \theta_w \beta)(1 - \theta_w)}{\theta_w} \frac{1}{2} \left[ \frac{ur_{i,t} - ur_i}{1 - ur_i} \right] + \beta \mathbb{E}_t [\pi_{i,t+1}^w],$$

where  $ur_{i,t} = (L_i^S - L_{i,t}) / L_i^S$  is the unemployment rate. Notice that if wages were fully flexible ( $\theta_w \rightarrow 0$ ) then the unemployment rate would be constant. Thus, monetary policy rules that target the unemployment rate (“Mankiw rules”) have the potential to attain the flex-wage equilibrium.

### 4.3 Firms, Production and Trade

Production of the final good takes place in three stages. This setup allows us to separate the sticky price dynamics (in the first stage) from the trade dynamics (in the second and third

stages). In the first stage, material inputs are produced from capital and labor inputs. The material input producers set their prices according to the Calvo mechanism. In the second stage, intermediate goods are produced using materials from stage one as inputs. Some of the intermediate goods are tradeable while others are not. For the tradeable goods, countries purchase from the lowest-cost supplier available to them (depending both on the factory price and also on trade costs and exchange rates). In the last stage, each country combines the (domestically produced and imported) intermediate goods from stage two into a final good which is used for consumption, investment and government purchases.

**Material inputs** Firms use capital and labor to produce material inputs. There is a continuum of material inputs and firms are monopolistically competitive. Material input producers adjust their prices infrequently according to the standard Calvo mechanism.

Competitive firms produce aggregate material inputs  $M_{i,t}$  from a CES combination of individual material inputs  $m_{i,t}(s)$ , with  $s \in [0, 1]$ .

$$M_{i,t} = \left[ \int_0^1 m_{i,t}(s)^{\frac{\psi_m-1}{\psi_m}} ds \right]^{\frac{\psi_m}{\psi_m-1}}. \quad (4.11)$$

Denoting the price of material input  $s$  by  $p_{i,t}^m(s)$ , the demand for each variety is

$$m_{i,t}(s) = M_{i,t} \left( \frac{p_{i,t}^m(s)}{p_{i,t}^M} \right)^{-\psi_m}, \quad (4.12)$$

where  $p_{i,t}^M$  is the price of a unit of aggregate material input:

$$p_{i,t}^M = \left[ \int_0^1 p_{i,t}^m(s)^{1-\psi_m} ds \right]^{\frac{1}{1-\psi_m}}. \quad (4.13)$$

The individual material producing firms hire labor,  $L_{i,t}(s)$ , and capital,  $K_{i,t}(s)$ , to produce a specific variety of the material:

$$m_{i,t}(s) = Z_i^M (K_{i,t}(s))^\alpha (L_{i,t}(s))^{1-\alpha}. \quad (4.14)$$

Cost minimization implies that individual material firms have a common capital-to-labor ratio

$$\frac{K_{i,t}(s)}{L_{i,t}(s)} = \frac{\alpha}{1-\alpha} \frac{W_{i,t}}{R_{i,t}} = \frac{\mathbb{N}_i^k u_{i,t} K_{i,t-1}}{\mathbb{N}_{i,t}^w L_{i,t}}. \quad (4.15)$$

and a common nominal marginal cost of production

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

The individual material input producers are monopolistically competitive and act in the interest of the capital owners in their country. They adjust their prices  $p_{i,t}^m(s)$  according to the Calvo mechanism with reset probability  $1 - \theta_p$ . Taking the demand curve for their variety (4.12) as given, the profit maximization problem for a material input producer in country  $i$  that can reset its price is

$$\max_{p_{i,t}^{M,*}} \mathbb{E}_t \left[ \sum_{j=0}^{\infty} (\theta_p \beta)^j \frac{MU_{i,t+j}^k}{P_{i,t+j}} \left[ p_{i,t}^{M,*} - MC_{i,t+j} \right] M_{i,t+j} \left( \frac{p_{i,t}^{M,*}}{P_{i,t+j}^M} \right)^{-\psi_m} \right].$$

The optimal reset price is

$$p_{i,t}^{M,*} = \frac{\psi_m}{\psi_m - 1} \frac{\mathbb{E}_t \sum_{j=0}^{\infty} (\theta_p \beta)^j \frac{MU_{i,t+j}^k}{P_{i,t+j}} (p_{i,t+j}^M)^{\psi_m} MC_{i,t+j} \mathbb{N}_{i,t+j} M_{i,t+j}}{\mathbb{E}_t \sum_{j=0}^{\infty} (\theta_p \beta)^j \frac{MU_{i,t+j}^k}{P_{i,t+j}} (p_{i,t+j}^M)^{\psi_m} \mathbb{N}_{i,t+j} M_{i,t+j}}. \quad (4.16)$$

Using (4.13),  $p_{i,t}^M$  evolves according to

$$p_{i,t}^M = \left[ \theta_p (p_{i,t-1}^M)^{1-\psi_m} + (1 - \theta_p) (p_{i,t}^{M,*})^{1-\psi_m} \right]^{\frac{1}{1-\psi_m}}. \quad (4.17)$$

Some of the material inputs  $M_{i,t}$  are transformed into tradable varieties that are traded subject to iceberg costs and eventually assembled into a traded intermediate goods; others are directly transformed into a non-tradable intermediate good.

**Traded intermediate goods** Traded intermediates are modelled as in Eaton and Kortum (2002). Each country demands a set of tradable varieties, which can potentially be produced in any country. Competition ensures that the price paid reflects the minimum unit cost across suppliers (inclusive of trade costs).

There is a continuum of varieties of tradable goods indexed by  $\nu \in [0, 1]$  and produced by perfectly competitive firms. The production function for each variety is linear. Specifically,

$$y_{i,t}^T(\nu) = z_i^T(\nu) M_{i,t}^T(\nu)$$

where  $y_{i,t}^T(\nu)$  is the quantity of variety  $\nu$  produced,  $M_{i,t}^T(\nu)$  is the amount of material input

used in production and  $z_i^T(\nu)$  is productivity for good  $\nu$ .

While every country can produce every variety, countries will specialize in those varieties for which they have a comparative advantage. Varieties for which the country has a comparative disadvantage will be imported from abroad. Letting  $x_{i,t}^T(\nu)$  be the quantity of variety  $\nu$  purchased by country  $i$  we can write the quantity of net exports of  $\nu$  as

$$nx_{i,t}(\nu) = y_{i,t}^T(\nu) - x_{i,t}^T(\nu).$$

The nominal cost to produce one unit of variety  $\nu$  in country  $i$  is  $p_{i,t}^M/z_i^T(\nu)$ . We adopt the standard “iceberg” formulation of trade costs: To ship one unit from country  $j$  to country  $i$  requires producing  $\kappa_i^j \geq 1$  units in country  $j$  (with  $\kappa_i^i = 1$ ). Competition implies that the price paid for variety  $\nu$  in country  $i$  is the lowest effective price available:  $p_{i,t}^T(\nu) = \min_j \{ \kappa_i^j p_{j,t}^M E_{i,t}^j / z_j^T(\nu) \}$  where  $E_{i,t}^j \equiv \frac{E_{i,t}}{E_{j,t}}$  is the nominal exchange rate in units of country  $j$ 's currency relative to country  $i$ 's currency.

The tradable varieties are combined into an aggregate “traded” intermediate good  $Y_{i,t}^T$ :

$$Y_{i,t}^T = \left( \int_0^1 (x_{i,t}^T(\nu))^{\frac{\psi_T-1}{\psi_T}} d\nu \right)^{\frac{\psi_T}{\psi_T-1}}. \quad (4.18)$$

where  $\psi_T$  is the elasticity of substitution across the tradable varieties. Following Eaton and Kortum (2002) the productivity parameters  $z_i^T$  are drawn from a Fréchet distribution with shape parameter  $\vartheta$  and scale parameter  $Z_i$ . Assuming that  $1 + \vartheta > \psi_T$  and following the steps in Eaton and Kortum (2002), one can solve for the equilibrium (nominal) price of the traded intermediate good  $P_{i,t}^T$  as

$$P_{i,t}^T = \left[ \Gamma \left( 1 + \frac{1 - \psi_T}{\vartheta} \right) \right]^{\frac{1}{1 - \psi_T}} \Phi_{i,t}^{-\frac{1}{\vartheta}}, \quad (4.19)$$

where  $\Gamma(\cdot)$  is the Gamma function and where  $\Phi_{i,t} \equiv \sum_{j=1}^N Z_j (p_{j,t}^M E_{i,t}^j \kappa_i^j)^{-\vartheta}$ .

**Non-traded intermediate good** In addition to the traded intermediate goods, there is also a non-traded intermediate good denoted by superscript  $N$ . The non-traded intermediate good is produced by competitive firms in each country. Its production is also linear,

$$Y_{i,t}^N = Z_{i,t}^N M_{i,t}^N, \quad (4.20)$$

where  $M_{i,t}^N$  is the quantity of material inputs used in production of the non-traded intermediate  $Y_{i,t}^N$ . Notice that the productivity of non-traded goods producers,  $Z_{i,t}^N$ , is time-varying and constitutes one of the stochastic variables in our model. The price of the non-traded good is

$$P_{i,t}^N = \frac{P_{i,t}^M}{Z_{i,t}^N}.$$

**Final Goods** The final goods are assembled by competitive firms from a CES combination of the traded and non-traded intermediate goods. Final goods producers solve

$$\max \{P_{i,t}Y_{i,t} - P_t^N Y_t^N - P_t^T Y_t^T\}$$

subject to

$$Y_{i,t} = \left( \omega_{i,t}^{\frac{1}{\psi_y}} (Y_{i,t}^N)^{\frac{\psi_y-1}{\psi_y}} + (1 - \omega_{i,t})^{\frac{1}{\psi_y}} (Y_{i,t}^T)^{\frac{\psi_y-1}{\psi_y}} \right)^{\frac{\psi_y}{\psi_y-1}}. \quad (4.21)$$

Here,  $\psi_y$  is the elasticity of substitution between non-traded and traded goods. The weights  $\omega_{i,t}$  for each country pair fluctuate around a long-run average  $\bar{\omega}_i$ , calibrated to the average share of non-traded goods in a country's aggregate demand. Fluctuations in  $\omega_{i,t}$ , in addition to fluctuations in  $Z_{i,t}^N$ , serve as forcing variables in our model.

## 4.4 Monetary Policy

Monetary policy in the euro area is set by the ECB. The ECB follows a ‘‘Mankiw rule’’ that targets GDP-weighted averages of unemployment and inflation throughout the euro area (Mankiw, 2001). The specific monetary policy rule is

$$i_{\epsilon,t} = \phi i_{\epsilon,t-1} + (1 - \phi) \left[ \bar{r} + \phi_{ur} \sum_{i=1}^N \frac{\mathbb{N}_i GDP_i}{\mathbb{N}_{\epsilon} GDP_{\epsilon}} ur_{i,t} + \phi_{\pi} \sum_{i=1}^N \frac{\mathbb{N}_i GDP_i}{\mathbb{N}_{\epsilon} GDP_{\epsilon}} \pi_{i,t} \right]. \quad (4.22)$$

Here  $\mathbb{N}_{\epsilon}$  and  $GDP_{\epsilon}$  denote the steady state population and GDP for the euro area. The parameters  $\phi$ ,  $\phi_u$  and  $\phi_{\pi}$  govern interest rate persistence, the interest rate reaction to high unemployment and the reaction to high inflation respectively. The RoW follows an analogous interest rate rule that responds to fluctuations in unemployment and inflation in the RoW.

## 4.5 Aggregation and Market Clearing

Market clearing for materials requires

$$M_{i,t} = M_{i,t}^N + \int_0^1 M_{i,t}^T(\nu) d\nu.$$

Market clearing for the traded varieties requires that each country's sales of traded varieties equal their production. The share of country  $j$ 's total expenditures on traded intermediate goods from country  $i$  is given by

$$\varpi_i^j = Z_j (p_{i,t}^M E_{j,t}^i \kappa_j^i)^{-\vartheta} \Phi_{j,t}^{-1}. \quad (4.23)$$

Then, country  $i$ 's sales are given by all countries' expenditure on traded intermediate goods from country  $i$ ,  $\sum_{j=1}^N (Z_j p_{i,t}^M E_{j,t}^i \kappa_j^i)^{-\vartheta} \Phi_{j,t}^{-1} \mathbb{N}_{j,t} P_{j,t}^T Y_{j,t}^T$ , whereas perfect competition and zero profits imply that the value of production must be equal to its cost,  $\mathbb{N}_{i,t} p_{i,t}^M M_{i,t}^T$

$$\sum_{j=1}^N Z_j (p_{i,t}^M E_{j,t}^i \kappa_j^i)^{-\vartheta} \Phi_{j,t}^{-1} \mathbb{N}_{j,t} P_{j,t}^T Y_{j,t}^T = \mathbb{N}_{i,t} p_{i,t}^M M_{i,t}^T.$$

The market clearing condition for the final good is

$$\mathbb{N}_{i,t} Y_{i,t} = \mathbb{N}_{i,t} (C_{i,t} + G_{i,t}) + \mathbb{N}_i^k (I_{i,t} + a(u_{i,t}) K_{i,t-1}),$$

where aggregate consumption in country  $i$  is  $\mathbb{N}_{i,t} C_{i,t} = c_{i,t}^k \mathbb{N}_i^k + c_{i,t}^w \mathbb{N}_{i,t}^w$  and  $G_{i,t}$  is government consumption. The level of total government spending  $\mathbb{N}_{i,t} G_{i,t}$  is assumed constant.<sup>18,19</sup> Finally, the bond market clearing conditions is  $\sum_{i=1}^N \mathbb{N}_i^k B_{i,t} = 0$ .

Real GDP is defined as total production evaluated at fixed (steady state) prices  $P_i$ ,

$$GDP_{i,t} = P_i Y_{i,t} + NX_{i,t}$$

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<sup>18</sup>Government spending is financed with lump-sum nominal taxes  $\mathbb{N}_{i,t}^w T_{i,t}^w + \mathbb{N}_i^k T_{i,t}^k = \mathbb{N}_{i,t} P_{i,t} G_{i,t}$ . In steady state, lump-sum taxes per person are equalized across workers and capital owners (i.e.  $T_i^w = T_i^k = P_i G_i$ ). Out of steady state, changes in the real tax burden are born by capital owners (i.e.  $T_{i,t}^w = P_{i,t} G_i$ ). This assumption ensures that migration decisions are not driven by changes in the real tax burden for workers.

<sup>19</sup>We abstract from cross-country fiscal transfers because they are empirically not relevant for the euro area. The European Commission's budget is only about 1% of EU GDP and more than 80% of the budget goes either to the common agriculture policy or to growth-supporting infrastructure project. There is no set of policies that links government expenditure to member countries' business cycle. Asdrubali, Sørensen and Yosha (1996) and Hoffmann et al. (2019) confirm that fiscal transfers play a very limited role in risk sharing in the euro area.

where real net exports are  $NX_{i,t} = \int_0^1 p_i^T(v) nx_{i,t}(v) dv$ .

## 4.6 Forcing Variables

To generate migration and unemployment as seen in the data, the model requires shocks that generate 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 ( $\omega_{i,t}$ ) in equation (4.21) and shocks to TFP in the non-traded sector ( $Z_{i,t}^N$ ) in equation (4.20). Specifically, we assume that

$$\omega_{i,t} = \omega_i (1 - \rho_\omega) + \rho_\omega \omega_{i,t-1} + \varepsilon_{i,t}^\omega$$

$$Z_{i,t}^N = Z_i^N (1 - \rho_Z) + \rho_Z Z_{i,t-1}^N + \varepsilon_{i,t}^Z.$$

where  $\rho_\omega < 1$  is the persistence of the shock to the preference weights and  $\rho_Z < 1$  is the persistence of non-tradeable TFP.

## 5 Model Solution and Estimation

The model is expressed at a quarterly frequency and is calibrated to match the euro area sample of 18 countries. Given a set of parameters, we solve the model using a first-order approximation around a zero inflation steady state. We partition the parameters into a set of calibrated parameters and a set of estimated parameters. Parameters that have commonly accepted values used in the international business cycle literature or parameters that have direct analogues in the data (e.g., trade shares, country sizes, etc.) are calibrated accordingly. Taking the calibrated parameters as given, we estimate the remaining five parameters.

### 5.1 Calibrated Parameters

Table 1 lists the calibrated parameter values for our baseline specification.

#### *Preferences and Technology*

We assume a discount factor of  $\beta = 0.99$ , which implies an annual real interest rate of roughly 4 percent. The intertemporal elasticity of substitution is set to  $\sigma = 0.5$ .

The elasticity of substitution between material input varieties is  $\psi_m = 10$ , implying a markup of roughly 11 percent, in line with studies by Basu and Fernald (1995) and Basu and Kimball (1997) among others. We set  $\alpha = 0.30$  to match a labor income share  $\frac{wL}{GDP} =$

$(1 - \alpha)^{\frac{\psi_m - 1}{\psi_m}}$  of 0.63 consistent with the data reported in Karabarbounis and Neiman (2013). We set the depreciation rate to  $\delta = 0.021$ , which implies an annual depreciation rate of 8 percent.

We set the Calvo pricing parameter to approximate observed frequencies of price adjustment from 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 baseline trade elasticity is  $1 + \vartheta = 1.5$ , which is often used in international business cycle models (see e.g. Backus, Kehoe and Kydland, 1994).<sup>20</sup> The elasticity of substitution between non-traded and traded goods is set to  $\psi_y = 0.44$  (Stockman and Tesar, 1995). Trade costs  $\kappa_i^j$  are set to match trade flows relative to each country’s domestic spending using OECD data on trade in value added. The same data allows us to calculate the steady-state share of non-traded goods in a country’s total demand,  $\omega_i$ , and a country’s overall size, measured by total demand,  $N_i Y_i$ . For the average country in our sample, non-traded goods constitute about 37 percent of overall demand and imports make up roughly 31 percent of of GDP.

### *Migration and Population*

We set  $\frac{N_i^w}{N_i} = 0.5$ . This corresponds to the fraction of hand-to-mouth consumers in Campbell and Mankiw (1989) and is consistent with the calibration in Martin and Philippon (2017) for euro area countries. Conditional on values for  $N_i^w$ , we choose  $\tau_j^i$ , so the migration flows  $n_j^i N_i^w$  in the model match observed bilateral migration flows in the data.<sup>21</sup>

### *Wage Rigidity and Labor Markets*

We set the wage rigidity parameter to  $\theta_w = 0.87$ . This value is based on estimates from Druant et al. (2009) and Grigsby, Hurst and Yildirmaz (2021). We use Eurostat data on unemployment rates and labor force participation ratios to calibrate  $ur_i$  and  $L_i^S$  for each country. For the average country in our sample, the unemployment rate is 9.5 percent and 49 percent of the population are in the labor force.

### *Fiscal and Monetary Policy*

We set the steady-state ratio of government purchases to GDP to the observed value in each

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<sup>20</sup>Estimates of the trade elasticity range from 0.5 to as high as 6. Head and Mayer (2014) cite high values for studies that exploit *cross-country* variations in tariffs across finely disaggregated goods (see also Fontagné, Guimbar and Orefice, 2019). Because the focus of our paper is on business cycle fluctuations, estimates that use *time-series* variation in tariffs or exchange rates are more relevant. Those estimates tend to be quite low, especially in the short run (Cravino, 2014; Boehm, Levchenko and Pandalai-Nayar, 2020).

<sup>21</sup>Backing out values for  $\tau_j^i$  requires a complete matrix of bilateral migration flows. For most country pairs, at least one of the two countries reports data. However, we are missing data for a small number of country pairs. We impute the missing flows based on a gravity equation framework. Appendix Section A.2 provides more details on this procedure as well as a table with the exact bilateral migration flows (Table A12)



country. The monetary policy rule (4.22) is parameterized as  $\phi = 0.75$ ,  $\phi_u = -1.4$  and  $\phi_\pi = 1.4$ , in line with Mankiw (2001).

## 5.2 Estimated Parameters

We estimate the variance of the idiosyncratic location preference shocks ( $\frac{1}{\gamma}$ ), the investment adjustment cost parameter ( $f''$ ), the utilization adjustment cost parameter ( $a''$ ) and the two persistence parameters ( $\rho_\omega$  and  $\rho_Z$ ). Given an initial guess for  $[\gamma, f'', a'', \rho_\omega, \rho_Z]$ , we choose realizations of preference and productivity shocks ( $\epsilon_{i,t}^\omega$  and  $\epsilon_{i,t}^Z$ ) to match unemployment differentials and consumption differentials for every country.<sup>22</sup> The model then generates the remaining endogenous variables. Our parameter estimates are chosen to match the following seven euro-area moments: (i) the OLS slope coefficient of net migration on unemployment in equation (3.5), (ii) the volatility (standard deviation) of investment relative to the volatility of GDP, (iii) the volatility of utilization relative to the volatility of GDP, (iv) the autocorrelation of GDP, (v) the contemporaneous correlation of GDP and the unemployment rate and (vi and vii) the autocorrelation of the two structural innovations ( $\epsilon_{i,t}^\omega$  and  $\epsilon_{i,t}^Z$ ).

We target the population-weighted average volatilities of the double-demeaned data (we also double-demean the data generated by the model). We double-demean variables that have a trend (e.g. GDP) by first taking logs, then removing a country-specific linear trend and finally adjusting the log deviations from this linear trend by subtracting a weighted average of deviations for all of the countries in our sample.

The slope coefficient of regression (3.5) is the most important moment to target since it summarizes the relationship between labor mobility and unemployment in the euro area. We target the standard deviation of investment to GDP and utilization to GDP because these moments are important for determining the investment adjustment costs and the capital utilization elasticity. We target the persistence of GDP overall and the correlation of GDP with the unemployment rate to ensure that the model matches overall business cycle features. Finally, we also target the persistence of the structural innovations ( $\epsilon_{i,t}^\omega$  and  $\epsilon_{i,t}^Z$ ). Under the null hypothesis that the model is correctly specified, these innovations should have zero serial correlation. Because we are targeting seven moments to estimate only five parameters, we are technically over-identified and thus the model moments will not exactly match the moments in the data.

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<sup>22</sup>Note that while our empirical analysis was based on annual data, we calibrate our model at a *quarterly* frequency. We recover the innovations  $\epsilon_t^\omega$  and  $\epsilon_t^Z$  to match the quarterly unemployment rate and consumption differentials.

### 5.3 Model and Data Comparison

Table 2 shows the measures of model fit for the seven targeted moments described above as well as other business cycle moments. By double-demeaning the data, we remove country and time fixed effects leaving just country-specific variation. Similarly, the shocks in the model are idiosyncratic, country-specific innovations. We refer to the country-specific fluctuations in the data and in the model as “business cycle” fluctuations with the understanding that the common component of the business cycle has been removed. Recall that Figure 4 showed that only about a fifth of unemployment variation in the euro area can be attributed to a common cycle and that the majority of unemployment variation is country-specific.

Column (1) reports the (population-weighted) moments in the data, column (2) reports results for the baseline model and columns (3) and (4) show results for the model with only preference shocks ( $\omega$ ) and only productivity shocks ( $Z^N$ ) (we hold the estimated parameters fixed in those specifications.)

The table shows that the estimated model does a good job matching key business cycle moments in the euro area. This suggests that the model should serve as a reasonable framework to evaluate the relative effects of exchange rate flexibility and labor mobility. Columns (3) and (4) also indicate that both shocks are needed to match the data. Demand shocks ( $\omega$ ) produce greater fluctuations in unemployment and migration compared to TFP shocks. TFP shocks ( $Z^N$ ) are necessary for generating sufficiently volatile, procyclical investment rates and countercyclical net exports. TFP shocks also play an important role in producing inflation and investment volatility. Demand and supply shocks have different implications for inflation; this will be important in the results to follow.

## 6 Effects of Labor Mobility in a Currency Union

We are interested in whether labor mobility is indeed an effective substitute for independent monetary policy in the euro area. To get at this question, we use the estimated model to explore different counterfactuals – in particular, we solve the model assuming the countries either have independent monetary policies or have higher migration rates. In each scenario, we use the same sequence of shocks as in the baseline model. To simulate the counterfactual with greater labor mobility, we adjust  $\gamma$  to match the U.S. slope coefficient from our regression of net migration on unemployment ( $-0.26$  rather than  $-0.08$ , see Figure 5). In simulations with flexible exchange rates, we assume that each country pursues an independent monetary policy following (4.22).

Table 3 summarizes the key results of the counterfactual experiments. We begin by ex-

aming business cycle outcomes, then conduct a utility-based welfare analysis, and conclude with a discussion of the economic reasoning for our findings.

## 6.1 Stabilizing Fluctuations in Production and Employment

Table 3 presents results for seven scenarios. Columns (1) and (2) report results for the model assuming no migration: column (1), labeled ‘Fixed,’ reports results under the currency union while column (2), labeled ‘Float’ gives results for the model with independent monetary policy and floating exchange rates. Columns (3), (4) and (5) report model simulations with the baseline level of labor mobility but under different assumptions about monetary policy and price adjustment. The baseline case in column (3) reflects current conditions in the euro area with a fixed exchange rate and an average migration elasticity that matches the data. The slope coefficient on net migration is  $-0.08$  and the volatility of unemployment is 2.28, as in the data. Column (5), labeled ‘Flex,’ is the baseline model but with flexible wages and prices. Columns (6) and (7) show results for the model with rates of labor mobility similar to the United States with a slope coefficient on net migration of  $-0.26$ .

To see the impact of labor mobility on cyclical fluctuations, we can compare column (1) — with no migration and fixed exchange rates — to the baseline in column (3), and to the case of higher labor mobility in column (6). Two things stand out from this comparison. First, as labor mobility increases, the volatility of *per capita* variables (the unemployment rate, GDP, and consumption) tends to decline, while the volatility of *aggregate* variables tends to increase. Workers migrate to countries that are above trend and leave countries that are below trend, increasing total output in the country of destination while reducing output per person. Second, the results for the baseline case are quite similar to the “no mobility” results. This is an indication that current labor mobility rates in the euro area are actually low, and quite far from the degree of labor mobility in the United States.

Next consider how the results with increased labor mobility compare with the counterfactual of floating exchange rates. The results for the baseline level of labor mobility with independent monetary policy are shown in column (4) and with completely flexible prices and wages in column (5). The flexible price setting will be a useful benchmark for welfare comparisons in section 6.2 since this is a case in which there are no distortions due to price and wage rigidity and there are no fluctuations in unemployment. The first thing to note is that the outcomes under floating exchange rates come very close to the outcomes with flexible prices. By targeting fluctuations in unemployment, independent monetary policy closely approximates the flexible price equilibrium. The more interesting comparison is between columns (3) and (4). Moving from fixed to floating exchange rates leads to a considerable reduction in business

cycle volatility. For instance, the volatility of unemployment falls from 2.28 to 0.24 and the volatility of per capita consumption falls from 2.80 to 2.01.

The results in Table 3 suggest that both higher labor mobility and flexible exchange rates work to reduce fluctuations in per capita terms. The volatility of unemployment, consumption and output all decline with floating exchange rates as well as with greater labor mobility, though the decline is much sharper with independent monetary policy.

Figure 7 shows that the basic pattern in Table 3 holds for most of the countries in the euro area. The dark bars display the volatility of the unemployment rate in the baseline model and correspond to (the square root of) the idiosyncratic variance displayed in Figure 4. For each country, the volatility of unemployment in the baseline falls with higher migration. The reductions are greatest for Germany, Belgium, Spain, Ireland and Greece – each of which experience reductions in unemployment volatility of roughly 25-35 percent. For the typical country however, the stabilizing role of migration is more modest with reductions in unemployment variation of about 10-15 percent. In all cases, floating exchange rates dramatically reduce unemployment volatility relative to the baseline.

## 6.2 Welfare Cost of a Currency Union

We next turn to a formal welfare assessment of the costs of operating under different exchange rate regimes and for different degrees of labor mobility. We adapt standard techniques from the New Keynesian literature to our setting (see Woodford, 2003; Galí, 2008) to measure the compensating variation for workers and capital owners relative to the allocations in the flexible price equilibrium. Because preferences of workers and capitalists differ, and because they have different consumption paths, we need to make two separate welfare calculations.

**Approximate Welfare Losses** The welfare losses for capital owners can be measured as the additional consumption required to compensate them for experiencing inefficient consumption fluctuations and for reduced average consumption caused by wage and price inflation. In the appendix we show that these losses can be approximated (up to a second order) as

$$\frac{dc_{i,t}^k}{c_i^k} \simeq \frac{1}{2} \frac{1}{\sigma} (\hat{c}_{i,t}^k)^2 + \frac{1}{2} \frac{Y_i}{C_i} \left[ \frac{1-\alpha}{\mu} \Theta_w (\pi_t^w)^2 + \left( \frac{\mathbb{N}}{\mathbb{N}^k} \frac{\mu-1+\alpha}{\mu} + \frac{1-\alpha}{\mu} \right) \psi_m \Theta_p (\pi_t^p)^2 \right] \quad (6.1)$$

where  $\Theta_w = \frac{\theta_w}{(1-\theta_w\beta)(1-\theta_w)}$ ,  $\Theta_p = \frac{\theta_p}{(1-\theta_p\beta)(1-\theta_p)}$ , and the steady-state markup is  $\mu = \frac{\psi_m}{\psi_m-1}$ . Here,  $\hat{c}_{i,t}^k$  is the date  $t$  consumption “gap” for capital owners in country  $i$  relative to the flex-price

equilibrium. That is,  $\hat{c}_{i,t}^k = \ln c_{i,t}^k - \ln c_{i,t}^{k,\text{Flex}}$ .<sup>23</sup> The terms multiplying the wage and materials inflation rates reflect the steady state share of the respective income received by capital owners.

The calculation for workers is slightly more complicated as workers experience two counteracting influences on welfare. Like the capital owners, workers dislike inefficient fluctuations in consumption caused by price and wage rigidity and they suffer from forgone output caused by inflation. At the same time, workers have the option to move to locations with better economic conditions. Combining (4.4) and (4.5), the flow utility for a worker can be expressed in terms of their current consumption together with their current migration rate  $\hat{n}_{i,t}^i$ . With this expression for utility, we can approximate the consumption required to compensate workers as

$$\frac{dc_{i,t}^w}{c_i^w} = \frac{1}{\sigma} \frac{1}{2} (\hat{c}_{i,t}^w)^2 + \frac{1}{2} \frac{1-\alpha}{\mu} \frac{Y_i}{C_i} \left[ \Theta_w (\pi_t^w)^2 + \psi_m \Theta_p (\pi_t^p)^2 \right] - \frac{1}{2} \frac{1}{\gamma c_i^w} (\hat{n}_{i,t}^i)^2 \quad (6.2)$$

This expression is very close to the expression for the capital owners with the exception of the term for  $(\hat{n}_{i,t}^i)^2$  which reduces the loss to the workers. Quantitatively, given the current variation in migration rates observed throughout the euro area, the contribution of the third term is quite small relative to the value of consumption smoothing.

To calculate the variances in the expressions above, we use the recovered shocks from our estimation procedure. This means the variances reflect the business cycle conditions that prevailed during our sample period. Also, by using the shocks from the sample period, we can sidestep the estimation of the variance-covariance matrix of shock innovations.

**Welfare in a Currency Union versus High Labor Mobility** Panel C of Table 3 reports the statistics used for the welfare calculations in (6.1) and (6.2). The first two rows report the volatility of the consumption gap for workers and capital owners. Comparing columns (1), (3) and (6), we see that, as mobility increases, consumption volatility for workers declines, while it increases for capital owners. Because we are reporting consumption gaps, the volatilities are small compared to the overall volatility of consumption in panel A. By definition, the gaps are zero in the flex-price case (column 5). The next three rows report the volatility of the migration rate  $\hat{n}_{i,t}^i$  and the volatility of wage and price inflation.

Panel D reports the per capita cost (in euros) of each component of equations (6.1) and (6.2) relative to the flex-price allocation in column (5).<sup>24</sup> The last two rows report the total

<sup>23</sup>This expression assumes that the flex-price equilibrium is constrained efficient. Specifically, we consider allocations in which the unconditional expected value of any variable is equal to its flex-price counterpart.

<sup>24</sup>To calculate these terms, we multiply the country-specific variances by the coefficients given in equations (6.1) and (6.2); we then scale this amount by the country-specific average annual per-capita consumption spending over the sample period. The total welfare cost is the average of the welfare costs for workers and capital owners and corresponds to the cost associated with wage inflation, material price inflation as well as the average of the first 3 rows in Panel D.

welfare cost in euros. The flex-price equilibrium has zero welfare cost because, by definition, the gap terms are zero and the coefficients on wage and price inflation in (6.1) and (6.2) are both zero.

Notice first that the welfare costs associated with consumption variability are very small while the the welfare costs associated with inflation are substantial. This is a standard finding in New Keynesian models (Rotemberg and Woodford, 1997; Galí, 2008; Coibion, Gorodnichenko and Wieland, 2012). The cost of inefficient consumption volatility for workers is only two euros in the baseline and is essentially zero for the capital owners. In contrast, the welfare costs of wage and price inflation are substantial. Taken together, wage and price inflation in the baseline entail costs of 271 euros per year ( $224 + 47$ ).

By adopting a floating exchange rate, countries can greatly reduce the cost of business cycles. The costs for capital owners fall from 354 euros to only 124 euros – a reduction of 65 percent. Similarly, the average cost for workers falls from 191 to 62 euros or nearly 68 percent. In comparison, if the euro area had migration rates comparable to the United States, the cost of business cycles would fall much less. Shifting to high migration rates results in a reduction of business cycles costs of roughly 25 percent for capital owners and only 21 percent for workers. Taken as whole, the results suggest that, overall, a shift toward flexible exchange rates or toward higher labor mobility would improve welfare, but plausible rates of labor migration are not enough to deliver the full gains of independent monetary policy.

The results in Table 3 allow us to assess the cost of joining a currency union and how that cost would change depending on the degree of labor mobility. The bottom row of Panel D shows the welfare cost per capita averaging over workers and capital owners under different model scenarios. In each case, the cost is expressed relative to the flex-price optimal allocations. The opportunity cost of giving up flexible exchange rates is the difference between the welfare losses in the currency union ('Fixed') and the welfare losses with floating exchange rates ('Float'). Stated another way, this difference is the cost facing an average country contemplating joining the currency union. With no labor mobility, this cost is 195 euros per person (annually). As labor becomes more mobile, the cost falls. With the baseline mobility, the cost falls to 180 euros. If labor flows in the euro area were as responsive as they are in the United States, the cost would be only half as large (93 euros).

The welfare improvements in Table 3 mask considerable differences at the country level. Figure 8 shows the welfare measures for each country separately. (The figure reports the average across workers and capital owners.) While we saw above that increased migration reduces unemployment volatility in all countries, Figure 8 shows that only a small number of countries experience an increase in welfare. Two of the largest countries in the euro area,

Germany and Spain, experience large welfare gains from greater labor mobility. Gains are also positive for Portugal and Greece. On the other hand, many countries in the euro area experience significant welfare losses from greater migration, particularly very small countries on the periphery (Cyprus and the Baltics, for example).

To understand why some countries actually suffer from mobility, the figure also shows how these welfare calculations depend on the shocks that each country experiences. The middle panel shows the welfare improvements of high migration if the countries experienced only preference shocks (shocks to  $\omega_{i,t}$ ). In this case, every country benefits from higher migration. The rightmost panel shows the opposite case in which countries experience only productivity shocks ( $Z_{i,t}$ ). In this case, almost all countries suffer. This suggests first that productivity shocks (supply shocks) present a problem for Mundell’s argument and second, that many countries in the euro area are buffeted by productivity disturbances.

As we can see in Table 3, most of the welfare costs are driven by inflation – the welfare impacts of inefficient variation in consumption in contrast are very small. The same is true country-by-country. Thus, in Figure 8, nearly all of the welfare bars reflect the welfare costs of inflation rather than consumption stabilization. Spain, Germany, and Portugal are dominated by preference shocks and thus labor mobility improves welfare by stabilizing inflation. Cyprus and the Baltics however tend to experience TFP shocks and welfare declines with greater mobility as inflation becomes more volatile.

**Supply and Demand Shocks in a Currency Union** To better understand why labor mobility poses a problem with supply shocks, we briefly present a special case of the model that can be solved analytically. Consider a small “home” country that is part of a currency union. The country is sufficiently small that it has no influence over economic variables in the rest of the world.<sup>25</sup> The steady-state share of domestically produced tradable intermediates in total traded intermediate goods, is denoted by  $\varpi$ . Since we are focusing on a single country we suppress the  $i$  subscripts.

We make the following simplifying assumptions: (i) There is no capital ( $\mathbb{N}^k = 0$ ,  $\alpha = 0$ ); (ii) wages are flexible ( $\theta_w = 0$ ) so per capita employment is constant and normalized to 1; (iii) we set  $\psi_y = 1$  so final good production is  $Y_t = (Y_t^N)^{\omega_t} (Y_t^T)^{1-\omega_t}$ ; (iv) trade is balanced at all times; finally, (v) we examine the model’s limiting behavior as  $\beta \rightarrow 0$ . This final assumption makes both the migration decision (equation 4.6) and the price setting decision (equation 4.16)

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<sup>25</sup>We consider the limiting case in which the country’s population approaches zero in proportion to the shape parameter for the Frechet distribution  $Z$ . See Alvarez and Lucas Jr (2007). We also require that  $Z\kappa^\theta$  is constant in the limit as  $Z$  approaches 0. ( $\kappa$  is the trade cost parameter from the rest of the world to the small home country.) This ensures that the traded good exhibits home bias.

particularly simple. Starting at an initial steady state, equilibrium aggregate labor supply will satisfy

$$\tilde{N}_t = \hat{\gamma} \tilde{w}_t$$

where  $\tilde{w}_t$  is the percent deviation in the real wage and  $\hat{\gamma} = (1 - n^2) \gamma$  is the effective migration elasticity ( $n$  is the steady state share of households who do not move). The equilibrium material price will satisfy

$$\tilde{p}_t^M = (1 - \theta) \tilde{W}_t$$

(the nominal marginal cost of materials is equal to the wage). Output losses arise from fluctuations in  $p_t^M$ . Since wages are flexible, per-capita employment is constant and per-capita production of materials is

$$M_t = \frac{1}{v_t},$$

where  $v_t = \int_0^1 \left( \frac{p_t^M(s)}{p_t^M} \right)^{-\psi_m}$  is a measure of price dispersion. In a flexible-price equilibrium  $v_t = 1$  and there is no inefficiency in production. If prices differ across producers, then  $v_t > 1$  and there is an avoidable loss in output.

The following Lemma summarizes the key conditions that characterize the equilibrium. The proof is in the appendix.

**Lemma 1** *Starting from an initial steady state, the first-order approximate solution to the model must satisfy equations (i), (ii), and (iii) below. Equation (iv) gives the second order approximate loss from nominal rigidity:*

$$(i) \quad \tilde{N}_t = \hat{\gamma} \tilde{w}_t$$

$$(ii) \quad \tilde{N}_t = -\Psi_1 \left( \tilde{E}_t + \tilde{p}_t^M \right) + \tilde{\omega}_t$$

$$(iii) \quad \tilde{w}_t = \omega \tilde{Z}_t - (1 - \omega)(1 - \varpi) \tilde{E}_t + \Psi_2 \tilde{p}_t^M$$

$$(iv) \quad v_t \approx 1 + \Theta_v (\tilde{p}_t^M)^2,$$

$$\text{with } \Psi_1 = 1 + \vartheta(1 + \varpi), \Psi_2 = \frac{1}{1-\theta} - \omega + (1 - \omega)\varpi \text{ and } \Theta_v = \frac{1}{2} \frac{\theta}{1-\theta} \psi_m (\psi_m - 1 + 2\theta).$$

We consider two cases: either the nominal exchange rate is fixed ( $\tilde{E}_t = 0$ ) or it is set to ensure no change in the price of materials ( $\tilde{p}_t^M = 0$ ) – a form of price-level targetting. By eliminating fluctuations in the materials price, exchange rate flexibility effectively eliminates all losses due to nominal rigidity.

With a fixed exchange rate (in the currency union), Lemma 1 implies

$$\tilde{N}_t = \frac{\hat{\gamma}}{\Psi_1 + \hat{\gamma} \Psi_2} \left[ \Psi_1 \tilde{\omega}_t + \omega \Psi_2 \tilde{Z}_t \right],$$



$$\tilde{w}_t = \frac{1}{\Psi_1 + \hat{\gamma}\Psi_2} \left[ \Psi_1 \tilde{\omega}_t + \omega \Psi_2 \tilde{Z}_t \right],$$

and

$$\tilde{p}_t^M = \frac{\tilde{\omega}_t - \hat{\gamma}\omega \tilde{Z}_t}{\Psi_1 + \hat{\gamma}\Psi_2}.$$

Naturally, both employment and the real wage are increasing in the demand shock ( $\tilde{\omega}_t$ ) and the productivity shock ( $\tilde{Z}_t$ ). Also, as we saw in the quantitative model, as the effective migration elasticity  $\hat{\gamma}$  increases, wage fluctuations are reduced while aggregate employment fluctuations increase.

The crucial difference between the two exchange rate regimes is that the materials price fluctuates in the currency union whereas it remains constant in the floating exchange rate regime. Because only some prices adjust, there are inefficient fluctuations in the purchases of different varieties of material inputs. Lemma 1 shows that these inefficiencies are directly tied to the variations in  $p_t^M$ .

The cost of being in a currency union is the expected output lost under the fixed exchange rate compared to the optimal monetary policy. For simplicity, we assume demand shocks and productivity shocks are uncorrelated and have variances  $\sigma_\omega^2$ , and  $\sigma_Z^2$ . The following proposition quantifies the costs of the union and shows how these costs vary with migration.

**Proposition 1 (Cost of currency union)** *The expected cost of the currency union is*

$$\Theta_v \frac{\sigma_\omega^2 + (\hat{\gamma}\omega)^2 \sigma_Z^2}{(\Psi_1 + \hat{\gamma}\Psi_2)^2},$$

where  $\Psi_1 > 0$ ,  $\Psi_2 > 0$  and  $\Theta_v > 0$  are defined in Lemma 1. Higher migration rates reduce the expected cost of being in a currency union if

$$\frac{\Psi_1}{\Psi_2} \hat{\gamma} \omega^2 < \frac{\sigma_\omega^2}{\sigma_Z^2}.$$

This proposition shows that labor mobility alleviates the costs associated with demand shocks but exacerbates costs coming from productivity shocks. Put differently, Mundell's hypothesis holds for demand shocks – not for productivity shocks.

In the limit as migration vanishes (as  $\hat{\gamma} \rightarrow 0$ ), the cost of being in the currency union is  $\frac{\Theta_v}{\Psi_1^2} \sigma_\omega^2$ . That is, the cost of the union is a pure reflection of the prevalence of demand shocks. At the other extreme, as migration becomes infinitely elastic ( $\hat{\gamma} \rightarrow \infty$ ), the cost of being in the currency union approaches  $\frac{\Theta_v}{\Psi_2^2} \omega^2 \sigma_Z^2$ . For intermediate values of  $\hat{\gamma}$ , greater mobility will lead to improvements in efficiency only if demand shocks are sufficiently prevalent.

To better understand the economic intuition, we return to the quantitative model and

generate impulse responses for an economy calibrated to match Belgium.<sup>26</sup> Figure 9 shows impulse responses to a one percent increase in  $\omega$ . Following the increase in demand, production increases at both the aggregate and per capita levels (panels b and c). Real wages rise for workers in Belgium and unemployment falls (panel c) both of which lead to a modest, yet sustained inflow of workers (panel a). Naturally, the inflow of workers is greater in the “high mobility” case given by the dashed lines in the figure. The increase in demand also causes wages and prices to rise. In a high migration environment, the additional inflow of workers eases these inflationary pressures and attenuates the drop in unemployment. Thus, in the face of demand shocks, migration stabilizes unemployment and inflation.

Figure 10 shows impulse responses for a positive TFP shock. Again, real wages rise and workers gradually enter the country. Unlike the demand shock however, the increase in TFP puts downward pressure on prices and wages. With higher migration, the additional supply of workers push wages and prices down even more. Rather than tempering the deflationary pressure from the shock, migration makes deflation even more pronounced. While migration can act as a substitute for monetary policy in the face of demand shocks, supply shocks present a problem: migration stabilizes per capita employment and production but it destabilizes inflation. Because inflation receives such a large weight in the welfare expressions (6.1) and (6.2), labor mobility can raise the costs of a common currency if countries are exposed to supply shocks.

## 7 Conclusion

Euro area countries experienced large differences in unemployment over the last fifteen years, raising concerns about whether sharing a common monetary policy is sustainable without further reforms. In this paper, we examine Mundell’s assertion that if factors are mobile across national boundaries, then a flexible exchange rate system becomes unnecessary. We ask to what extent, given the conditions in the euro area now, does labor mobility provide the benefits of independent monetary policy. We first compare the degree of labor mobility over the business cycle to labor mobility in the United States. The data paint a clear picture: migration flows react to cyclical variations in unemployment rates in the euro area 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 role of labor mobility in stabilizing business cycles in a multi-country DSGE model, augmented to include cross-country migration and

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<sup>26</sup>We use Belgium for the purposes of exposition. The results are broadly consistent across countries with some modest variation in the magnitude of the effects.

frictions in the labor market that give rise to unemployment. The model is calibrated to match the main features of the European countries in our dataset including country size, migration patterns, and trade flows. The model features shocks to the demand and supply of each country's non-traded good. We choose the realizations of these shocks so that the model generates time series of unemployment and consumption that match those observed in the data. Our model replicates the low degree of labor mobility in the euro area and matches well the dynamic behavior of macro variables observed in the 1995-2018 period.

We then use the model to evaluate the benefits of greater labor mobility or the adoption of independent monetary policies relative to the baseline. Our analysis cautions against a simple answer: while, on average, labor mobility stabilizes unemployment rates (as does monetary policy), labor mobility increases the dispersion in aggregate output and consumption across the euro area. Labor mobility can also generate large changes in wage and price inflation. We find that there is substantial heterogeneity across the euro area in the assessment of the benefits of labor mobility, as that assessment depends on the nature of the shocks that confront individual countries and the metric used to assess the different outcomes.

The empirical evidence suggests that the euro area is moving toward increased labor mobility, but at a slow pace. Indeed, the model suggests that business cycle fluctuations in the euro area are closer to the "no mobility" benchmark than to the extent of labor mobility observed in the United States. If labor mobility remains at such a low degree, it may be that the euro area will need to turn to other mechanisms, such as fiscal transfers, to mitigate business cycles and to provide the adjustment that would otherwise be borne by a flexible exchange rate.

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Table 1: CALIBRATION

Parameter	Value	Target / Source
<b>Preferences</b>		
Coefficient of relative risk aversion	2	Standard value
Discount factor	0.99	Standard value
<b>Technology</b>		
Curvate of production function	0.30	Labor income share of 0.63 for Germany (Karabarbounis and Neiman, 2013)
Depreciation rate	0.021	Annual depreciation rate of 8 percent
Elasticity of substitution bw. materials	10	e.g. Basu and Fernald (1995), Basu and Kimball (1997)
Sticky price probability	0.77	Price duration: 13 months (Alvarez et al., 2006)
<b>Trade and Country Size</b>		
Trade elasticity	$1 + \vartheta$	e.g. Cravino (2014); Boehm, Levchenko and Pandalal-Nayar (2020)
Elasticity of substitution bw. $Y^N$ and $Y^T$	0.44	Stockman and Tesar (1995)
Share of non-traded goods in total demand	$\omega_i$	OECD TiVA (2005-2015)
Trade preference weights	$\kappa_i^t$	Import shares for traded goods; OECD TiVA (2005-2015)
Country size	$N_i Y_i$	Total demand; OECD TiVA (2005-2015)
<b>Migration</b>		
Population	$N_i$	Europe: Eurostat ('95-'15)
Migration costs	$\tau_i^t$	Bilateral gross migration flows (see text for details)
Share of workers	$\frac{N_i^w}{N_i}$	0.5 Campbell and Mankiw (1989), Martin and Philippon (2017)
<b>Labor Markets</b>		
Unemployment rate	$w_i$	Eurostat ('95-'15)
Labor force	$L_i^s$	Eurostat ('95-'15)
Nominal wage rigidity	$\theta_w$	Druant et al. (2009)
<b>Fiscal and Monetary Policy</b>		
Gov't purchases over final demand	$\frac{G_i}{Y_i}$	x Eurostat ('95-'15)
Taylor rule persistence	$\phi$	0.75 Clarida, Gali and Gertler (2000)
Taylor rule GDP coefficient	$\phi_{GDP}$	0.50 Clarida, Gali and Gertler (2000)
Taylor rule inflation coefficient	$\phi_\pi$	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 2: ESTIMATION

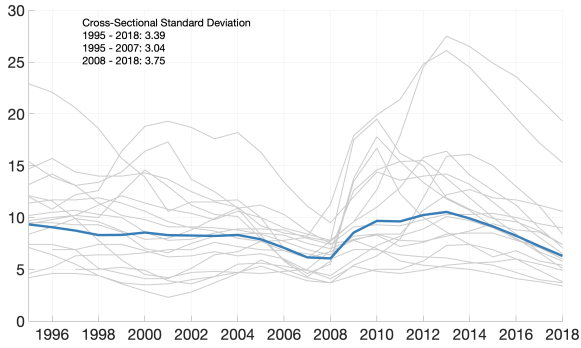
	(1)	(2)	(3)	(4)
	Data	Baseline model	Only $\omega$ shocks	Only $Z^N$ shocks
<b>Estimated Parameters</b>				
Migration propensity ( $\gamma$ )		0.14	0.14	0.14
Investment adjustment cost ( $f''$ )		1.20	1.20	1.20
Utilization adjustment cost ( $a''$ )		0.02	0.02	0.02
Persistence preference weights ( $\rho_\omega$ )		0.96	0.96	0.96
Persistence TFP shocks ( $\rho_Z$ )		0.88	0.88	0.88
<b>Targeted Moments</b>				
Slope coefficient $\widehat{nm}_{i,t}$ on $\widehat{ur}_{i,t}$	-0.08	-0.08	-0.06	-0.06
Volatility investment to GDP	3.63	3.55	1.30	4.15
Volatility utilization to GDP	0.98	1.02	0.95	1.17
GDP ( $GDP$ )	0.95	0.94	0.93	0.95
Unemployment ( $ur$ )	-0.63	-0.58	-0.89	-0.47
Persistence $\varepsilon_{i,t}^\omega$	0.00	0.33	0.33	0.00
Persistence $\varepsilon_{i,t}^Z$	0.00	0.07	0.00	0.07
<b>Other Moments</b>				
<i>Time-Series Standard Deviation</i>				
Unemployment rate ( $ur$ )	2.28	2.28	2.43	0.73
Consumption per capita ( $C$ )	2.80	2.80	2.05	2.00
Investment per capita ( $I$ )	8.07	12.93	2.71	12.11
GDP per capita	2.45	3.64	2.23	2.85
GDP	2.60	3.73	2.25	2.94
Inflation	2.20	2.72	0.65	2.71
Net exports over GDP ( $\frac{nx}{GDP}$ )	1.24	0.96	0.41	1.18
Net migration rate ( $nm$ )	0.26	0.18	0.16	0.09
<i>Persistence</i>				
Net exports over GDP ( $\frac{nx}{GDP}$ )	0.89	0.96	0.96	0.96
Investment per capita ( $I$ )	0.88	0.96	0.97	0.96
Net migration rate ( $nm$ )	0.65	0.83	0.86	0.74
<i>Correlation with GDP</i>				
Consumption per capita ( $C$ )	0.80	0.96	0.93	1.00
Investment per capita ( $I$ )	0.84	0.79	0.73	0.99
Net exports over GDP ( $\frac{nx}{GDP}$ )	-0.43	-0.51	0.36	-0.79
Inflation ( $\pi$ )	0.07	0.05	0.85	-0.03

*Notes:* Moments are calculated based on double-demeaned quarterly data (except moments that refer to net migration, which refer to annual data; in that case, we time-aggregate the simulated quarterly data). The displayed moments are calculated as the **weighted average** across countries.

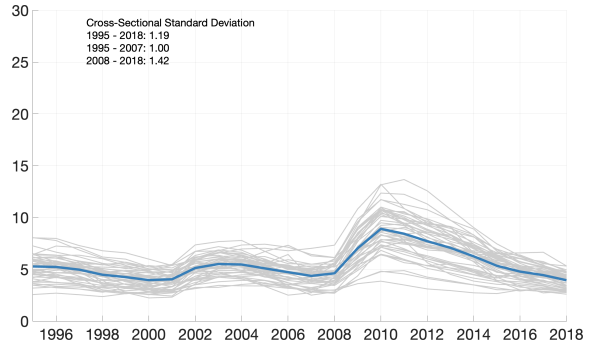
Table 3: MUNDELL'S TRADEOFF

	No mobility		Baseline mobility			High mobility	
	(1) Fixed	(2) Float	(3) Fixed	(4) Float	(5) Flex	(6) Fixed	(7) Float
<b>Panel A: Volatility, Per-Capita Variables (percent)</b>							
Unemployment rate	2.36	0.24	2.28	0.24	0.00	1.73	0.27
GDP per capita	4.46	3.44	4.43	3.50	3.55	3.37	3.41
Consumption per capita	2.89	2.03	2.80	2.01	2.06	2.02	1.88
Net migration	0.00	0.00	0.19	0.17	0.16	1.77	1.60
<b>Panel B: Volatility, Aggregate Variables (percent)</b>							
GDP	4.46	3.44	4.09	3.37	3.53	6.44	6.19
Consumption	2.89	2.03	3.34	2.81	2.81	6.96	6.56
<b>Panel C: Volatility Measures for Welfare (percent)</b>							
Consumption gap workers	1.03	0.15	1.00	0.14	0.00	0.68	0.11
Consumption gap capital owners	0.26	0.04	0.26	0.04	0.00	0.33	0.07
Migration gap workers	0.00	0.00	0.01	0.00	0.00	0.16	0.04
Wage inflation	1.03	0.43	0.99	0.45	1.90	0.74	0.49
Material price inflation	0.97	0.58	0.97	0.61	1.96	0.91	0.68
<b>Panel D: Welfare Costs (euros per capita)</b>							
Consumption gap workers	3	0	2	0	0	1	0
Consumption gap capital owners	0	0	0	0	0	0	0
Migration gap workers	0	0	0	0	0	0	0
Wage inflation	51	8	47	9	0	24	11
Material price inflation	227	77	224	84	0	188	108
Workers (Total)	197	57	191	62	0	143	79
Capital owners (Total)	362	114	354	124	0	281	159
Total	280	85	273	93	0	212	119
<b>Cost of Currency Union (euros per capita)</b>							
<b>Total</b>	<b>195</b>	<b>–</b>	<b>180</b>	<b>–</b>	<b>–</b>	<b>93</b>	<b>–</b>

*Notes:* Table displays several moments as observed in the data (1995 - 2018) and derived from alternative model simulations. Data moments are based on double-demeaned data. The weighted average across countries is displayed. For the high mobility case, we adjust the migration parameter ( $\gamma$ ) to match the slope coefficients for the United States. For the floating exchange rate case, all countries follow a Mankiw rule. Inflation measures record annualize rates. The last row displays the cost of the currency union, calculated as the welfare cost under fixed exchange rates less the welfare cost under floating exchange rates.



(a) Euro area



(b) U.S.

Figure 1: UNEMPLOYMENT RATES IN EURO AREA COUNTRIES AND US STATES

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

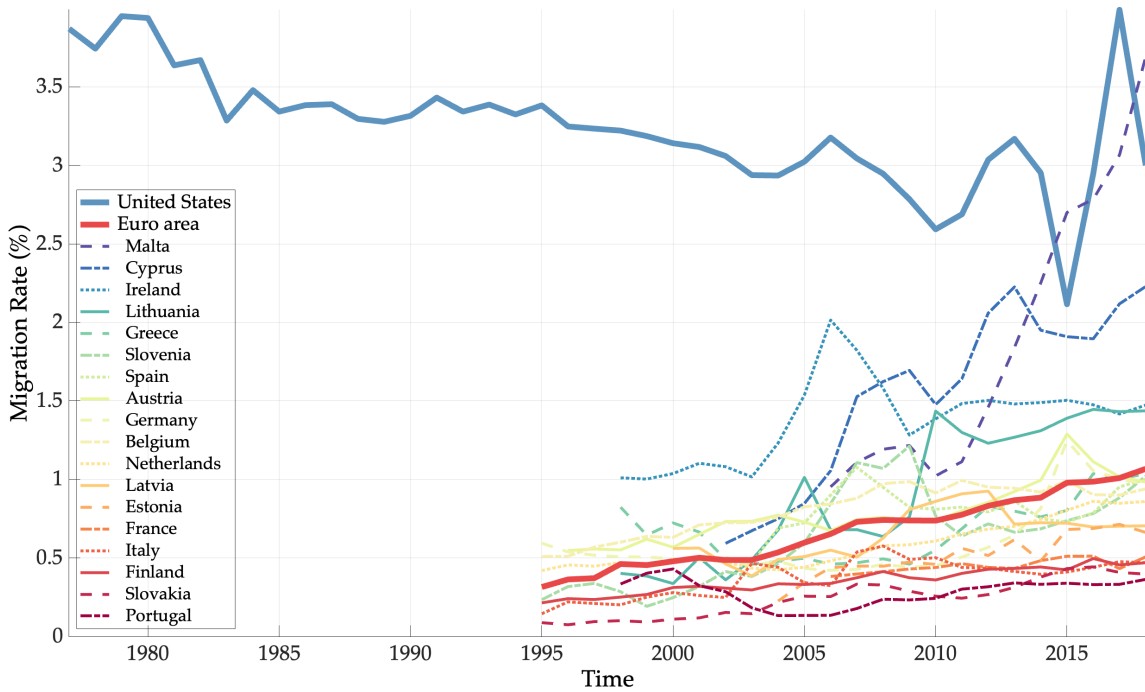


Figure 2: MIGRATION RATES OVER TIME

Note: The figure plots the migration-to-population ratio over time for the average of U.S. States, the average of euro area countries and individual euro area countries. The average for the European sample is an average over all countries with available data in any given year.

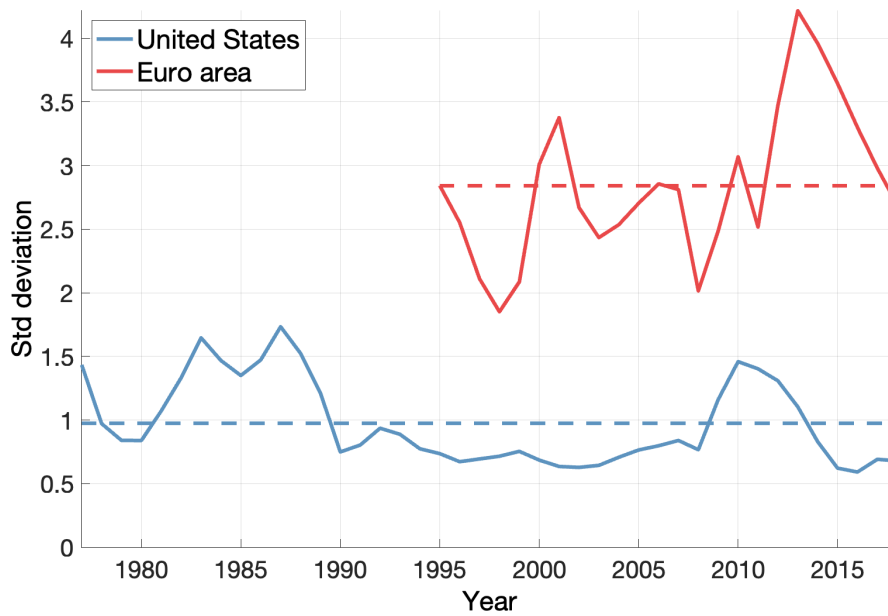


Figure 3: CROSS-SECTIONAL STANDARD DEVIATIONS IN UNEMPLOYMENT RATES

*Note:* The figure plots cross-sectional standard deviation in demeaned unemployment rates,  $\widehat{ur}_{i,t}$ , for the U.S. states and for the euro area countries. The dotted lines are the respective time averages. See the text for the definition of demeaned unemployment rates.

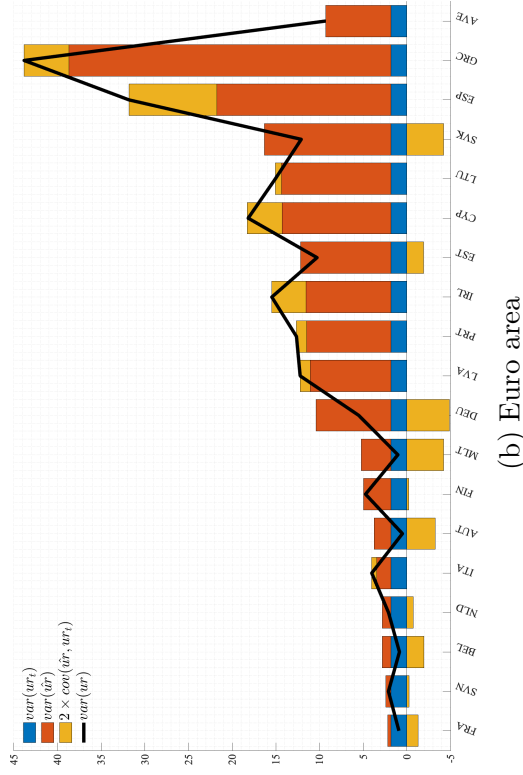
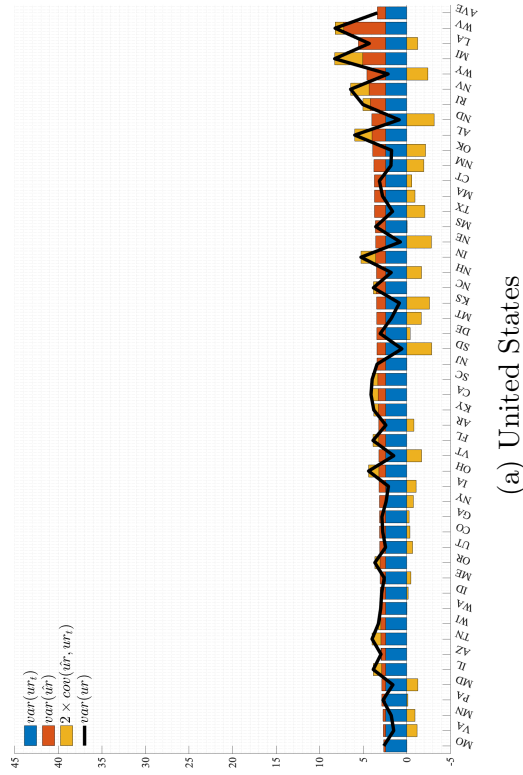


Figure 4: VARIANCE DECOMPOSITION

Notes: Figure displays the time-series variance decomposition of the unemployment rates in both the United States and the euro area based on equation (3.3.) States / Countries are sorted by the idiosyncratic component  $var(\widehat{ur}_{i,t})$ . The figure also displays the composition for the average state / country (AVE) as the bar most to the right.

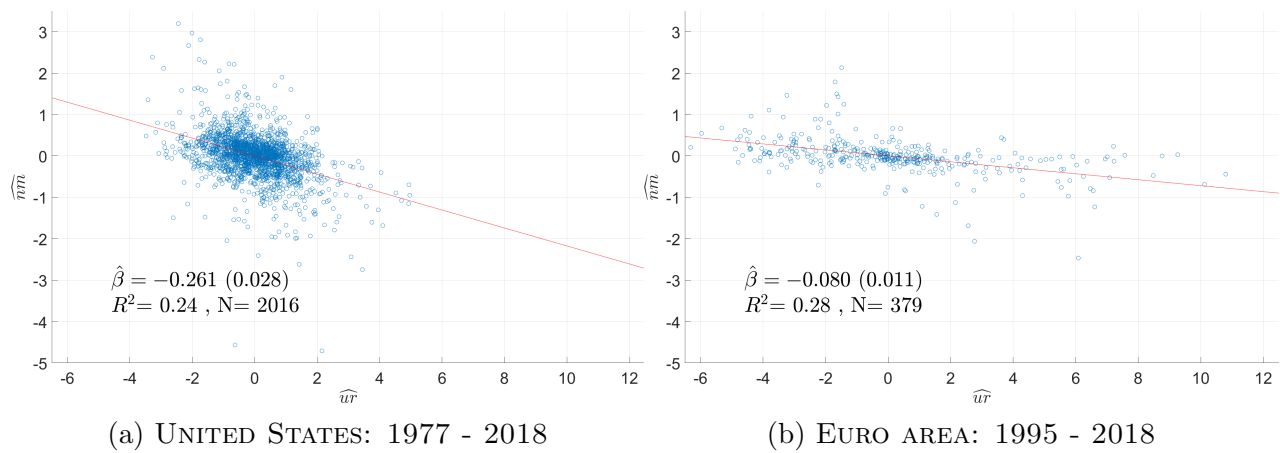


Figure 5: NET MIGRATION VS. UNEMPLOYMENT

*Note:* The first panel plots the demeaned state net migration rates after controlling for wages,  $\widehat{nm}_{i,t} - \hat{\alpha}\widehat{w}_{i,t}$  against the demeaned state unemployment rates  $\widehat{ur}_{i,t}$  for the United States over 1977 - 2018. See equation (3.5). The second panel plots the corresponding data for the sample of euro area countries, 1995 - 2018. Driscoll and Kraay (1998) standard errors in parentheses. The estimated coefficient on wages is  $\hat{\alpha} = 0.007(0.003)$  for the U.S. states and  $\hat{\alpha} = 0.002(0.007)$  for the euro area.)



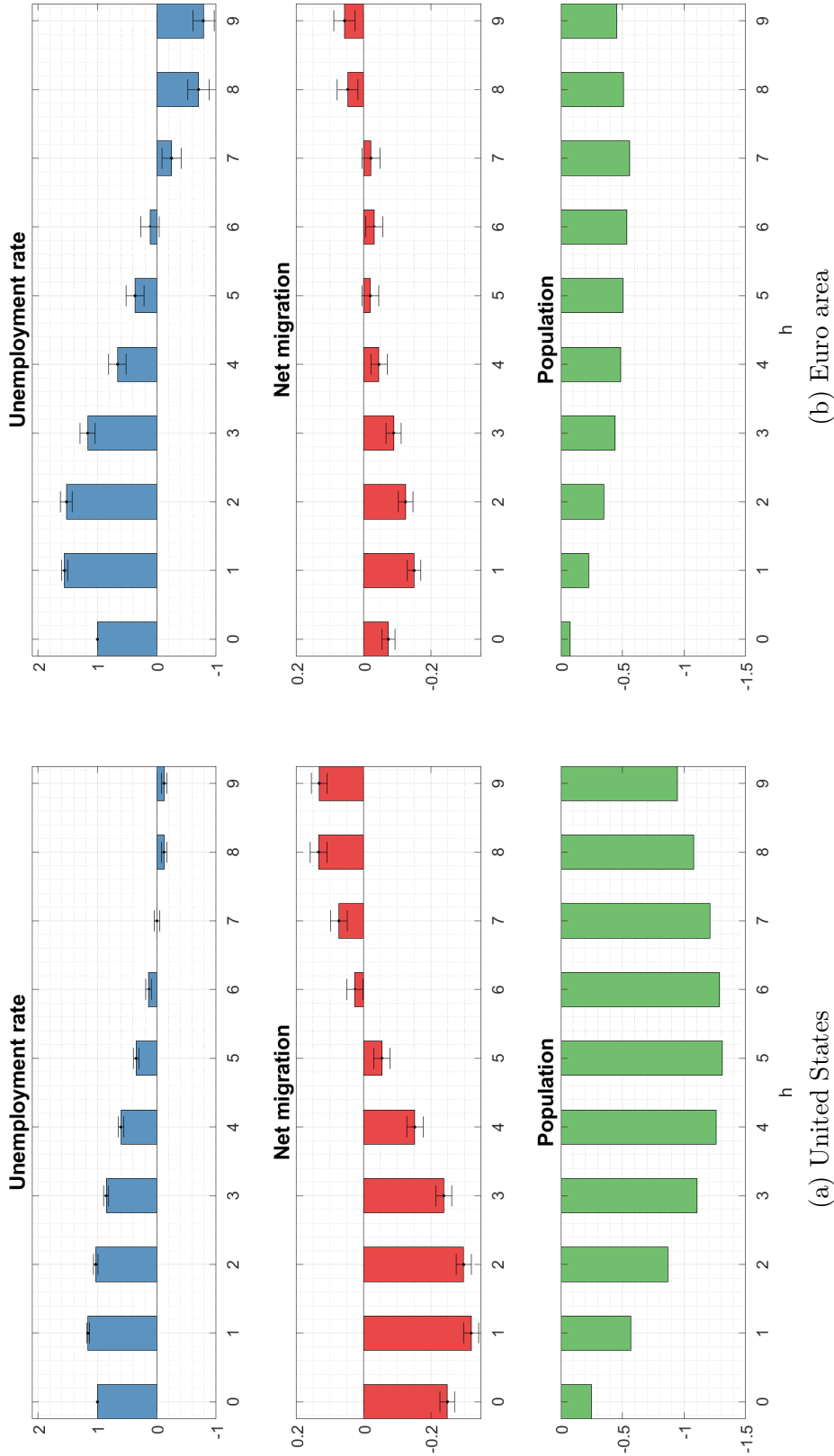


Figure 6: LOCAL PROJECTIONS

Notes: Figure displays the estimated coefficients (and standard errors) from local projection regressions (see equation (3.4)) for the United States (panel (a)) and for the euro area (panel (b)). The first set displays the coefficients from regressing the demeaned unemployment rate at time  $t+h$ ,  $\widehat{u}r_{i,t+h}$ , on the demeaned unemployment rate at time  $t$ ,  $\widehat{u}r_{i,t}$  controlling for two lags  $\widehat{u}r_{i,t-1}$  and  $\widehat{u}r_{i,t-2}$ . The second set regresses the demeaned net migration rate at time  $t+h$ ,  $\widehat{nm}_{i,t+h}$ , on the demeaned unemployment rate at time  $t$ ,  $\widehat{u}r_{i,t}$  controlling for two lags  $\widehat{u}r_{i,t-1}$  and  $\widehat{u}r_{i,t-2}$ . The estimated population response at horizon  $h$  is calculated from the estimated coefficients as  $\left(\sum_{k=0}^h (1 + \beta^k) - 1\right)$  of the net migration regression.

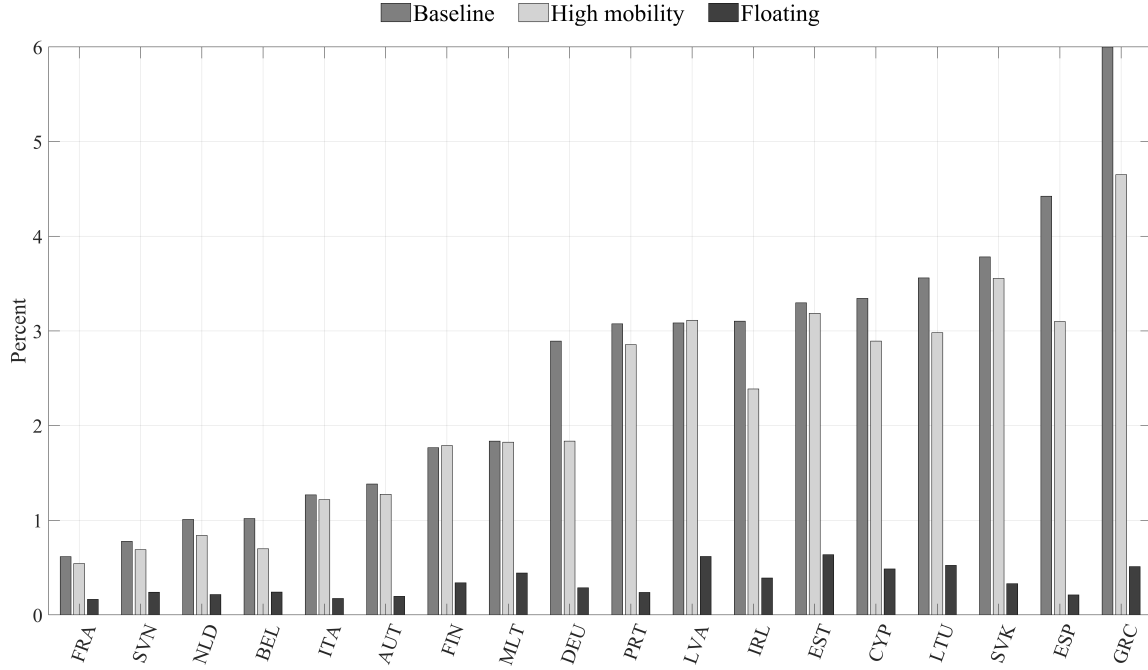


Figure 7: UNEMPLOYMENT VOLATILITY BY COUNTRY

*Note:* The figure displays the standard deviation of the unemployment rate in the baseline model, the high-mobility counterfactual and the floating exchange rate counterfactual.

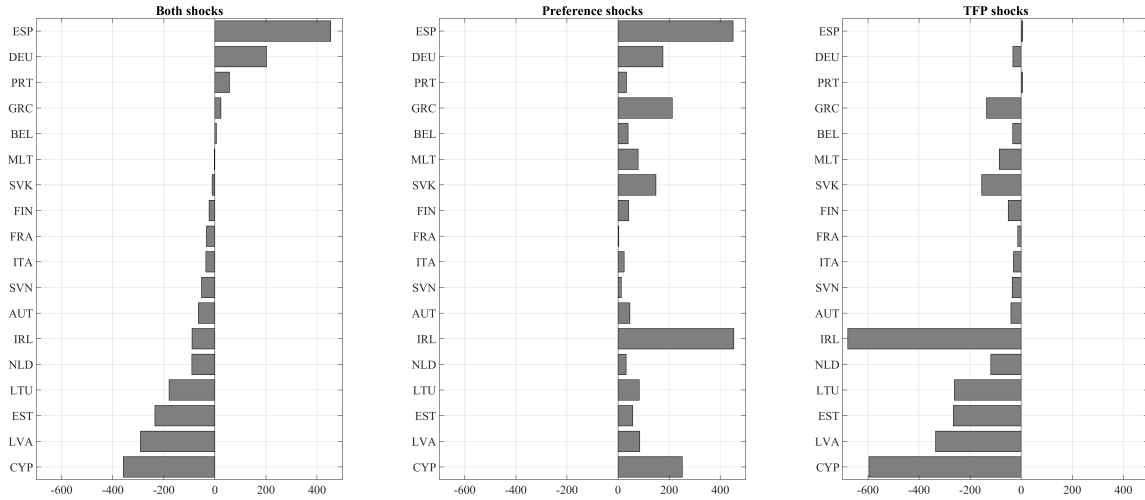


Figure 8: GAINS FROM MOBILITY BY COUNTRY

*Note:* The figure displays the gains from mobility defined as the opportunity cost of the union for the average household in the baseline model less the opportunity cost of the union in the high-mobility counterfactual. The opportunity cost of the union is defined as the welfare cost for the average household in the union less the welfare cost under floating exchange rates. Results are displayed for the case when both shocks are included, only preference shocks are included or only TFP shocks are included.

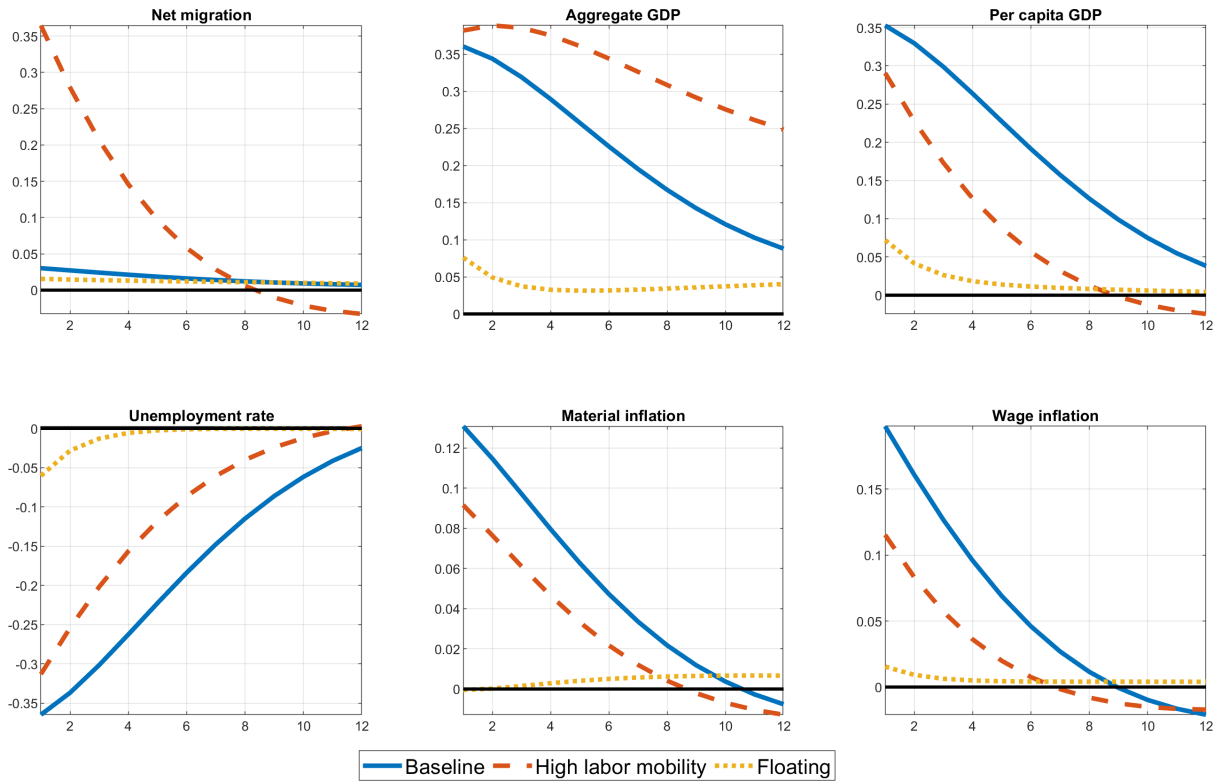


Figure 9: IMPULSE RESPONSE: PREFERENCE SHOCK

*Note:* The figure displays impulse responses to a preference shock for Belgium (the responses are similar for other countries).

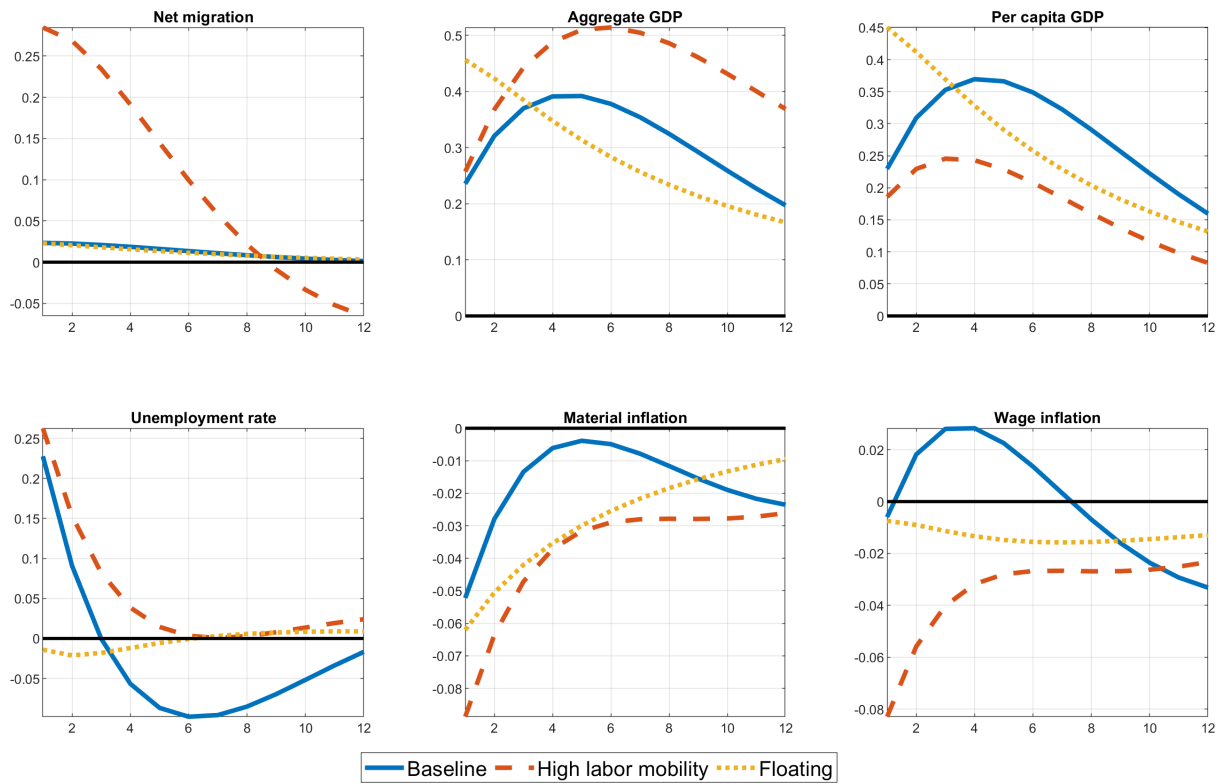


Figure 10: IMPULSE RESPONSE: TFP SHOCK

*Note:* The figure displays impulse responses to a TFP shock for Belgium (the responses are similar for other countries).