APPENDIX TO:

QUANTIFYING THE BENEFITS OF LABOR MOBILITY
IN A CURRENCY UNION*

Christopher L. House  Christian Proebsting
University of Michigan and NBER  KU Leuven

Linda L. Tesar
University of Michigan and NBER

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*House: chouse@umich.edu; Proebsting: Christian.Probsting@kuleuven.be; Tesar: ltesar@umich.edu.
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A Data sources

In this Appendix, we present data sources on migration for the United States, Canada and Europe. Whereas the main body of the text focuses on the euro area, we also include non-euro area countries in the Appendix and provide empirical results for various European samples.

A.1 U.S. states


- **Bilateral migration**: 1975/’76 - 2017/’18; Source: IRS Statistics of Income Division, data from 1990 onwards downloaded from the IRS website on 5/27/20; data prior to 1990 taken from Molloy, Smith and Wozniak (2011)


A.1.1 More details on migration data.

We use data from the Internal Revenue Service (IRS) to calculate state-to-state migration flows. The IRS has calculated migration rates based on the universe of tax filers. It compares mailing addresses on tax returns and then classifies tax returns as 'migrant' whenever the geographic code changes, and 'non-migrant' otherwise. The IRS then reports the number of tax returns that flow between any two geographical areas (counties or states), including the number of non-migrants. Combining this information allows us to calculate migration rates. The IRS reports numbers for both the number of returns (approximating households) and the number of exemptions claimed (approximating people). We focus on the number of exemptions claimed. The IRS data does not allow us to directly observe migration flows, but we only observe locations of tax filers at certain points in time, e.g. a tax filer lived at
some point in 1999 in Ohio and at some point in 2000 in Michigan. Our best guess is that the move between the two states took place between July 1st 1999 and June 30th 2000. So migration in year $t$ refers to migration between July 1st of calendar year $t - 1$ and June 30th of calendar year $t$. To be consistent we also define the unemployment rate in year $t$ as the average unemployment rate between July 1st of calendar year $t - 1$ and June 30th of calendar year $t$. Table A3 displays some summary statistics on migration in the United States.

A.2 Europe

In this section, we provide our data sources for European countries. For the purpose of this section, ‘Europe’ encompasses all countries in EU28 + EFTA, excluding Liechtenstein. Data on population stems from Eurostat (Population on 1 January by age and sex, [demo_pjan]) and data on unemployment rates is taken from AMECO (Table 1.3 Population and Employment: Unemployment, definition EUROSTAT [ZUTN]), which is complemented by data from ILOSTAT (Employment office records: Unemployment rate: total) for Cyprus (for 1995 and 1996). In the main body of the text, we confine our attention to countries in the euro area.

A.2.1 More details on migration data

We use migration data at different stages of our analysis. Foremost, in the empirical section, we use migration data to estimate the relationship between cyclical unemployment and cyclical net migration. This migration data is aggregate in the sense that we only look at a country’s total net migration and not its net migration broken down by partner country. Most of this aggregate migration data is directly taken from Eurostat or national statistical agencies. For some national data sources we adjust the reported levels either up- or downward if their definitions of migrants refer to either shorter or longer periods of stay.

Most of this section, however, discusses how we split up these aggregate flows into bilateral flows. We use these bilateral flows to (i) report the share of internal, i.e. within-Europe, migration in total migration and (ii) to calibrate the steady-state, bilateral migration costs across countries in our quantitative DSGE model. In many cases, the data sources that report aggregate migration flows also provide a breakdown by partner country. As with the aggregate data, we adjust some of the levels reported by national data sources to adjust for differences in definitions. With bilateral data, however, we face two additional challenges: First, whenever two countries report numbers on the same flow of migrants, we have to reconcile these two
reported numbers. Second, for a small number of countries, we do not observe any bilateral flows and we have to impute them because the model calibration requires a complete set of bilateral migration flows.

Table A1 contains a list of data sources for migration data. Tables A2 and ?? provide information on data periods covered by these data sources. Table A4 displays some summary statistics on migration in Europe.

**Adjusting for Different Definitions of ‘Migrant’ across Countries** The UN defines a migrant as any person moving in or out of a country for at least 12 months. As of 2015, almost all countries publishing data on Eurostat abide by this definition (regulation No. 862/2007), although the harmonization process from national definitions to the UN definition took more time in some countries than in others. Observations that do not follow this regulation are flagged in the dataset and we discard them. Whenever national definitions of migrants differ from the UN definition, they mostly do so in that they define a different minimum length of stay. For example, in Germany, the Netherlands, Austria and Switzerland, national definitions include migrants that move for less than 12 months (e.g. seasonal workers, exchange students), and numbers of migrants according to these definitions produce higher numbers. In many Eastern European countries (such as Poland, Slovak Republic, Bulgaria), migrants only refer to those changing their permanent residence, which leads to substantially smaller numbers of migrants compared to the UN definition. The Scandinavian countries have national definitions that are in line with the UN definition. As is common for many statistics published on Eurostat, harmonization mostly concerns definitions and concepts, but not necessarily the underlying sources used to compile the migration statistics. Administrative data is used in countries where registration is mandatory (e.g. all Scandinavian countries). Some countries rely on survey data (e.g. in the UK). Despite these differences in underlying sources the main advantage of these statistics is that they either source their information from data covering virtually the entire population (administrative data) or are based on surveys that are specifically designed to collect migration data. This reduces errors stemming from small samples.\footnote{An alternative data source is the labor force survey (LFS) that, as a byproduct, records a respondent’s country of residence.}

Tables A2 display data availability for all countries for aggregate (i.e. overall immigration and emigration). All countries report on Eurostat, but starting dates differ and we extrapolate
We now discuss how we adjust the data from national source to be consistent with the harmonized definition used by Eurostat. Let $\tilde{v}_{i,t}$ denote the migration flow (either immigration or emigration) at time $t$ reported by country $i$ according to its national definition. The corresponding value using the harmonized definition proposed by the UN and enacted by Eurostat is denoted by $v_{i,t}$. For time periods with missing values for $v_{i,t}$, we replace these missing values by $\text{adj}_i \tilde{v}_{i,t}$, where we calculate the adjustment factor $\text{adj}_i$ as

$$\text{adj}_i = \frac{1}{S} \sum_s \left( \frac{\tilde{v}_{i,s}}{v_{i,s}} \right).$$

Here, $s$ indexes all periods for which data according to both ‘national’ and ‘harmonized’ definitions of migrants exist, and $S$ is the number of those periods. We apply this factor to both aggregate and bilateral migration data. For some countries bilateral migration data is not reported on Eurostat (in particular, Germany), but migration data is available for country groups. In those cases, we calculate the adjustment factor based on either data reported for the EU27 / EU28 aggregate. The first two columns in Table A2 report the adjustment factor for all countries with available data (for both inflows and outflows). National data indicate higher migration figures than Eurostat in particular for Austria and Germany to a lesser extent Belgium and the Netherlands, i.e. these countries probably include seasonal workers or exchange students in their national statistics.

**Bilateral Migration Flows**  To numerically solve the model, we need a complete matrix of bilateral migration flows, $v_{i,j,t}$, to pin down the migration cost parameters, $\tau^j_i$. Intuitively, a higher observed flow of migrants between any country pair suggests a lower migration cost. We calibrate the migration cost parameter to match the average migration flows over our sample period. That is, at this stage, we are purely interested in estimating “average” bilateral migration flows as opposed to year-to-year changes in these migration flows.

For our European sample, we face two issues. First, whenever two countries report numbers
on the same flow of migrants, we need to reconcile these two reported numbers because these so-called mirror flows rarely coincide across reporting countries. Following a method commonly used in the trade literature (Gaulier and Zignago, 2010), the reconciled value is a weighted average of the two reported numbers. For details of this calculation, a discussion of data sources and data availability, see Foschi et al. (2022).

The second issue is that bilateral migration data is not available for all countries; indeed it is missing for 8 countries (Czech Republic, Greece, Cyprus, Hungary, Malta, Poland, Portugal, Romania), which means that we do not have bilateral data for $56 = 8 \times 7$ observations. (Note that we have bilateral data e.g. for Norway and Portugal because Norway reports emigration and immigration data with Portugal.) Here, we show how we estimate these values. It is helpful that for all countries, we have total migration data, e.g. we know the total number of immigrants coming into Portugal and emigrants leaving Portugal, but not broken down by country of origin / destination. We therefore proceed in 3 steps:

1. For each country, we calculate the average share of emigrants over the time period, denoted by $sh_{i}^{out}$. For countries reporting bilateral migration data, we also calculate the share of emigrants that go to the RoW aggregate, denoted by $sh_{i}^{RoW}$.

2. We run the following regression:

$$\ln v_{i,j} = \beta_i + \beta_j + \beta z_{i,j} + \epsilon_{i,j}$$

(A.1)

where $v_{i,j}$ are averages over time of the migration flows from $j$ to $i$, $v_{i,j,t}$. The control vector $z_{i,j}$ contains a set of gravity variables (distance, common language, common currency,...) as well as data on bilateral (long-run) migration stocks taken from United Nations (2017) (see below). We run this regression on all bilateral pairs with $i \neq j$ (excluding the RoW aggregate).

3. We approximate the missing values for $v_{i,j}$ by the predicted values from the regression.

4. Given our (estimated) values for $v_{i,j}$, we calculate migration flows as follows:

$$migr_{j,i} = \frac{v_{j,i}}{\sum_{j \neq i, RoW} v_{j,i}} \times sh_{i}^{out} \times (1 - sh_{i}^{RoW}) \times v_{i} \quad \text{for} \quad j \neq i, RoW$$

$$migr_{RoW,i} = sh_{i}^{out} \times sh_{i}^{RoW} \times v_{i}$$

$$migr_{i,i} = (1 - sh_{i}^{out}) \times v_{i}$$
if bilateral migration data was available for that country, and

\[
migr_{j,i} = v_{j,i} \quad \text{for } j \neq i, \text{RoW}
\]

\[
migr_{i,i} = (1 - sh_{i}^{\text{out}}) \times v_{i}
\]

\[
migr_{\text{RoW},i} = \max(0, v_{i} - \sum_{j \neq i} \migr_{j,i})
\]

otherwise. Migration from RoW to country \(i\) is

\[
migr_{i,\text{RoW}} = \max(0, v_{i} - \sum_{j \neq \text{RoW}} \migr_{i,j})
\]

and the number of people staying in RoW is simply the world population less the sum across all elements in the \(\migr\) matrix. The resulting bilateral matrix of migration flows is given by Table A9. Notice that in the our quantitative model we focus on the euro area and therefore collapse the RoW and all non-euro area countries (see Section C.5 and Table A12).

Table A8 displays the estimated coefficients from regression (A.1). We observe that sending and receiving country fixed effects explain most of the variation in migration flows, indicating that countries’ characteristics (e.g. its population size) are good predictors of the number of emigrants. The \(R^2\) of the regression with only country fixed effects is 0.71. Adding standard gravity regression bilateral variables improves the fit somewhat (\(R^2 = 0.75\)). The estimated coefficients indicate that distance reduces the number of bilateral migration flows, whereas contiguity increases it. Surprisingly, sharing a common language tends to reduce migration flows indicating that language barriers might play a less important role than commonly thought. The fit of the regression improves substantially when adding bilateral migration stocks to the regression (\(R^2 = 0.87\)), with both the number of long-term migrants from \(i\) living in \(j\) and the number of long-term migrants from \(j\) living in \(i\) being almost equally important. This suggests that the average level of migration flows from e.g. France to Germany does not only increase in the share of French living in Germany, but also with the share of Germans living in France, because flows from France to Germany could capture both French moving

\footnote{For a few countries (Cyprus, Hungary and Portugal) the number of imputed emigrants to RoW is slightly negative. This suggests that the total emigration figures reported by these countries might be too low. We set these numbers equal to zero. Similarly, for a few countries (Portugal and Romania), the number of imputed immigrants from RoW is slightly negative. This suggests that the total immigration figures reported by these countries might be too low. We set these numbers equal to zero.}
to Germany or Germans returning from France to Germany. Finally, the difference in GDP per capita between the two countries is also a good predictor of migration flows, with larger differences attracting more migration flows.

A.2.2 Additional data

We require additional data to be used for our model calibration and estimation:

- **National account variables**: GDP, private consumption, investment, net exports and government purchases. Employment. See Table A1 for data sources. Government purchases are constructed as the sum of government consumption and government gross fixed capital formation. See House, Proebsting and Tesar (2017) for more details.


We calculate the labor force as

\[ l_i = \frac{\text{empl}_i}{1 - u_i}, \]

where \( \text{empl}_i \) is data on the number of employed and \( u_i \) is the unemployment rate. The labor force participation rate is defined as the labor force divided by population. Net exports over GDP are calculated as real net exports over 2005 nominal GDP.

**Rest of the World.** Our model features a rest-of-the-world (RoW) aggregate that sums up variables across all countries in the world besides those specified in the model. Here, we provide a few more details.


Information from the OECD TiVA directly allow us to construct trade shares and domestic absorption for RoW because the database includes a rest-of-world aggregate (which we adjust to match our country composition).

We set the labor force participation rate to 50 percent, the unemployment rate to 6 percent and the share of government purchases in domestic absorption to 19 percent, which are in line with data for the US.
B Additional empirical results

B.1 Results for a wider set of European countries

In the Appendix, we provide statistics calculated in the main body of the text for alternative sets of European countries.

- Canada: all 10 provinces
- Euro core: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Spain
- Euro area: euro core + Cyprus, Estonia, Malta, Latvia, Lithuania, Slovenia, Slovakia
- Europe: euro area + Bulgaria, Czechia, Denmark, Hungary, Poland, Romania, Sweden, Iceland, Norway, Switzerland and the United Kingdom

The additional results are displayed in Tables A5, A6 and Figures A1, A2, A3, A4 and A5

B.2 Results for alternative empirical specifications

In the main body of the text, we regress double-demeaned net migration on double-demeaned unemployment rates. In this subsection, we consider alternative detrending methods. We consider the following specifications:

Baseline:

$$\hat{nm}_{i,t} = \beta \bar{u}r_{i,t} + \epsilon_{i,t}$$

Time dummies

$$nm_{i,t} - nm_t = \beta (ur_{i,t} - ur_i) + \gamma_t + \epsilon_{i,t}$$

NAWRU

$$\hat{nm}_{i,t} = \beta_0 + \beta \left[ ur_{i,t} - ur_{i,t}^{NAWRU} - \frac{1}{N} \sum_{i=1}^N \frac{pop_i}{pop} (ur_{i,t} - ur_{i,t}^{NAWRU}) \right] + \epsilon_{i,t}$$
Baxter King

\[ nm_{i,t} - nm_{i,t}^{BK} - \frac{1}{N} \sum_{i=1}^{N} \frac{pop_{i}}{pop} (nm_{i,t} - nm_{i,t}^{BK}) = \beta_0 + \beta \left[ ur_{i,t} - ur_{i,t}^{BK} - \frac{1}{N} \sum_{i=1}^{N} \frac{pop_{i}}{pop} (ur_{i,t} - ur_{i,t}^{BK}) \right] + \epsilon_{i,t} \]

The first specification corresponds to our baseline specification. The second specification uses time dummies instead of removing annual averages. The third specification replaces the trend unemployment rate by the non accelerating wage rate of unemployment (NAWRU) published by the European Commission for the sample of European countries. And the fourth specification applies the Baxter-King bandpass filter (2 to 12 years, order 4) to estimate the trend for either net migration or unemployment. While results differ somewhat across specifications, the results are generally robust to these different methods of extracting the cyclical component (see Table A7).

B.3 Regressions including wage differentials

We have also estimated versions of (3.5) including measures of regional wage differentials:

\[ \tilde{nm}_{i,t} = \beta \tilde{ur}_{i,t} + \gamma \tilde{w}_{i,t} + \epsilon_{i,t} \]

Here, \( \tilde{w}_{i,t} \) is the double-demeaned log of real wages:

\[ \tilde{w}_{i,t} = w_{i,t} - \alpha_i t - (w_t - w), \]

where \( \alpha_i \) is estimated from country-by-country regressions

\[ w_{i,t} = \alpha_{i,0} + \alpha_i t + \epsilon_{i,t}. \]

In other words, we log-linearly detrend real wages country by country and then also take out the cross-sectional average real wage for each year.

Data on wages for the United States is taken from the BEA regional accounts and corresponds to the ratio of ‘wages and salaries’ to ‘wage and salary employment (number of jobs)’. Since CPI data at the state level is not available for most of our sample, we deflate wages by the national CPI. For European countries, our wage series refer to the labor cost index deflated by national CPIs, both taken from Eurostat.
C Model: Additional details

C.1 Labor market

The maximization problem of a trade union in any particular market $i$ is:

$$\max_{W^*_i(t)} \mathbb{E}_t \left[ \sum_{j=0}^{\infty} (\theta_w \beta)^j \frac{W^*_i(t)}{P_{i,t+j}} l_{i,t+j} \right],$$

where trade unions take into account that labor demand, $l_{i,t+j} (t)$, depends on the chosen wage $W^*_i(t)$:

$$\max_{W^*_i(t)} \mathbb{E}_t \left[ \sum_{j=0}^{\infty} (\theta_w \beta)^j \frac{W^*_i(t)}{P_{i,t+j}} \left( \zeta \left( \frac{W_{i,t+j} - W^*_i(t)}{W_{i,t+j}} \right) + L^D_{i,t+j} \right) \right].$$

Taking the first-order condition yields

$$\mathbb{E}_t \left[ \sum_{j=0}^{\infty} (\theta_w \beta)^j \frac{L^D_{i,t+j} + \zeta}{P_{i,t+j}} \right] = 2W^*_i(t) \mathbb{E}_t \left[ \sum_{j=0}^{\infty} (\theta_w \beta)^j \frac{\zeta}{P_{i,t+j} W_{i,t+j}} \right]$$

$$W^*_i(t) = \frac{1}{2} \mathbb{E}_t \sum_{j=0}^{\infty} (\theta_w \beta)^j \left( L^D_{i,t+j} + \zeta \right) P_{i,t+j}^{-1} W_{i,t+j}^{-1}.$$

Log-linearizing yields

$$\tilde{w}^*_i(t) = \tilde{A}_{i,t} - \tilde{B}_{i,t},$$

with $A_{i,t} = (L^D_{i,t} + \zeta) P_{i,t}^{-1} + \theta_w \beta A_{i,t+1}$ and $B_{i,t} = \zeta P_{i,t}^{-1} W_{i,t}^{-1} + \theta_w \beta B_{i,t+1}$. Log-linearizing $A_{i,t}$ yields:

$$A_{i} \tilde{A}_{i,t} = L^D_i \tilde{L}_{i,t} - (L^D_i + \zeta) \tilde{P}_{i,t} + \beta \theta_w A_{i} \tilde{A}_{i,t+1}.$$  

Multiplying both sides by $(1 - \beta \theta_w)$ and noticing that $\tilde{L}_{i,t}^D = \tilde{L}_{i,t}$

$$(1 - \beta \theta_w)A_{i} \tilde{A}_{i,t} = (1 - \beta \theta_w) L^D_i \tilde{L}_{i,t} - (1 - \beta \theta_w) (L^D_i + \zeta) \tilde{P}_{i,t} + \beta \theta_w (1 - \beta \theta_w) A_{i} \tilde{A}_{i,t+1}.$$  

Notice that $A_{i}(1 - \beta \theta_w) = L^D_i + \zeta = 2\zeta$ and $L^D_i = \zeta$:

$$2\zeta \tilde{A}_{i,t} = (1 - \beta \theta_w) \tilde{L}_{i,t} - 2\zeta (1 - \beta \theta_w) \tilde{P}_{i,t} + \beta \theta_w 2\zeta \tilde{A}_{i,t+1}.$$  

And dividing by $2\zeta$

$$\tilde{A}_{i,t} = (1 - \beta \theta_w) \left( \frac{1}{2} \tilde{L}_{i,t} - \tilde{P}_{i,t} \right) + \beta \theta_w \tilde{A}_{i,t+1}.$$
Similarly, we have

\[ \tilde{B}_{i,t} = -(1 - \beta \theta_w) \left( \tilde{W}_{i,t} + \tilde{P}_{i,t} \right) + \beta \theta_w \tilde{B}_{i,t+1}. \]

Combining these two expressions, we have, we have

\[ \bar{w}_{i,t}^* = \tilde{A}_{i,t} - \tilde{B}_{i,t} = (1 - \beta \theta_w) \left( \frac{1}{2} \tilde{L}_{i,t} + \tilde{W}_{i,t} \right) + \beta \theta_w \bar{w}_{i,t+1}^*. \]

In a next step, we have to find the law of motion for aggregate wages. From the demand for each labor type, we have

\[ l_{i,t}(t) = L_{i,t}^D + \zeta \left( 1 - \frac{W_{i,t}(t)}{W_{i,t}} \right) \]

Aggregating across labor types, we get

\[ \int_0^1 l_{i,t}(t) dt = L_{i,t}^D + \zeta - \frac{\zeta}{W_{i,t}} \int_0^1 W_{i,t}(t) dt. \]

The LHS is just equal to \( L_{i,t}^D \). We then get

\[ W_{i,t} = \int_0^1 W_{i,t}(t) dt. \]

A fraction \( \theta_w \) of labor unions cannot their wage; the remaining labor unions set a wage \( W_{i,t}^* \). We therefore have the following law of motion

\[ \tilde{W}_{i,t} = \theta_w \tilde{W}_{i,t-1} + (1 - \theta_w) \bar{w}_{i,t}^* \]

\[ (1 - \theta_w) \bar{w}_{i,t}^* = \tilde{W}_{i,t} - \theta_w \tilde{W}_{i,t-1}. \]

Plugging this in the equation for the optimal reset wage yields

\[ \tilde{W}_{i,t} - \theta_w \tilde{W}_{i,t-1} = (1 - \beta \theta_w)(1 - \theta_w) \left( \frac{1}{2} \tilde{L}_{i,t} + \tilde{W}_{i,t} \right) + \beta \theta_w \left( \tilde{W}_{i,t+1} - \theta_w \tilde{W}_{i,t} \right) \]

\[ \theta_w \left( \tilde{W}_{i,t} - \tilde{W}_{i,t-1} \right) = (1 - \beta \theta_w)(1 - \theta_w) \frac{1}{2} \tilde{L}_{i,t} + \beta \theta_w \left( \tilde{W}_{i,t+1} - \tilde{W}_{i,t} \right) \]

\[ \pi_{i,t}^w = \frac{(1 - \beta \theta_w)(1 - \theta_w)}{2 \theta_w} \tilde{L}_{i,t} + \beta \pi_{i,t+1}^w. \]

Finally, notice that \( \tilde{L}_{i,t} \) can be replaced by the change in the unemployment rate, \( \Delta u_{r_{i,t}} = \).
\[
\frac{L_i - L_{i,t}}{L_i}
\]

\[
\tilde{L}_{i,t} = \frac{L_{i,t} - L_i}{L_i} = -\Delta ur_{i,t} \frac{L_i^S}{L_i} = -\frac{\Delta ur_{i,t}}{1 - ur_i}.
\]

**Wage dispersion** Effective labor is produced according to:

\[
L_{i,t} = \int_0^1 l_{i,t}(t)dt - \frac{1}{2} \left[ \int_0^1 (l_{i,t}(t))^2 dt - \left( \int_0^1 l_{i,t}(t)dt \right)^2 \right].
\]

Labor demand for each type is given by

\[
l_{i,t}(i) = L^D_{i,t} + \zeta_i \left( 1 - \frac{W_{i,t}(i)}{W_{i,t}} \right)
\]

with \(L^D_{i,t} \equiv \int_0^1 l_{i,t}(t)dt\). Inserting labor demand into effective labor yields

\[
L_{i,t} = L^D_{i,t} - \frac{1}{2} \zeta_i \left[ \int_0^1 \left( L^D_{i,t} + \zeta_i \left( 1 - \frac{W_{i,t}(i)}{W_{i,t}} \right) \right)^2 dt - (L^D_{i,t})^2 \right]
\]

\[
= L^D_{i,t} - \frac{1}{2} \zeta_i \left[ (L^D_{i,t})^2 + 2\zeta_i L^D_{i,t} \int_0^1 \left( 1 - \frac{W_{i,t}(i)}{W_{i,t}} \right) dt + \zeta_i^2 \int_0^1 \left( 1 - \frac{W_{i,t}(i)}{W_{i,t}} \right)^2 dt - (L^D_{i,t})^2 \right]
\]

\[
= L^D_{i,t} \int_0^1 \frac{W_{i,t}(i)}{W_{i,t}} dt - \frac{\zeta_i}{2} \int_0^1 \left( 1 - \frac{W_{i,t}(i)}{W_{i,t}} \right)^2 dt
\]

\[
= L^D_{i,t} - \frac{\zeta_i}{2} \int_0^1 \left( 1 - \frac{W_{i,t}(i)}{W_{i,t}} \right)^2 dt,
\]

where the last line uses \(W_{i,t} = \int_0^1 W_{i,t}(i)dt\). Solving further yields

\[
L_{i,t} = L^D_{i,t} - \frac{\zeta_i}{2} \int_0^1 \left[ 1 - 2 \frac{W_{i,t}(i)}{W_{i,t}} + \left( \frac{W_{i,t}(i)}{W_{i,t}} \right)^2 \right] dt
\]

\[
= L^D_{i,t} - \frac{\zeta_i}{2} \left[ 1 - 2 \int_0^1 \frac{W_{i,t}(i)}{W_{i,t}} dt + \int_0^1 \left( \frac{W_{i,t}(i)}{W_{i,t}} \right)^2 dt \right]
\]

\[
= L^D_{i,t} - \frac{\zeta_i}{2} \left[ \int_0^1 \left( \frac{W_{i,t}(i)}{W_{i,t}} \right)^2 dt - 1 \right]
\]

\[
= L^D_{i,t} - \frac{\zeta_i}{2} (v_{i,t}^W - 1),
\]
where \( v_{i,t}^W = \int_0^1 \left( \frac{W_{i,t}(\varepsilon)}{W_{i,t}} \right)^2 \, d\varepsilon \) is the wage dispersion term, which is bound by 1 from below.

### C.2 Migration decisions

We review the proofs underlying equations (4.4) and (4.5). Similar proofs are also outlined in Caliendo, Dvorkin and Parro (2015).

**Lemma 2**

(i) The expected value of \( v_{j,t}(\varepsilon_t) \) is

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

(ii) The share of workers that relocate from \( i \) to \( j \) is

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

**Proof.** We prove the various parts of the lemma one at time.

**Part (i)** The value to a worker of living in country \( i \) at time \( t \) is

\[
v_{i,t}(\varepsilon_t) = \max_j \left\{ \varphi_j U \left( c_{j,t}^w \right) + \frac{1}{\gamma} \varepsilon_{j,t} - \tau_j^i + \beta \mathbb{E}_t (V_{j,t+1}) \right\}.
\]

For simplicity, define \( U_{j,t}^w = \varphi_j U \left( c_{j,t}^w \right) \). Denoted by \( V_{i,t} \) the expected value of \( v_{j,t}(\varepsilon_t) \), where the expectation is taken over the preference shocks \( \varepsilon_t \). We assume that \( \varepsilon_t \) follows a Type-I Extreme Value distribution with the cumulative distribution function is given by

\[
F(\varepsilon) = e^{-e^{-\gamma - \bar{\gamma}}}.
\]

Here, \( \bar{\gamma} = \int_{-\infty}^{\infty} x \exp(-x - \exp(-x)) \, dx \) is Euler’s constant. The corresponding pdf is denoted by

\[
f(\varepsilon) = e^{-\gamma} e^{-e^{-x - \bar{\gamma}}}.
\]

We are interested in solving for the following object:

\[
V_{i,t} = \mathbb{E}_t \left[ \max_j \left\{ U_{j,t}^w + \frac{1}{\gamma} \varepsilon_{j,t} - \tau_j^i + \beta \mathbb{E}_t (V_{j,t+1}) \right\} \right]
\]
Define

\[ \tilde{\epsilon}_{j,k,t} = \gamma \left\{ \beta \mathbb{E}_t (V_{j,t+1} - V_{k,t+1}) + U_{j,t}^w - U_{k,t}^w - (\tau_j^t - \tau_k^t) \right\}. \]

The value of location \( j \) exceeds the value of location \( k \) if \( \epsilon_{k,t} < \tilde{\epsilon}_{j,k,t} + \epsilon_{j,t} \). Then, the probability that location \( j \) is chosen is the probability that its value exceeds the value of all other locations, i.e.

\[ \Pi_{k \neq j} \Pr (\epsilon_{k,t} < \tilde{\epsilon}_{j,k,t} + \epsilon_{j,t}) = \Pi_{k \neq j} F (\tilde{\epsilon}_{j,k,t} + \epsilon_{j,t}). \]

Recalling that the expected value of a function of a continuous random variable is \( \mathbb{E} (g(x)) = \int_{-\infty}^{\infty} g(x) f(x) \, dx \), the expected value \( V_{i,t} \) can be written as

\[ V_{i,t} = \sum_j \int_{-\infty}^{\infty} \left\{ U_{j,t}^w - \tau_j^t + \beta \mathbb{E}_t (V_{j,t+1}) + \frac{1}{\gamma} \epsilon_{j,t} \right\} f(\epsilon_{j,t}) \prod_{k \neq j} F (\tilde{\epsilon}_{j,k,t} + \epsilon_{j,t}) \, d\epsilon_{j,t}, \]

where each location \( j \) is weighted by the probability that it is the maximum. Next, we substitute for the functional forms of the pdf and the cdf. For this, note that

\[ f(\epsilon_{j,t}) \prod_{k \neq j} F (\tilde{\epsilon}_{j,k,t} + \epsilon_{j,t}) = e^{-\epsilon_{j,t} - \gamma} e^{-\epsilon_{j,t} - \gamma} \times \prod_{k \neq j} e^{-\tilde{\epsilon}_{j,k,t} - \epsilon_{j,t} - \gamma} \]

\[ = e^{-\epsilon_{j,t} - \gamma} e^{-\epsilon_{j,t} - \gamma} \times \prod_{k \neq j} e^{-\tilde{\epsilon}_{j,k,t} - \epsilon_{j,t} - \gamma} \]

\[ = e^{-\epsilon_{j,t} - \gamma} \times \prod_k e^{-\epsilon_{j,t} - \gamma} = e^{-\epsilon_{j,t} - \gamma} \sum_k e^{-\epsilon_{j,t}}. \]

Defining \( \lambda_{j,t} = \ln \sum_k e^{-\tilde{\epsilon}_{j,k,t}} \) and considering the change of variables \( \zeta_{j,t} = \epsilon_{j,t} + \gamma \), we then have

\[ f(\epsilon_{j,t}) \prod_{k \neq j} F (\tilde{\epsilon}_{j,k,t} + \epsilon_{j,t}) = e^{-\zeta_{j,t}} \times e^{-\epsilon_{j,t} - \gamma} e^{\lambda_{j,t}} e^{-\gamma} = e^{-\zeta_{j,t} - e^{\gamma} \lambda_{j,t} - \gamma} \]

Plugging this into the expression for \( V_{i,t} \) above, we get

\[ V_{i,t} = \sum_j \int_{-\infty}^{\infty} \left\{ U_{j,t}^w - \tau_j^t + \beta \mathbb{E}_t (V_{j,t+1}) + \frac{1}{\gamma} (\zeta_{j,t} - \gamma) \right\} e^{-\zeta_{j,t} - e^{\gamma} \lambda_{j,t} - \gamma} \, d\zeta_{j,t}. \]
Consider another change of variable, $x_{j,t} = \zeta_{j,t} - \lambda_{j,t}$. We then obtain

$$V_{i,t} = \sum_j \int_{-\infty}^{\infty} \left\{ U^w_{j,t} - \tau_j^i + \beta \mathbb{E}_t (V_{j,t+1}) + \frac{1}{\gamma} (x_{j,t} + \lambda_{j,t} - \bar{\gamma}) \right\} e^{-(x_{j,t} + \lambda_{j,t} - \bar{\gamma})} dx_{j,t}$$

$$= \sum_j e^{-\lambda_{j,t}} \left\{ U^w_{j,t} - \tau_j^i + \beta \mathbb{E}_t (V_{j,t+1}) + \frac{1}{\gamma} (\lambda_{j,t} - \bar{\gamma}) \right\} \int_{-\infty}^{\infty} e^{-x_{j,t} + \bar{\gamma}} dx_{j,t} + \frac{1}{\gamma} \int_{-\infty}^{\infty} x_j e^{-x_j + \bar{\gamma}} dx_j$$

$$= \sum_j e^{-\lambda_{j,t}} \left\{ U^w_{j,t} - \tau_j^i + \beta \mathbb{E}_t (V_{j,t+1}) + \frac{1}{\gamma} (\lambda_{j,t} - \bar{\gamma}) \right\} + \frac{1}{\gamma} \int_{-\infty}^{\infty} x_j e^{-x_j + \bar{\gamma}} dx_j,$$

where we use that $\int_{-\infty}^{\infty} e^{-x_j + \bar{\gamma}} dx_j = 1$. Notice that the last term is equal to $\bar{\gamma}$. So, we can write

$$V_{i,t} = \sum_j e^{-\lambda_{j,t}} \left\{ U^w_{j,t} - \tau_j^i + \beta \mathbb{E}_t (V_{j,t+1}) + \frac{1}{\gamma} (\lambda_{j,t} - \bar{\gamma}) \right\} + \frac{1}{\gamma} \int_{-\infty}^{\infty} x_j e^{-x_j + \bar{\gamma}} dx_j.$$

Notice that $\frac{1}{\gamma} \lambda_{j,t}$ can be rewritten using the definition of $\lambda_{j,t}$ and the definition of $\bar{\epsilon}_{j,k,t}$:

$$\frac{1}{\gamma} \lambda_{j,t} = \frac{1}{\gamma} \ln \sum_k e^{-\bar{\epsilon}_{j,k,t}}$$

$$= \frac{1}{\gamma} \ln \sum_k e^{-\gamma \{ \beta \mathbb{E}_t (V_{j,t+1}) + U^w_{j,t} - (\tau_j^i - \bar{\epsilon}_{j,k,t}) \}}$$

$$= \frac{1}{\gamma} \ln \left\{ e^{-\gamma \{ \beta \mathbb{E}_t (V_{j,t+1}) + U^w_{j,t} - \tau_j^i \}} \sum_k e^{\gamma \{ \beta \mathbb{E}_t (V_{j,t+1}) + U^w_{j,t} - \tau_k^i \}} \right\}$$

$$= - \beta \mathbb{E}_t (V_{j,t+1}) + U^w_{j,t} - \tau_j^i + \frac{1}{\gamma} \ln \sum_k e^{\gamma \{ \beta \mathbb{E}_t (V_{j,t+1}) + U^w_{j,t} - \tau_k^i \}}.$$

Inserting this back into the term for $V_{i,t}$, we have

$$V_{i,t} = \sum_j e^{-\lambda_{j,t}} \frac{1}{\gamma} \ln \sum_k e^{\gamma \{ \beta \mathbb{E}_t (V_{k,t+1}) + U^w_{k,t} - \tau_k^i \}}$$

$$= \frac{1}{\gamma} \ln \sum_k \exp \left( \gamma \{ \beta \mathbb{E}_t (V_{k,t+1}) + U^w_{k,t} - \tau_k^i \} \right) \sum_j e^{-\lambda_{j,t}}.$$
Similarly, we have

\[
e^{-\lambda_{j,t}} = e^{\gamma \{ \beta \mathbb{E}_t (V_{j,t+1}) + U_{j,t}^w - \tau_j^t \} \left( \sum_k e^{-\gamma \{ \beta \mathbb{E}_t (V_{k,t+1}) + U_{k,t}^w - \tau_k^t \} } \right)}
\]

\[
e^{-\lambda_{j,t}} = \frac{\exp \left( \gamma \{ \beta \mathbb{E}_t (V_{j,t+1}) + U_{j,t}^w - \tau_j^t \} \right)}{\sum_k \exp \left( \gamma \{ \beta \mathbb{E}_t (V_{k,t+1}) + U_{k,t}^w - \tau_k^t \} \right)}
\]

and summing over \( j \), we get \( \sum_j e^{-\lambda_{j,t}} = 1 \). Hence,

\[
V_{i,t} = \frac{1}{\gamma} \ln \sum_k \exp \left[ \gamma \{ \beta \mathbb{E}_t (V_{k,t+1}) + U_{k,t}^w - \tau_k^t \} \right] \sum_j e^{-\lambda_{j,t}}
\]

which completes the proof of part (i).

**Part (ii)** From the previous proof, recall that the probability to move from \( i \) to \( j \) is the probability that location \( j \)'s value exceeds the value of all other locations: \( \prod_{k \neq j} F(\tilde{\epsilon}_{j,k,t} + \epsilon_{j,t}) \, d\epsilon_{j,t} \).

The expected probability is then

\[
n_{j,t}^i = \int_{-\infty}^{\infty} f(\epsilon_{j,t}) \prod_{k \neq j} F(\tilde{\epsilon}_{j,k,t} + \epsilon_{j,t}) \, d\epsilon_{j,t}.
\]

Using the definitions introduced above, we have

\[
n_{j,t}^i = \int_{-\infty}^{\infty} e^{-\zeta_{j,t} - e^{-\gamma (\zeta_{j,t} - \lambda_{j,t})}} \, d\epsilon_{j,t}.
\]

And using the change of variable, \( x_{j,t} = \zeta_{j,t} - \lambda_{j,t} \), we have

\[
n_{j,t}^i = \int_{-\infty}^{\infty} e^{-\lambda_{j,t} - x_{j,t} - e^{-x_{j,t}}} \, dx_{j,t}
\]

\[
= e^{-\lambda_{j,t}} \int_{-\infty}^{\infty} e^{-x_{j,t} - e^{-x_{j,t}}} \, dx_{j,t}.
\]

Recall that \( \int_{-\infty}^{\infty} e^{-x_{j,t} - e^{-x_{j,t}}} \, dx_{j,t} = 1 \). Then, from the expression for \( e^{-\lambda_{j,t}} \), we get

\[
n_{j,t}^i = \frac{\exp \left( \gamma \{ \tilde{\varphi}_j U_{j,t}^w - \tau_j^t + \beta \mathbb{E}_t (V_{j,t+1}) \} \right)}{\sum_k \exp \left( \gamma \{ U_{k,t}^w - \tau_k^t + \beta \mathbb{E}_t (V_{k,t+1}) \} \right)}
\]

which completes the proof. ■
C.3 Production of tradable intermediates

Zero profit condition for producers of tradable intermediate goods. To close the model, we use the zero profit condition for producers of tradable intermediate goods. Their revenue is given by their sales to all countries, \( \sum_{j=1}^{N} \sum_{t=1}^{T} \frac{E_{j,t}}{E_{i,t}} P_{j,t}Y_{j,t} \). Their total costs are their purchases of material inputs, \( \sum_{i=1}^{K} \sum_{t=1}^{T} \frac{M_{i,t}}{M_{i,t}} \).

We can rewrite the RHS term using the market clearing condition for materials, \( M_{i,t} = M_{i,t}N_{i,t} \), and the zero profit condition in the non-traded sector, \( p_{i,t}M_{i,t}N_{i,t} = P_{i,t}Y_{i,t} \).

Finally, we can rewrite \( M_{i,t} \) in terms of the underlying production factors:\(^3\)

\[
Z_{i}^M \left( \frac{u_{i,t}K_{i,t-1}}{L_{i,t}} \right)^{\alpha} (N_{i,t}L_{i,t})^{1-\alpha} = N_{i,t}M_{i,t}v_{i,t}^{p},
\]

where \( v_{i,t}^{p} = \int \left( \frac{p_{i,t}^{M}(s)}{p_{i,t}^{M}} \right)^{-\psi_{m}} ds \) measures price dispersion across material inputs.

\(^3\)Aggregating the demand for each material variety, \( m_{i,t}(s) = \frac{M_{i,t}N_{i,t}^{\alpha}}{N_{i,t}^{1-\alpha}} \), across varieties yields

\[
\int m_{i,t}(s)ds = M_{i,t} \int \left( \frac{p_{i,t}^{M}(s)}{p_{i,t}^{M}} \right)^{-\psi_{m}} ds \equiv M_{i,t}v_{i,t}^{p}.
\]

Inserting the production function, \( m_{i,t}(s) = Z_{i}^{m}(K_{i,t}(s))^{\alpha} (L_{i,t}(s))^{1-\alpha} \) we have

\[
Z_{i}^{m} \int (K_{i,t}(s))^{\alpha} (L_{i,t}(s))^{1-\alpha} ds = M_{i,t}v_{i,t}^{p}.
\]

Next, using the optimal capital-to-labor ratio \( \frac{K_{i,t}(s)}{L_{i,t}(s)} = \frac{W_{i,t}}{W_{i,t}} = \frac{N_{i,t}^{\prime}u_{i,t}K_{i,t-1}}{N_{i,t}^{1-\alpha}L_{i,t}} \), and the market clearing condition for labor \( \int L_{i,t}(s)ds = N_{i,t}L_{i,t} \),

\[
Z_{i}^{M} \left( \frac{u_{i,t}K_{i,t-1}}{L_{i,t}} \right)^{\alpha} \int L_{i,t}(s)ds = N_{i,t}M_{i,t}v_{i,t}^{p},
\]

\[
Z_{i}^{M} \left( \frac{u_{i,t}K_{i,t-1}}{N_{i,t}L_{i,t}} \right)^{\alpha} (N_{i,t}L_{i,t})^{1-\alpha} = N_{i,t}M_{i,t}v_{i,t}^{p}.
\]
Taken together this yields the following zero-profit condition:

\[
\sum_{j=1}^{N} \omega_{j,t} N_{j,t} E_{j,t} P_{j,t} = \frac{P_{j,t}}{z_{j,t}} \left( \frac{E_{j,t}}{z_{j,t}} \right)^{\alpha} \left( \frac{N_{j,t} u_{j,t} K_{i,t}}{N_{t,i}} \right)^{1-\alpha} - P_{t,i} N_{t,i} Y_{t,i}.
\]

**Aggregation of Tradables**  We review the proofs underlying equations (4.19) and (4.23). Similar proofs are also outlined in Eaton and Kortum (2002). For simplicity, we omit the time subscript \( t \).

**Lemma 3**

(i) The distribution of the price for any good \( \nu \) actually paid in country \( i \) is:

\[
G_i(p) = 1 - \exp(-\Phi_i p^\theta),
\]

with \( \Phi_i = \sum_j Z_j (p_j M_i E_j)^{-\theta} \).

(ii) The probability that country \( i \) actually buys the good from any country \( j \) is:

\[
\omega_{i,j} = \frac{Z_j (p_j M_i E_j)^{-\theta}}{\Phi_i}.
\]

(iii) The price index in country \( i \) is:

\[
P_{i,t} = \left( \Gamma \left( 1 + \frac{1 - \psi_T}{\theta} \right) \right)^{-\frac{1}{1-\psi_T}} \Phi_i^{-\frac{1}{\theta}}.
\]

**Proof.** We prove the various parts of the lemma one at time.

Part (i)

With perfect competition, firms producing good \( \nu \) in country \( j \) confront consumers in country \( i \) with the price \( p_{t,j}(\nu) = \kappa_i^j z_j^T(\nu) E_i \), where \( \kappa_i^j \) is the iceberg trade cost to ship a good from \( j \) to \( i \), \( p_j \) is the cost of the input bundle used for the production of the tradable intermediate, \( z_j^T(\nu) \) is the firms’ productivity to produce good \( \nu \) and \( E_i \equiv E_i^0 \) is the exchange rate that converts country \( j \)'s currency into country \( i \)'s currency. According to the Fréchet
distribution, the cdf of this price is given by\textsuperscript{4}

\[ G_{i,j}(p) = Pr(P_{i,j}^T < p) = 1 - \exp \left(-Z_j(p_j^M \kappa_j^i E_j^i)^{-\theta} p^\theta \right). \]

But country \(i\) actually buys good \(\nu\) from the cheapest provider. So the distribution of the price actually paid by country \(i\) for good \(\nu\) is:

\[
G_i(p) = Pr \left( \min \{P_{i,j}^T; j = 1, ..., N \} < p \right) \\
= 1 - \prod_j Pr \left( P_{i,j}^T > p \right) \\
= 1 - \prod_j \exp \left(-Z_j(p_j^M \kappa_j^i E_j^i)^{-\theta} p^\theta \right) \\
= 1 - \exp \left(-p^\theta \sum_j Z_j(p_j^M \kappa_j^i E_j^i)^{-\theta} \right) \\
= 1 - \exp(-\Phi_i p^\theta),
\]

with \(\Phi_i = \sum_j Z_j(p_j^M \kappa_j^i E_j^i)^{-\theta}\).

Part (ii)

Country \(i\) actually buys a good \(\nu\) from country \(j\) if country \(j\)'s price \(P_{i,j}^T\) is the cheapest price. The probability of this event is

\[
Pr(p_{i,j}^T < \min_{j \neq k} p_{i,k}^T).
\]

Suppose that \(p_{i,j}^T\) is equal to \(p\). Then, we can rewrite this probability as the probability that \(p_{i,k}^T \geq p\) for all \(k \neq j\):

\[
\Pi_{k \neq j} Pr \left( P_{i,k}^T \geq p \right) = \Pi_{k \neq j} (1 - G_{i,k}(p)) = \exp \left(-\sum_{k \neq j} Z_k(p_k^M \kappa_k^i E_k^i)^{-\theta} p^\theta \right)
\]

Now, we integrate this over all possible prices \(p\) weighted by their density

\[
dG_{i,j}(p) = \theta p^{-\theta - 1} Z_j(p_j^M \kappa_j^i E_j^i)^{-\theta} \exp \left(-Z_j(p_j^M \kappa_j^i E_j^i)^{-\theta} p^\theta \right) dp
\]

\textsuperscript{4}The Fréchet distribution is

\[
F(z) = Pr(Z \leq z) = \exp \left(-Z z^{-\theta} \right).
\]

Notice that the shape parameter has to be strictly positive (see e.g Donaldson, 2018).
to obtain:

\[
\omega_i^j = \int_0^\infty \exp \left( -\sum_{k \neq j} Z_k (p_k^M \kappa_i^k S_i^k)^{-\theta} p \right) dG_{i,j}(p)
\]

\[
= \int_0^\infty \exp \left( -\sum_{k \neq j} Z_k (p_k^M \kappa_i^k S_i^k)^{-\theta} p \right) \vartheta p^{-\theta-1} Z_j (p_j^M \kappa_i^j E_i^j)^{-\theta} \exp \left( -Z_j (p_j^M \kappa_i^j E_i^j)^{-\theta} p \right) dp
\]

\[
= \int_0^\infty \exp \left( -\sum_{k} Z_k (p_k^M \kappa_i^k S_i^k)^{-\theta} p \right) \vartheta Z_j (p_j^M \kappa_i^j E_i^j)^{-\theta} p^{-\theta-1} dp
\]

\[
= \int_0^\infty \exp (-\Phi_i p^\theta) \vartheta Z_j (p_j^M \kappa_i^j E_i^j)^{-\theta} p^{-\theta-1} dp
\]

\[
= \frac{Z_j (p_j^M \kappa_i^j E_i^j)^{-\theta}}{\Phi_i} \int_0^\infty \exp (-\Phi_i p^\theta) \vartheta \Phi_i p^{-\theta-1} dp
\]

\[
= \frac{Z_j (p_j^M \kappa_i^j E_i^j)^{-\theta}}{\Phi_i} \int_0^\infty dG_i(p)
\]

\[
= \frac{Z_j (p_j^M \kappa_i^j E_i^j)^{-\theta}}{\Phi_i}
\]

Part (iii)

The gamma function is defined as \( \Gamma(a) = \int_0^\infty x^{a-1} \exp(-x) dx \). Given the CES structure in (4.18) the price index in country \( i \) is given by

\[
\left( P_i^T \right)^{1-\psi_T} = \int_0^1 \left( p_i^T(\nu) \right)^{1-\psi_T} d\nu.
\]

Instead of integrating over products \( \nu \), we can integrate over the actual prices of these products.

The distribution of the price of good \( \nu \) actually paid by country \( i \) is \( G_i(p) \). Hence, we can rewrite this expression as

\[
\left( P_i^T \right)^{1-\psi_T} = \int_0^\infty p^{1-\psi_T} dG_i(p)
\]

\[
= \int_0^\infty p^{1-\psi_T} \vartheta \Phi_i p^{-\theta-1} \exp \left( -\Phi_i p^\theta \right) dp,
\]

where we use our expression for the price index, \( G_i(p) = 1 - \exp \left( -\Phi_i p^\theta \right) \) and hence \( dG_i(p) = \vartheta \Phi_i p^{-\theta-1} \exp \left( -\Phi_i p^\theta \right) \).
Let $x = \Phi \phi^\rho$. Then, $dx = \Phi \phi^\rho \phi^{\rho-1} dp$ and $p^{1-\psi_T} = \left(\frac{x}{\Phi}\right)^{1-\psi_T}$. Hence,

\[
(P_T)^{1-\psi_T} = \int_0^\infty \left(\frac{x}{\Phi}\right)^{1-\psi_T} \exp(-x) dx = \Phi^{1-\psi_T} \int_0^\infty x^{1-\psi_T} \exp(-x) dx = \Phi^{1-\psi_T} \Gamma \left(1 + \frac{1 - \psi_T}{\rho}\right)^{\frac{1}{1-\psi_T}} \Phi^{-\frac{1}{\rho}}.
\]

Notice that the gamma function is only defined for values of $a$ larger than 0. This implies that we require $1 + \frac{1 - \psi_T}{\rho} > 0$, or $1 + \theta > \psi_T$. ■

C.4 Fiscal policy

The model includes country-specific aggregate government spending $N_{i,t}G_{i,t}$. We set the level of total government spending $N_{i,t}G_{i,t}$ to match observed levels of government spending in each country in the euro area. Government spending is financed with lump-sum nominal taxes $N_{i,t}'T_{i,t}' + N_{i,t}'T_{i,t} = N_{i,t}'P_{i,t}G_{i,t}$. We assume that governments keep aggregate government expenditure, $N_{i,t}G_{i,t}$, constant. In steady state, lump-sum taxes per person are equalized across workers and capital owners (i.e. $T_{i,t} = P_{i,t}G_{i,t}$). Out of steady state, changes in the real tax burden are born by capital owners (i.e. $T_{i,t} = P_{i,t}G_{i,t}$). This assumption ensures that migration decisions are not driven by changes in the real tax burden for workers.

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. The lack of fiscal transfers is also confirmed by Hoffmann et al. (2019) who show In a decomposition exercise in the spirit of Asdrubali, Sørensen and Yoshia (1996) that the “fiscal channel [has been] of very limited importance” in sharing risk across euro area countries since 1999, in contrast to the findings for the United States where a $1$ decrease in per capita income in a U.S. state is associated with a $0.20 - 0.40$ net transfer from the federal government (Asdrubali, Sørensen and Yoshia, 1996; Feyrer and Sacerdote, 2013; Sala-i-Martin and Sachs, 1991).
C.5 Calibrating bilateral trade preference weights & the bilateral migration matrix

Since steady-state asset holdings are not uniquely pinned down with incomplete markets, we can choose the initial asset holdings. As is common in the literature, we decide to log-linearize our model around a steady state with zero net foreign asset (i.e. zero net exports) for every region. We choose our bilateral trade matrix \( \bar{\varpi} \) to satisfy this condition and to look as “similar” as possible to the trade matrix implied by the data, \( \tilde{\varpi} \). In particular, we minimize

\[
\min_{\varpi_i} \sum_j \sum_i \frac{1}{2} \left( \frac{\varpi_j - \varpi_i}{k + \tilde{\varpi}_j} \right)^2
\]

subject to

\[
\sum_i \frac{\varpi_i}{N_i Y_i^T} = 1 \quad \forall j
\]

\[
\sum_j \varpi_j = 1 \quad \forall i
\]

\[
\varpi_i \geq 0
\]

\[
1 \geq \varpi_i,
\]

with \( k > 0 \).\(^5\) Our loss function specifies our idea of “similarity” between the two matrices. The first constraint describes the relationship between the trade preference weight and net exports. The second to fourth constraints are purely technical constraints on the parameters. In practice we set \( k = 0.1 \). Let \( \lambda_j \) and \( \lambda_i \) denote the Lagrange multiplier on the first two constraints. We solve for these parameters using the two constraints and setting the preference weights to

\[
\varpi_j = \min \left( 1, \max \left[ 0, \tilde{\varpi}_j - (k + \tilde{\varpi}_j) \left( \lambda_i + \lambda_j \frac{N_i Y_i^T}{N_j Y_j^T} \right) \right] \right).
\]

We proceed similarly to adjust our bilateral migration matrix that we have constructed from the data (see Appendix Section A.2). This implies that the steady-state share of mobile households in the total population, \( \frac{N_i^w}{N_i} \), is constant across countries. Since our calibration is done at a quarterly frequency, we convert our bilateral migration matrix constructed from the data to a quarterly frequency. Specifically, we divide cross-country migration flows by 4 and

\(^5\)Notice that we require \( k > 0 \) because elements in \( \tilde{\varpi}_j \) might be equal to 0.
accordingly raise the share of workers that stay in the same country.

D Model: Equilibrium conditions and steady state

D.1 Capital owner’s budget constraint

The budget constraint of the capital owners is given by

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

Multiplying both sides by \( N^k_i \) and using the definition of aggregate consumption,

\[ N^k_i P_{i,t}c_{i,t}^k = N^w_i P_{i,t}C_{i,t} - (W_{i,t}L_{i,t} - T_{i,t}^w) N^w_i, \]

we obtain

\[ N^w_i W_{i,t}L_{i,t} + N^w_i K_{i,t-1} (R_{i,t}u_{i,t} - P_{i,t}a(u_{i,t})) + N^k_i \Pi_{i,t} - (N^k_i T_{i,t} + N^w_i T_{i,t}^w) \]

We can replace \( N^k_i T_{i,t} + N^w_i T_{i,t}^w \) using the government budget constraint combined with the market clearing condition of the final good

\[ N^k_i T_{i,t} + N^w_i T_{i,t} = N_{i,t}P_{i,t}G_{i,t} = N_{i,t}P_{i,t} (Y_{i,t} - C_{i,t}) - N^k_i P_{i,t} (I_{i,t} + K_{i,t-1}a(u_{i,t})). \]

We then get:

\[ N_{i,t}P_{i,t}Y_{i,t} + N^k_i \left( \frac{B_{i,t}}{(1 + i_\varepsilon_{i,t})E_{i,t}} - \frac{B_{i,t-1}}{E_{i,t}} \right) = N^w_i W_{i,t}L_{i,t} + N^k_i R_{i,t}u_{i,t}K_{i,t-1} + N^k_i \Pi_{i,t}. \]

The profit term \( N^k_i \Pi_{i,t} \) consists of profits by monopolistically competitive producers of varieties:

\[ N^k_i \Pi_{i,t} = N_{i,t}P_{i,t}^M M_{i,t} - N^w_i W_{i,t}L_{i,t} - N^k_i R_{i,t}u_{i,t}K_{i,t-1}. \]

\[ ^6 \text{We ignore the quadratic penalty term on foreign bond holdings because they are zero in steady state and do not affect the budget constraint up to a first order.} \]
Inserting this term into the budget constraint gives

\[ N_i^k \left( \frac{B_{i,t}}{(1 + i_{i,t})E_{i,t}} - \frac{B_{i,t-1}}{E_{i,t}} \right) = N_{i,t} p_{i,t} M_{i,t} - N_{i,t} P_{i,t} Y_{i,t} \]

In steady state, this equation becomes

\[ N_i^k (\beta - 1) \frac{B_i}{S_i} = N_i (p_i M_i - P_i Y_i). \]

That is, in steady state the net foreign asset position is proportional to net exports. We start from a steady state with zero net exports, i.e. the net foreign asset position is zero as well.

Log-linearizing the budget constraint around a steady state with a zero net foreign asset position \((B_i = 0 \text{ for all } i)\) yields

\[ N_i^k \left( \frac{1}{\beta} \Delta B_{i,t-1} - \Delta B_{i,t} \right) = N_i \left( Y_i \tilde{Y}_{i,t} - M_i \left( \frac{p_i}{P_{i,t}} \right) + \tilde{M}_{i,t} \right). \]

### D.2 Definitions: Net exports and GDP

**Net exports** Nominal net exports \((NNX)\) are defined as the value of exports minus the value of imports. Exports are equal to the revenue of tradable intermediate good firms through sales abroad; imports are equal to expenditure on tradable goods acquired abroad, i.e.:

\[
NNX_{i,t} = \left( \sum_{j \neq i} N_{j,t} \frac{E_{j,t}}{E_{i,t}} p_{j,t} Y_{j,t} \right) - \left( (1 - \omega_{i,t}^i) P_{i,t} Y_{i,t} \right) = \sum_{j=1}^N \omega_{j,t}^i \frac{N_{j,t}}{N_{i,t}} \frac{E_{j,t}}{E_{i,t}} \frac{p_{j,t}}{p_{i,t}} Y_{j,t}^T - P_{i,t} Y_{i,t}^T
\]

Given the zero-profit condition of the final-good firms, this yields

\[
NNX_{i,t} = \left( \sum_{j=1}^N \omega_{j,t}^i \frac{N_{j,t}}{N_{i,t}} \frac{E_{j,t}}{E_{i,t}} p_{j,t} Y_{j,t}^T \right) - P_{i,t} Y_{i,t} + P_{i,t}^{N,Y} Y_{i,t}^N.
\]

Recall the zero-profit condition for firms producing tradable intermediate goods:

\[
\sum_{j=1}^N \omega_{j,t}^i \frac{N_{j,t}}{N_{i,t}} \frac{E_{j,t}}{E_{i,t}} P_{j,t} Y_{j,t}^T = P_{i,t}^M M_{i,t} - P_{i,t}^{N,Y} Y_{i,t}^N.
\]
Then, net exports can be written as

\[ NNX_{i,t} = p_{i,t}^M M_{i,t} - P_{i,t} Y_{i,t}, \]

which is the change in the current account (adjusted for income on net foreign assets).

Alternatively, net exports can be derived from aggregating net exports across all traded varieties: The value of net exports of the traded intermediate good are:

\[ nx_{i,t}(\nu) = p_{i,t}^T (\nu) \left( y_{i,t}^T (\nu) - x_{i,t}^T (\nu) \right). \]

Aggregating across all traded good varieties:

\[ NNX_{i,t} = \int_0^1 p_{i,t}^T (\nu) nx_{i,t}(\nu) d\nu = \int_0^1 p_{i,t}^T (\nu) y_{i,t}^T (\nu) d\nu - \int_0^1 p_{i,t}^T (\nu) x_{i,t}^T (\nu) d\nu. \]

Zero profit by the variety producers requires \( p_{i,t}^T (\nu) y_{i,t}^T (\nu) = p_{i,t}^M M_{i,t}^T (\nu) \). The second term is equal to \( P_{i,t}^T Y_{i,t}^T \) because producers of the aggregate traded good make zero profits.

\[ NNX_{i,t} = \left( P_{i,t}^M \int_0^1 M_{i,t}^T (\nu) d\nu \right) - P_{i,t}^T Y_{i,t} = P_{i,t}^M M_{i,t}^T - P_{i,t}^T Y_{i,t}. \]

Adding and subtracting \( p_{i,t}^M M_{i,t}^N = P_{i,t}^N Y_{i,t}^N \) yields

\[ NNX_{i,t} = p_{i,t}^M M_{i,t} - P_{i,t} Y_{i,t}. \]
GDP  Nominal GDP using the production approach is calculated by adding up the value added in each sector. That is

\[ NGDP_{i,t} = \int_0^1 p_{i,t}(s)m_{i,t}(s)ds \]

\[ + \left( p_{i,t}^M M_{i,t} - \int_0^1 p_{i,t}(s)m_{i,t}(s)ds \right) \]

\[ + \left( \int_0^1 p_{i,t}^T(y_{i,t}^T(\nu) - \int_0^1 p_{i,t}^M M_{i,t}^T(\nu)d\nu \right) \]

\[ + \left( p_{i,t}^T \gamma_{i,t}^T - \int_0^1 p_{i,t}^T(\nu)x_{i,t}^T(\nu)d\nu \right) \]

\[ + \left( P_{i,t}^T Y_{i,t}^T - P_{i,t}^N Y_{i,t}^N - P_{i,t}^M M_{i,t}^N \right) \]

\[ + \left( P_{i,t}^N Y_{i,t}^N - P_{i,t}^T Y_{i,t}^T - P_{i,t}^N Y_{i,t}^N \right). \]

The first term is value added by the individual material input producers; the second term is value added by firms producing the aggregate material; the third term is value added in the production of the traded intermediate good, the fourth term is value added in the production of the aggregate traded good, the fifth term is value in the production of the non-traded intermediate good and the last term is value added in the production of the final good. Canceling terms, we obtain

\[ NGDP_{i,t} = p_{i,t}^M M_{i,t} + \left( \int_0^1 p_{i,t}^T(y_{i,t}^T(\nu) - x_{i,t}^T(\nu))d\nu \right) + P_{i,t} Y_{i,t} \]

Market clearing for materials requires that \( M_{i,t} = M_{i,t}^N + \int_0^1 M_{i,t}^T(\nu)d\nu: \)

\[ NGDP_{i,t} = \int_0^1 p_{i,t}^T(\nu) \left( y_{i,t}^T(\nu) - x_{i,t}^T(\nu) \right) d\nu + P_{i,t} Y_{i,t} \]

Using the definition of nominal net exports, we obtain

\[ NGDP_{i,t} = NNX_{i,t} + P_{i,t} Y_{i,t} = p_{i,t}^M M_{i,t}. \]

Real GDP is nominal GDP evaluated at constant prices. Real value added in each sector is calculated as real output less real intermediate consumption where both output and inter-
mediate consumption are deflated using their own deflators (in national accounting, this is called “double deflation method”). That is, real GDP is

\[
GDP_{i,t} = \int_0^1 p_i^T(\nu) \left( y_{i,t}^T(\nu) - x_i^T(\nu) \right) d\nu + P_i Y_{i,t}
\]

Up to a first-order approximation around the non-stochastic steady state, the following zero-profit conditions hold:

\[
\begin{align*}
\int_0^1 p_i^T(\nu) y_{i,t}^T(\nu) &\approx p_i^M \int_0^1 M_{i,t}^T(\nu) d\nu \\
\int_0^1 p_i^T(\nu) x_{i,t}^T(\nu) &\approx P_i Y_{i,t}^T \\
P_i Y_{i,t} &\approx P_i^{N} Y_{i,t}^{N} + P_i^{T} Y_{i,t}^{T}.
\end{align*}
\]

Plugging these expressions into the expression for real GDP, we obtain:

\[
GDP_{i,t} \approx p_i^M \int_0^1 M_{i,t}^T(\nu) d\nu + P_i^{N} Y_{i,t}^{N}.
\]

Using the market clearing condition for \(M_{i,t}\), we get

\[
GDP_{i,t} \approx p_i^M M_{i,t} + P_i^{N} Y_{i,t}^{N} - p_i^M M_{i,t}^{N}.
\]

Finally, using the production function in the non-traded sector, \(Y_{i,t}^{N} = Z_{i,t}^{N} M_{i,t}^{N}\), and \(P_i^{N} = \frac{P_i^M}{Z_i^{N}}\), we get

\[
GDP_{i,t} \approx p_i^M M_{i,t} + \left( \frac{Z_{i,t}^{N}}{Z_i^{N}} - 1 \right) p_i^M M_{i,t}^{N}.
\]

## D.3 Steady state

We implicitly add several subsidies that make sure that the non-stochastic steady state is efficient. In particular, there is a wage subsidy of the wage on the worker and a production subsidy on the firm’s side. These subsidies are financed in a lump-sum fashion on workers and capital owners.

To solve for the steady state, we proceed in three steps:

1. We first solve for real prices (rental price of capital, \(\frac{R_i}{Z_i}\), real price of materials, \(\frac{P_i^M}{Z_i}\)) and
shares in GDP (share of consumption expenditure in GDP, \( \frac{C_i}{Y_i} \)) and share of investment in GDP, \( \frac{I_i}{Y_i} \). This requires data on relative country size in terms of countries’ domestic absorption, \( \frac{N_i Y_i}{N_j Y_j} \), but it does not require separate information on population, \( N_i \) or domestic absorption per capita, \( Y_i \). In a standard international DSGE model, only total country size matters, but not GDP per capita. Importantly, at this stage we cannot and do not need to solve for the real wage \( \frac{W_i}{P_i} \). The model only pins down wage payments as a share of GDP, i.e. \( \frac{W_i L_i}{P_i Y_i} \), but not the real wage \( \frac{W_i}{P_i} \).

2. We next solve for the steady-state values related to migration. Here, we require information on population measured in terms of persons, \( N_i \), data on the share of mobile households, \( \frac{N^w_i}{N_i} \), and data on bilateral migration flows, \( n^i_j \).

3. We then solve for the steady-state values related to the labor market. Here, we require data on unemployment rates, \( ur_i \), to solve for employment and the real wage \( \frac{W_i}{P_i} \).

The country-specific steady-state values are displayed in Table A10. The steady-state bilateral trade and migration matrices are displayed in Tables A11 and A12.

**DSGE block** We solve the model in a neighborhood of a non-stochastic steady state with zero inflation. Because inflation is zero, the Euler equations associated with the noncontingent nominal bonds imply that the nominal interest rate is \( 1 + i_i = \frac{1}{\beta} \) for all \( i \). Next, we use the capital Euler equation

\[
\frac{R_i}{P_i} = \frac{1}{\beta} - 1 + \delta. \tag{D.1}
\]

to determine the real rental price of capital \( \frac{R_i}{P_i} \) in each country. With zero inflation, the steady state price of the input bundle is a constant markup over the nominal marginal cost,

\[
p^M_i = \frac{\psi_m}{\psi_m - 1} MC_i.
\]

This can be seen from the reset equation and the law of motion for the nominal price of materials.

Next, from the demand for the traded intermediate goods and since we normalize \( \kappa_i^j = 1 \), we observe that the price ratio of the input bundle to the final traded good is a function of a
country’s openness, $1/\varpi^i$:

$$
\frac{p^M_i}{\bar{P}^M_i} = \Gamma^{-\frac{1}{1-\varpi^i}} \left( \frac{\varpi^i}{Z_i^i} \right)^{-\frac{1}{\varpi^i}}.
$$

We can adjust the technology levels $Z^M_i$ in each country such that $P^T_i = P^T_j$ (and $S_i = S_j = 1$). That is, the real exchange rate of traded goods is unity for all country pairs. We also assume that the production of the non-traded good transforms the input bundle into the non-traded good at a country-specific rate such that $P^N_i = P^T_i$ and hence, $P^N_i = P^T_i = P_i$. This then implies that $P_i = P_j$ across all countries. These normalizations have no effect on the dynamics of the model, but allow us to easily solve for the remaining steady-state variables.

Given these normalizations, we can solve for the transport cost parameters using

$$
\kappa^i_j = \left( \frac{\varpi^i_j}{\varpi^i} \right)^{\frac{1}{\varpi^i}}. \quad (D.3)
$$

Demand for non-traded goods as a share of total demand is then simply given by $\omega_i$.

$$
\omega_i = \frac{N_i Y_i^N}{N_i Y_i}, \quad (D.4)
$$

Nominal net exports for country $i$ are the difference of total sales of traded intermediates, $\sum_j \varpi^i_j S_j N_j P^T_j Y^T_j$, and total purchases of traded intermediates, $\sum_j \varpi^i N_i P^T_i Y^T_i$. The ratio of net exports to expenditure on the traded good is then

$$
\frac{N X_i}{P^T_i Y_i} = \sum_j \varpi^i_j \frac{N_j Y^T_j}{N_i Y_i} - 1. \quad (D.5)
$$

As explained in Section C.5, we adjust these import shares $\varpi^i_j$ somewhat to guarantee that net exports are zero in steady state. To derive the share of investment, we insert the marginal product of capital equation, $p^M_i M_i = \frac{R}{K^T} K_i$, into the zero net export condition, $p^M_i M_i = \frac{p^N_i}{Z^N_i}$. Then, one can solve for technology $Z^N_i$ as $Z^N_i = \Gamma^{-\frac{1}{1-\varpi^i}} \left( \frac{\varpi^i}{Z^N_i} \right)^{-\frac{1}{\varpi^i}}$. We can recover the technology levels $Z^M_i$ from the cost minimization problem of the first-stage producers and verify that the equation determining the price level of the traded good indeed is satisfied.

---

7The price in the non-traded sector is simply $P^N_i = p^N_i/\varpi^N_i$. Then, one can solve for technology $Z^N_i$ as

$$
Z^N_i = \Gamma^{-\frac{1}{1-\varpi^i}} \left( \frac{\varpi^i}{Z^N_i} \right)^{-\frac{1}{\varpi^i}}. \quad (D.5)
$$

We can recover the technology levels $Z^M_i$ from the cost minimization problem of the first-stage producers and verify that the equation determining the price level of the traded good indeed is satisfied.
\[ P_i Y_i \]

\[
\frac{R_i N_i^k}{\alpha \delta N_i} I_i = P_i Y_i
\]

\[
I_i Y_i = \frac{\alpha \delta N_i}{r_i N_i^k}
\]  
(D.6)

where \( I_i = \delta K_i \). The consumption share is the residual of the market clearing condition \( Y_i = C_i + I_i \frac{N_i^k}{N_i} + G_i \):

\[
C_i Y_i = 1 - I_i Y_i \frac{N_i^k}{N_i} - G_i Y_i.
\]  
(D.7)

Finally, we adjust steady-state lump-sum transfers to ensure that workers and capital owners have the same level of consumption.

\[
c_i^w = c_i^k = C_i.
\]

To summarize, we solve for the steady state values as follows:

1. Calibrate the government expenditure shares \( \frac{G_i}{Y_i} \) to the counterpart in the data.

2. Given data on the share of non-traded goods in total demand, final demand of traded goods and bilateral trade flows, solve for country size, \( N_i Y_i \), the share of non-traded goods production, \( \frac{N_i Y_i^N}{N_i Y_i} \), and the trade preference matrix \( \varpi_i^j \). In this step, adjust \( \varpi_i^j \) to ensure that net exports are zero using equation (D.5) (see also Section C.5).

3. Given data on bilateral trade shares as well as the share of non-traded goods in total demand, solve for \( \omega_i \) and \( \kappa_i^j \) using (D.4) and (D.3).

4. Solve for the real rental price \( \frac{R_i}{Y_i} \) using equation (D.1), the relative price of the input bundle to the final good price (D.2), the investment share \( \frac{I_i}{Y_i} \) using equation (D.6) and the consumption share \( \frac{C_i}{Y_i} \) using equation (D.7)

**Migration** For the DSGE block, we only require data on a country’s total domestic absorption, \( N_i Y_i \), as a measure of an economy’s size. Given \( N_i Y_i \), the values for population, \( N_i \), and domestic absorption per capita, \( Y_i \), are irrelevant. This is no longer true if we allow

\(^8\)The markup term \( \frac{\delta m}{\zeta m-1} \) drops out because we assume the presence of subsidies to undo the effect of monopolistic competition on the steady state.
for migration. For the migration block, we require data on countries’ population, $N_i$. Given
values for $N_i$, we immediately have domestic absorption per capita, $Y_i$ from
\[ Y_i = \frac{N_i Y_i}{N_i}. \] (D.8)

Notice that this allows us to solve for $M_i$:
\[ M_i = \left( \frac{\rho_i^M}{\ell_i} \right)^{-1} Y_i = \Gamma^{1-\sigma} (\omega_i)^{\frac{1}{\sigma}} Y_i. \]

We can also write all shares previously expressed in terms of domestic absorption in levels:
\[ C_i = \frac{C_i}{Y_i} Y_i, \quad I_i = \frac{I_i}{Y_i} Y_i, \quad G_i = \frac{G_i}{Y_i} Y_i. \]

We adjust $\tau_j^i$ to perfectly match the bilateral migration flows $n_{ij}$ observed in the data. The number of workers residing in each country is then given by
\[ N_w^i = \sum_j n_{ij} N_j^w. \]

Values for $N_w^i$ can be backed out from the linear equation system $N_w^i = \sum_j n_{ij} N_j^w$, given $n_{ij}$ and an overall share of workers, $N^w/N$.\(^9\) Similar to our adjustment of trade costs to ensure zero net exports in steady state, we adjust the matrix of migration costs, $\tau_j^i$, to ensure that the share of workers in the population is the same across countries in steady state, $N_w^i/N_i = N^w/N$ for all $i$ (see also Section C.5).

Given the number of workers residing in each country, we can find the size of the capital owners, $N_k^i$, from data on total population $N_k^i = N_i - N_w^i$.

**Labor market** Employment, $L_i$, satisfies
\[ L_i = L_i^S (1 - ur_i). \]

We calibrate $L_i^S$ to labor force participation rates and $ur_i$ to unemployment rates. We set
\[ L_i^k = L_i^w = L_i. \]

\(^9\)Since the system of linear equations is homogenous, there is an infinite number of solutions and we have to impose a value $N^w/N$ to find a unique solution.
and similarly for $L_i^S$ and $ur_i$.

The elasticity of substitution between labor types can be derived from observed unemployment rates:

$$\frac{\psi_i - 1}{\psi_i} = \left( \frac{L_i}{L_i^S} \right)^{\frac{1}{\eta}} = (1 - ur_i)^{\frac{1}{\eta}}$$

$$\frac{1}{\psi_i} = 1 - (1 - ur_i)^{\frac{1}{\eta}}.$$
D.4 Log-linearized equilibrium conditions

1. Marginal utility of consumption (capital owners)

\[ MU_{i,t}^k = \left( c_{i,t}^k \right)^{-\frac{1}{\gamma}} \]

\[ -\sigma MU_{i,t}^k = c_{i,t}^k \]

2. Definition of consumption

\[ C_{i,t}^N_{i,t} = c_{i,t}^k N_{i,t}^k + c_{i,t}^w N_{i,t}^w \]

\[ \tilde{C}_{i,t}^N + \tilde{N}_{i,t} = c_{i,t}^k \frac{N_{i,t}^k}{C_{i,t}^N} \tilde{c}_{i,t}^k + c_{i,t}^w \frac{N_{i,t}^w}{C_{i,t}^N} \left( \tilde{c}_{i,t}^w + \tilde{N}_{i,t}^w \right) \]

3. Definition of workers’ consumption

\[ c_{i,t}^w = w_{i,t} L_{i,t} - T_{i,t}^w \]

\[ c_{i,t}^w \tilde{c}_{i,t}^w = w_{i,t} \left( \tilde{w}_{i,t} + \tilde{L}_{i,t} \right) \]

4. Capital Euler equation

\[
\frac{\mu_{i,t}}{P_{i,t}} = \beta E_t \left\{ \frac{MU_{i,t+1}^k}{MU_{i,t}^k} \left[ \mu_{i,t+1} r_{i,t+1} + \frac{\mu_{i,t+1}}{P_{i,t+1}} (1 - \delta) - a (u_{i,t+1}) \right] \right\} \\
\beta r_{i,t} \tilde{r}_{i,t+1} = \tilde{MU}_{i,t}^k - \tilde{MU}_{i,t+1}^k + \left( \frac{\mu_{i,t}}{P_{i,t}} \right) - \beta (1 - \delta) \left( \frac{\mu_{i,t+1}}{P_{i,t+1}} \right) \]

5. Price of capital

\[
1 = \frac{\mu_{i,t}}{P_{i,t}} \left( 1 - f_{i,t} - \frac{I_{i,t}}{I_{i,t-1}} f'_{i,t} \right) + \beta E_t \left\{ \frac{MU_{i,t+1}^k}{MU_{i,t}^k} \frac{\mu_{i,t+1}}{P_{i,t+1}} \left( \frac{I_{i,t+1}}{I_{i,t}} \right)^2 f'_{i,t+1} \right\} \\
\left( \frac{\mu_{i,t}}{P_{i,t}} \right) \frac{1}{f''} = (1 + \beta) \tilde{I}_{i,t} - \tilde{I}_{i,t-1} - \beta \tilde{I}_{i,t+1} \]
6. Law of motion for the capital stock

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

\[ \tilde{K}_{i,t} = (1 - \delta) \tilde{K}_{i,t-1} + \delta \tilde{I}_{i,t} \]

7. Optimal capital utilization

\[ r_{i,t} = a'(u_{i,t}) \]

\[ r_{i,t} = a''u_{i,t} \tilde{u}_{i,t} \]

8. Optimal factor employment

\[ \frac{\alpha}{1 - \alpha} \frac{W_{i,t}}{R_{i,t}} = \frac{N_{k}^{k} u_{i,t} K_{i,t-1}}{N_{i,t} L_{i,t}} \]

\[ \tilde{r}_{i,t} - \tilde{w}_{i,t} = \tilde{N}_{i,t} + \tilde{L}_{i,t} - \tilde{u}_{i,t} - \tilde{K}_{i,t-1} \]

9. Real marginal costs

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

\[ \tilde{mc}_{i,t} = -\tilde{Z}_{i,t} + \alpha \tilde{r}_{i,t} + (1 - \alpha) \tilde{w}_{i,t} \]
10. Price level of tradable intermediate goods:\(^\text{10}\)

\[ P_{i,t}^T = \frac{\Gamma \frac{1}{T^2}}{E_{i,t}} \left[ \sum_{j=1}^{N} Z_j \left( E_{j,t} \kappa_j^M \right)^{-\theta} \right]^{-\frac{1}{\theta}} \]

\[ \tilde{e}_{i,t} + \left( \frac{P_{i,t}^T}{P_{i,t}} \right) = \sum_{j=1}^{N} \omega_j \left( \tilde{e}_{j,t} + \left( \frac{p_{j,t}^M}{P_{j,t}} \right) \right) \]

11. Demand for tradable intermediate goods:

\[ \omega_{i,t}^j = Z_j \left( \Gamma \frac{1}{T^2} \kappa_j^M \frac{E_{j,t}}{P_{i,t}^T} \right)^{-\theta} \]

\[-\frac{1}{\theta} \omega_{i,t}^j = \left( \frac{p_{j,t}^M}{P_{j,t}} \right) - \left( \frac{P_{i,t}^T}{P_{i,t}} \right) + \tilde{e}_{j,t} - \tilde{e}_{i,t} \]

12. Zero-profit condition for producers of tradable intermediate goods:\(^\text{11}\)

\[ \sum_{j=1}^{N} \omega_j^j N_{j,t} E_{j,t} P_{i,t}^T Y_{j,t}^T = \sum_{j=1}^{N} \omega_j^j N_{j,t} E_{j,t} P_{i,t}^T Y_{j,t}^T \]

\[ = \left( \frac{p_{i,t}^M}{P_i} M_{i,t} - Y_{i,t}^N \right) \left( \tilde{e}_{i,t} + \tilde{N}_{i,t} + \left( \frac{\tilde{P}_{i,t}}{P_{i,t}} \right) + \tilde{Y}_{i,t}^T \right) \]

\[ = \left( \frac{p_{i,t}^M}{P_i} M_{i,t} - Y_{i,t}^N \right) \left( \tilde{e}_{i,t} + \tilde{N}_{i,t} + \left( \frac{\tilde{P}_{i,t}}{P_{i,t}} \right) + \tilde{Y}_{i,t}^T \right) \]

\[ \left( \frac{p_{i,t}^T}{P_{i,t}} \right)^{-\theta} = \Gamma^{-\frac{1}{\theta}} \sum_{j=1}^{N} \left( \frac{p_{j,t}^M}{P_{j,t}} \right)^{-\theta} \]

\[ \left( \frac{p_{i,t}^T}{P_{i,t}} \right)^{-\theta} \tilde{e}_{i,t} + \left( \frac{P_{i,t}^T}{P_{i,t}} \right) = \Gamma^{-\frac{1}{\theta}} \sum_{j=1}^{N} \left( \frac{p_{j,t}^M}{P_{j,t}} \right)^{-\theta} \left( \tilde{e}_{j,t} + \left( \frac{p_{j,t}^M}{P_{j,t}} \right) \right) \]

\[ \tilde{e}_{i,t} + \left( \frac{P_{i,t}^T}{P_{i,t}} \right) = \sum_{j=1}^{N} \omega_j^j \left( \tilde{e}_{j,t} + \left( \frac{p_{j,t}^M}{P_{j,t}} \right) \right) \]

\(^\text{10}\)Recall that \( P_{i,t}^N = P_i \) in steady state and \( \left( \frac{p_{j,t}^M}{P_{j,t}} \right) = \left( \frac{p_{j,t}^M}{P_{j,t}} \right) + Z_{i,t}^N \).

\(^\text{11}\)Recall that \( P_{i,t}^N = P_i \) in steady state and \( \left( \frac{p_{j,t}^M}{P_{j,t}} \right) = \left( \frac{p_{j,t}^M}{P_{j,t}} \right) + Z_{i,t}^N \).
13. Production of final good

\[ Y_{i,t} = \left( \omega_{i,t}^{\frac{1}{\psi_y}} Y_{i,t}^N \right)^{\frac{\psi_y - 1}{\psi_y}} + (1 - \omega_{i,t}) \frac{1}{\psi_y} \left( Y_{i,t}^T \right)^{\frac{\psi_y - 1}{\psi_y}} \]

\[ \hat{Y}_{i,t} = \omega_i Y_{i,t}^N + (1 - \omega_i) \hat{Y}_{i,t}^T \]

14. Production of materials

\[ M_{i,t} = \frac{Z_{i,t}}{\psi_t} \left( N_i^k u_{i,t} K_{i,t-1} \right)^{\alpha} L_{i,t}^{1-\alpha} N_{i,t}^{-\alpha} \]

\[ \hat{M}_{i,t} = \hat{Z}_{i,t} + \alpha \left( \hat{u}_{i,t} + \hat{K}_{i,t-1} \right) + (1 - \alpha) \hat{L}_{i,t} - \alpha \hat{N}_{i,t} \]

15. Demand for non-traded and traded intermediate goods

\[ Y_{i,t}^N = \omega_{i,t} Y_{i,t} \left( \frac{P_{i,t}^N}{P_{i,t}} \right)^{-\psi_y} \]

\[ \hat{Y}_{i,t}^N = \bar{\omega}_{i,t} + \bar{Y}_{i,t} - \psi_y \left( \frac{P_{i,t}^M}{P_{i,t}} \right)^{-\psi_y} + \psi_y \hat{Z}_{i,t}^N \]

\[ Y_{i,t}^T = (1 - \omega_{i,t}) Y_{i,t} \left( \frac{P_{i,t}^T}{P_{i,t}} \right)^{-\psi_y} \]

\[ \hat{Y}_{i,t}^T = \frac{\omega_i}{1 - \omega_i} \bar{\omega}_{i,t} + \bar{Y}_{i,t} - \psi_y \left( \frac{P_{i,t}^T}{P_{i,t}} \right)^{-\psi_y} \]

---

\[ \frac{\psi_y - 1}{\psi_y} Y_{i,t}^{\psi_y - 1} \hat{Y}_{i,t} = \omega_i^{\frac{1}{\psi_y}} Y_{i,t} \left( Y_{i,t}^N \right)^{\frac{\psi_y - 1}{\psi_y}} + (1 - \omega_i) \frac{1}{\psi_y} \left( Y_{i,t}^T \right)^{\frac{\psi_y - 1}{\psi_y}} - \left( \psi_y - 1 \right) \psi_y \left( \frac{\psi_y - 1}{\psi_y} Y_{i,t}^T - \frac{1}{\psi_y} \omega_i \bar{\omega}_{i,t} \right) \]

\[ \frac{\psi_y - 1}{\psi_y} \hat{Y}_{i,t} = \omega_i \left( \frac{\psi_y - 1}{\psi_y} \bar{Y}_{i,t} + \psi_y \hat{Y}_{i,t} \right) + (1 - \omega_i) \left( \psi_y - 1 \hat{Y}_{i,t} - \omega_i \bar{\omega}_{i,t} \right) \]

---

12 Notice that the price of the non-traded good is simply the price of the domestic intermediate good times a constant adjustment factor, i.e. \( P_{i,t}^N = \Gamma^{\frac{1}{1-\omega_i}} (\bar{\pi}_i) \psi_y \).

13 Notice that the price of the non-traded good is simply the price of the domestic intermediate good times a constant adjustment factor, i.e. \( P_{i,t}^N = \Gamma^{\frac{1}{1-\omega_i}} (\bar{\pi}_i) \psi_y \).
16. Market clearing for final goods\textsuperscript{14}

\[ Y_{i,t} = C_{i,t} + G_{i,t} + (I_{i,t} + a(u_{i,t}) K_{i,t-1}) \frac{N_i^k}{N_{i,t}} \]

\[ 
\tilde{Y}_{i,t} = \frac{C_i}{Y_i} \tilde{C}_{i,t} + \frac{I_i}{Y_i} \frac{N_i^k}{N_i} (\tilde{I}_{i,t} - \tilde{N}_{i,t}) - \frac{G_i}{Y_i} \tilde{N}_{i,t} + \frac{K_i}{Y_i} \tilde{N}_i \tilde{u}_{i,t} 
\]

17. Domestic Euler equation

\[ \frac{MU_k^{i,t}}{P_{i,t}} = (1 + i_{i,t}) \beta \mathbb{E} \left[ \frac{MU_k^{i,t+1}}{P_{i,t+1}} \right] \]

\[ \beta \Delta i_{i,t} - \tilde{\pi}_{i,t+1} = \tilde{MU}_{i,t} - \tilde{MU}_{i,t+1} \]

18. Phillips curve

\[ \tilde{\pi}_{i,t} + \left( \frac{\tilde{P}_{i,t}}{P_{i,t}} \right) \frac{(\tilde{P}_{i,t-1})}{(\tilde{P}_{i,t})} = \frac{(1 - \theta_p)(1 - \theta_p \beta)}{\theta_p} \left[ \tilde{m}_{C_{i,t}} - \left( \frac{\tilde{P}_{i,t}}{\tilde{P}_{i,t}} \right) \right] + \beta \left( \tilde{\pi}_{i,t+1} + \left( \frac{\tilde{P}_{i,t+1}}{\tilde{P}_{i,t}} \right) - \left( \frac{\tilde{P}_{i,t+1}}{\tilde{P}_{i,t}} \right) \right] \]

19. Monetary Policy

- Floating exchange rate:

\[ \Delta i_{i,t} = \phi_i \Delta i_{i,t-1} + (1 - \phi_i) \left( \phi_{GDP} \left( \tilde{N}_{i,t} + \tilde{GDP}_{i,t} \right) + \phi_{\pi} \tilde{\pi}_{i,t} \right) \]

- Fixed exchange rate:
  - Leader \( n \):

\[ \Delta i_{i,t} = \phi_i \Delta i_{i,t-1} + (1 - \phi_i) \sum_{j \in CU} \frac{N_j GDP_i}{N_{CU} GDP_{CU}} \left( \phi_{GDP} \left( \tilde{N}_{j,t} + \tilde{GDP}_{j,t} \right) + \phi_{\pi} \tilde{\pi}_{j,t} \right) \]

  - Follower \( j \):

\[ \left( \tilde{e}_{j,t} - \tilde{e}_{j,t-1} \right) - \tilde{\pi}_{j,t} = (\tilde{e}_{i,t} - \tilde{e}_{i,t-1}) - \tilde{\pi}_{i,t} \]

20. International Euler equation\textsuperscript{15}

\textsuperscript{14}Note that adjustment costs are zero in steady state, \( a(u_i) = 0 \). Notice also that the government keeps aggregate purchases constant, i.e. \( N_i G_{i,t} = N_i G_i \), so that \( \tilde{G}_{i,t} = -\tilde{N}_{i,t} \).

\textsuperscript{15}Our baseline model features incomplete markets. As an alternative, we could assume complete markets. Here, we present the “international Euler equation” for both cases for the sake of completeness.
• With complete markets

\[ \bar{MU}_{i,t}^k = \bar{e}_{i,t} \]

• With incomplete markets (Uncovered interest rate parity)

\[ 0 = \bar{e}_{1,t} \]

\[ \beta \Delta i_{i,t} - \bar{\pi}_{i,t+1} + \bar{e}_{i,t+1} - \bar{e}_{i,t} = \beta \Delta i_{1,t} - \bar{\pi}_{1,t+1} + \bar{e}_{1,t+1} - \bar{e}_{1,t} + \frac{B_i^{*}}{Y_i} \bar{B}_{1,t}^{*}, \quad \text{for} \ n > 1 \]

21. Budget constraint (for incomplete market case)

\[
\sum_{i=1}^{N} N_k^k Y_i \frac{\Delta B_i,t}{Y_i} = 0 \\
\frac{\Delta B_{i,t-1}}{Y_i} - \beta \frac{\Delta B_{i,t}}{Y_i} = \frac{N_i}{N_i^k} \left( \bar{Y}_i - \frac{p_i^M M_i}{P_i^M} \left( \frac{\bar{p}_i^M}{P_i^M} \bar{M}_i \right) \right) \quad \text{for} \quad i > 1
\]

22. Location choice\(^{16}\)

\[ \frac{1}{\gamma} (\bar{n}^i_{j,t} - \bar{n}^j_{j,t}) = \Delta V_{j,t} - \Delta V_{i,t} \quad \text{for} \quad i \neq j \]

\[ \sum_j n^i_{j,t} \bar{n}^j_{j,t} = 0 \]

\(^{16}\)We have

\[ n^i_{j,t} = \exp \left( \varphi_j U_{j,t} - \tau^j_i + \beta V_{j,t+1} \right) \]

\[ \ln n^i_{j,t} = \gamma \left( \varphi_j U_{j,t} - \tau^j_i + \beta V_{j,t+1} \right) - \gamma V_{i,t} \]

and similarly,

\[ \ln n^j_{j,t} = \gamma \left( \varphi_j U_{j,t} + \beta V_{j,t+1} \right) - \gamma V_{j,t} \]

Then,

\[ \ln n^i_{j,t} - \ln n^j_{j,t} = - \gamma \tau^j_i + \gamma V_{j,t} - \gamma V_{i,t} \]
23. Definition of population

\[ N_{i,t} = N_{i,t}^k + N_{i,t}^w \]
\[ \tilde{N}_{i,t} = \frac{N_{i,t}^w}{N_i} N_{i,t}^w \]

24. Stock of workers

\[ N_{i,t}^w = \sum_j n_{j,i}^w N_{j,t-1}^w \]
\[ \tilde{N}_{i,t}^w = \sum_j n_{j,i}^w \left( \tilde{n}_{i,t}^j + \tilde{N}_{j,t-1}^w \right) \]

25. Expected life-time utility\(^{17}\)

\[ \exp(V_{i,t})^\gamma = \frac{\exp \left( \phi_i U \left( c_{i,t}^w \right) + \beta V_{i,t+1} \right)}{n_{i,t}} \]
\[ \Delta V_{i,t} = \phi_i \frac{\partial U_i}{\partial c_i^w} c_i^w c_{i,t}^w + \beta \Delta V_{i,t+1} - \frac{1}{\gamma} n_{i,t}^i. \]

26. Wage Phillips curve

\[ \tilde{w}_{i,t} - \tilde{w}_{i,t-1} + \tilde{\pi}_{i,t} = \frac{(1 - \theta_w)(1 - \beta \theta_w)}{2 \theta_w} \frac{1}{\eta} \tilde{L}_{i,t} + \beta (\tilde{w}_{i,t+1} - \tilde{w}_{i,t} + \tilde{\pi}_{i,t+1}) \]

27. Percentage point change in the unemployment rate

\[ ur_{i,t} = 1 - \frac{L_{i,t}}{L_{i,t}^S} \]
\[ \Delta ur_{i,t} = (1 - ur_i) \left( \tilde{L}_{i,t}^S - \tilde{L}_{i,t} \right) \]

\(^{17}\)Taking logs, we have

\[ V_{i,t} = \phi_i U \left( c_{i,t}^w \right) + \beta V_{i,t+1} - \frac{1}{\gamma} \ln n_{i,t}^i. \]

In deviations from the steady state:

\[ \Delta V_{i,t} = \phi_i \frac{\partial U_i}{\partial c_i^w} c_i^w c_{i,t}^w + \beta \Delta V_{i,t+1} - \frac{1}{\gamma} n_{i,t}^i. \]
28. Real GDP

\[
GDP_{i,t} = P_i^M M_{i,t} + \left( P_i^N - \frac{P_i^M}{Z_{i,t}^N} \right) Y_{i,t}^N
\]

\[
\hat{GDP}_{i,t} = \hat{M}_{i,t} + \frac{P_i^N Y_{i,t}^N}{P_i^M M_{i,t}} \hat{Z}_{i,t}^N
\]

E Simplified model

We consider a two-country setup where the foreign economy is denoted by an asterisk. When we solve for the equilibrium, we focus on a limiting case of this two-country setup where the size of the foreign economy goes towards infinity, i.e. the home economy becomes a small open economy and the foreign economy becomes the rest of the world. Our exposition focuses on the home economy, but equivalent equations hold for the foreign economy as well.

The assumptions differ from those of the quantitative model in the following ways:

1. There is no capital ($N^k = 0, \alpha = 0$).
2. Wages are flexible ($\theta_\omega = 0$) so per capita employment is constant and normalized to 1.
3. We set $\psi_y = 1$ so final good production is $Y_i = (Y_i^N)^{\omega_i} (Y_i^T)^{1-\omega_i}$
4. Trade is balanced at all times.
5. We examine the model’s limiting behavior as $\beta \to 0$.

Each country produces material inputs. Some of these inputs are used to produce a non-traded good, whereas the remaining inputs are traded with the other country. Each country’s final good production is

\[
NGDP_{i,t} = P_i^N M_{i,t} + \left( P_i^N - \frac{P_i^M}{Z_{i,t}^N} \right) Y_{i,t}^N.
\]

In steady state, $NGDP_t = p_i^M M_i$, because $P_i^N = \frac{P_i^M}{Z_t^N}$. Real GDP is then

\[
GDP_{i,t} = P_i^M M_{i,t} + \left( P_i^N - \frac{P_i^M}{Z_{i,t}^N} \right) Y_{i,t}^N.
\]

Log-linearizing yields

\[
\hat{GDP}_{i,t} = \hat{M}_{i,t} + \frac{P_i^N Y_{i,t}^N}{P_i^M M_{i,t}} \hat{Z}_{i,t}^N.
\]

\[\text{Notice that nominal GDP is:}\]

\[
NGDP_{i,t} = p_i^N M_{i,t} + \left( p_i^N - \frac{p_i^M}{Z_{i,t}^N} \right) Y_{i,t}^N.
\]
final consumption good $C_t$ is a Cobb-Douglas aggregate of the non-traded good and the traded good:

$$C_t = \left( \frac{Y_t^N}{\omega_t} \right)^{\frac{\omega_t}{1-\omega_t}} \left( \frac{Y_t^T}{1-\omega_t} \right)^{\frac{1-\omega_t}{1-\omega_t}}$$

where $\omega_t$ is a shock that shifts the demand for domestic intermediates relative to foreign intermediates. The nominal prices of the final good, the non-traded good and the traded good are $P_t$, $P_t^N$ and $P_t^T$. Final good producers choose $Y_t^N$ and $Y_t^T$ to maximize $P_t C_t - P_t^T Y_t^T - P_t^N Y_t^N$, which results in the first order conditions

$$Y_t^N = \omega_t \frac{P_t C_t}{P_t^N},$$

$$Y_t^T = (1 - \omega_t) \frac{P_t C_t}{P_t^T}.$$

The non-traded good $Y_t^N$ is produced from materials using the production function: $Y_t^N = Z_t^N M_t^N$, where $Z_t^N$ is time-varying productivity and $M_t^N$ is the quantity of material inputs used in production of the non-traded intermediate. Denoting $p_t^M$ the nominal price of materials, the price of non-traded goods satisfies

$$P_t^N = \frac{p_t^M}{Z_t^N}.$$

The traded good is modelled as in Eaton and Kortum (2002). Denoting by $p_t^M$ the cost of the input bundle used to produce the tradable varieties, the equilibrium price of the traded good $P_t^T$ is given by

$$P_t^T = \hat{\Gamma} \Phi_t^{-\frac{1}{\delta}},$$

where $\hat{\Gamma} = \left[ \Gamma \left( 1 + \frac{1-\psi_x \phi}{\phi} \right) \right]^{-\frac{1}{1-\psi_x \phi}}$, $\Gamma (\cdot)$ is the Gamma function,

$$\Phi_t \equiv Z \left( p_t^M \right)^{-\theta} + Z^* \left( \frac{p_t^M e^*}{E_t \kappa^*} \right)^{-\theta}.$$

$E_t$ is the nominal exchange rate quoted as units of foreign currency per unit of domestic currency, and $\kappa^*$ is the trade cost for shipping from the foreign economy to the home economy.

The country’s share of total expenditure on its own traded varieties is given by

$$\omega_t = Z \left( \frac{p_t^M}{P_t^T} \right)^{-\theta} = \frac{Z \left( p_t^M \right)^{-\theta}}{Z (p_t^M)^{-\theta} + Z^* \left( \frac{p_t^M e^*}{E_t \kappa^*} \right)^{-\theta}}.$$
Similarly, the foreign country’s share of total expenditure on traded varieties produced by the Home country is given by

$$
\varpi^*_t = Z \left( \frac{E_4 p_t^M}{P^{M,*}} \right)^{-\vartheta} = \frac{Z \left( E_3 p_t^M \kappa_s \right)^{-\vartheta}}{Z^* \left( p_t^{M,*} \right)^{-\vartheta} + Z \left( E_4 p_t^M \kappa_s \right)^{-\vartheta}}
$$

The country’s sales are given by all countries’ expenditure on traded intermediate goods, which have to be equal to the value of production:

$$
\varpi_t N_t p_t^T Y_t^T + \frac{1}{E_t} \varpi^*_t N_t^* p_t^{T,*} Y_t^{T,*} = N_t^* p_t^M M_t^T.
$$

For simplicity, workers have no access to financial markets. This implies trade is balanced and the nominal payments for imports are matched by nominal revenues from exports:

$$
(1 - \varpi_t) N_t p_t^T Y_t^T = \frac{1}{E_t} \varpi^*_t N_t^* p_t^{T,*} Y_t^{T,*}
$$

Inserting the expressions for $\varpi_t$ and $\varpi^*_t$ and re-arranging yields

$$
E_t^{2\vartheta + 1} \left( p_t^M \right)^\vartheta \left( p_t^T \right)^{1+\vartheta} N_t Y_t^T = \left( \frac{1}{p_t^{M,*} p_t^{T,*}} \right)^{-\vartheta} Z N_t^* \frac{Z}{Z^*} p_t^{T,*} Y_t^{T,*}.
$$

In the SOE limiting case, $N^* \to \infty$. Following Alvarez and Lucas Jr (2007), we assume that $Z^* \to \infty$ at the same rate such that the term $\frac{N_t^*}{Z^*}$ stays constant. As $Z^* \to \infty$, the country’s share of total expenditure on its own traded varieties, $\varpi_t$, will go to zero. To prevent this, we suppose that the increase in productivity in the RoW is counterbalanced by an increase in trade costs, i.e. the ratio $\frac{Z^*}{\kappa}$ is constant as $N^* \to \infty$ and $Z^* \to \infty$.

Materials $M_t$ are produced by competitive firms from a CES combination of individual intermediate inputs

$$
M_t = \left[ \int_0^1 m_i(s) \frac{\nu_m - 1}{\nu_m} ds \right] ^ {\frac{\nu_m - 1}{\nu_m}}.
$$

(E.1)

Aggregate intermediate good firms maximize $p_t^M M_t - \int_0^1 p_t^M(s) m_i(s) ds$. Standard calculations imply that demand for any type is

$$
m_i(s) = M_t \left( \frac{p_t^M(s)}{p_t^M} \right)^{-\psi_m}
$$

(E.2)
and the competitive nominal price of the aggregate intermediate good is

\[ p^M_t = \left[ \int_0^1 p^M_t(s)^{1-\psi_m} \, ds \right]^{\frac{1}{1-\psi_m}}. \]

Individual varieties of intermediate inputs are produced by monopolistically competitive producers with linear production functions \( m_t(s) = L_t(s) \). These firms maximize \( p^M_t(s) m_t(s) - W_t L_t(s) \) subject to the production function and the demand curve (E.2). The optimal price is a fixed markup over nominal marginal costs \( W_t \). As is common in the New Keynesian literature, we introduce a subsidy that eliminates the inefficiency. As a result, firms’ desired price is equal to nominal marginal cost, \( p^M_t(s) = W_t \).

With sticky prices, the nominal price of the intermediate good in period \( t \) is

\[ p^M_t = \left[ \theta (p^M_{t-1})^{1-\psi_m} + (1 - \theta) (W_t)^{1-\psi_m} \right]^{\frac{1}{1-\psi_m}} \quad (E.3) \]

Note that any deviation from the flexible prices (\( W_t \neq 1 \)), is associated with fluctuations in \( p^M_t \). Moreover, fluctuations in \( p^M_t \) are associated with output losses. To see this, using (E.1), (E.2) and (E.3) and noting that per-capita labor is normalized to 1, we can write the aggregate production of materials as

\[ M_t = \frac{1}{v_t}, \]

where

\[ v_t = \int_0^1 \left( \frac{p^M_t(s)}{p^M_t} \right)^{-\psi_m} \]

is a measure of price dispersion. In a flex-price equilibrium \( v_t = 1 \) and there is no inefficiency in production. If some prices are stuck and differ across producers, then \( v_t > 1 \) and there is an avoidable loss in output equal to \((v_t - 1) \times 100\) percent.

The model is completed by a block describing monetary policy (which sets the exchange rate \( E_t \)) and a block describing migration (which sets \( N \)).

**Summary** The equilibrium is described by the following equations:

---

\(^{19}\)The revenue necessary to provide the subsidy are provided through lump sum taxes by the households. Profits earned by the monopolistically competitive firms are transferred back to the households.
1. Price index final good\(^{20}\)

\[
P_t = \left( \frac{p_t^M}{Z_t} \right)^{\omega_t} (P_t^T)^{1-\omega_t}
\]

2. Price index of the traded good

\[
(P_t^T)^{-\theta} = \hat{\lambda}^{-\theta} \left( Z \left( \frac{p_t^M}{p_t^T} \right)^{-\theta} + \hat{Z}^* \left( \frac{p_t^M}{E_t} \right)^{-\theta} \right)
\]

3. Balanced trade\(^{21}\)

\[
\frac{E_t p_t^M N_t}{v_t} = \frac{\text{const.}}{1 - \omega_t} \left( E_t^2 p_t^M P_t^T \right)^{-\theta}
\]

4. Labor demand / Phillips curve

\[
1 = \theta \left( \frac{p_{t-1}^M}{p_t^M} \right)^{1-\psi_m} + (1 - \theta) \left( \frac{W_t}{p_t^M} \right)^{1-\psi_m}
\]

5. Price dispersion

\[
v_t = \theta \left( \frac{p_t^M}{p_t^N} \right)^\psi + (1 - \theta) \left( \frac{W_t}{p_t^M} \right)^{-\psi}
\]

\(^{20}\)Inserting the optimal demand for \(Y^N_t = \omega_t \frac{P_t C_t}{p_t^N}\) and \(Y^T_t = (1 - \omega_t) \frac{P_t C_t}{p_t^M}\) into the Cobb-Douglas production function \(C_t = \left( \frac{Y^N_t}{\omega_t} \right)^{\omega_t} \left( \frac{Y^T_t}{1-\omega_t} \right)^{1-\omega_t}\) yields

\[
1 = \left( \frac{P_t}{p_t^N} \right)^{\omega_t} \left( \frac{P_t}{p_t^T} \right)^{1-\omega_t}
\]

\(^{21}\)Balanced trade requires

\[
E_t^{2\theta+1} \left( p_t^M \right)^\theta \left( P_t^T \right)^{1+\theta} N_t Y_t^T = \text{const.}
\]

Note that \(P_t^T Y_t^T = (1 - \omega_t) P_t C_t\). Further, balanced trade implies that the value of consumption \(P_t C_t\) must be equal to the value of production \(p_t^M M_t\). That is \(Y_t^T = (1 - \omega_t) \frac{p_t^M}{P_t^T} M_t\). Inserting this above yields

\[
(1 - \omega_t) \frac{p_t^M}{P_t^T} M_t, E_t^{2\theta+1} \left( p_t^M \right)^\theta \left( P_t^T \right)^{1+\theta} N_t = \text{const.}
\]

Solving for \(M_t\) and noticing that \(M_t = \frac{1}{v_t}\) yields

\[
\frac{E t^{2\theta+1} N_t}{v_t} = \frac{\text{const.}}{1 - \omega_t} \left( E_t^2 p_t^M P_t^T \right)^{-\theta}
\]
as well as one equation describing monetary policy (either $E_t = 1$ or $p_t^M = 1$) and one equation describing labor supply.

This yields a system of 7 equations in 7 endogenous variables ($P_t, P_t^T, p_t^M, E_t, N_t, v_t, W_t$).

We re-state the lemma from the main body of the text and provide the proof below.

**Lemma T**

*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:*

1. \[(i)\]
2. \[\ddot{N}_t = \dot{\gamma} \ddot{w}_t\]
3. \[\ddot{N}_t = -\Psi_1 \left( \ddot{E}_t + \ddot{p}_t^M \right) + \ddot{w}_t\]
4. \[\dot{w}_t = \omega \ddot{Z}_t - (1 - \omega)(1 - \omega)\ddot{E}_t + \Psi_2 \ddot{p}_t^M\]
5. \[v_t \approx 1 + \Theta_v (\ddot{p}_t^M)^2,\]
   with \[\Psi_1 = 1 + \vartheta(1 + \varpi),\]
   \[\Psi_2 = \frac{1}{1 - \theta} - \omega + (1 - \omega)\varpi\]
   and \[\Theta_v = \frac{1}{2} \frac{\theta}{1 - \theta} \psi_m (\psi_m - 1 + 2\theta).\]

*Proof.* Before log-linearizing the equations, we describe the log-linearized equations for the migration block. For the small economy, the relevant equations are

\[
\begin{align*}
\Delta V_t &= n (\ddot{w}_t + \beta \Delta V_{t+1}) + (1 - n) \left( \ddot{w}_t^* + \beta \Delta V_{t+1}^* \right) \\
\ddot{N}_t &= \gamma (\ddot{w}_t + \beta \Delta V_{t+1}) + n \left( \ddot{N}_{t-1} - \gamma \Delta V_t \right) + (1 - n) \left( \ddot{N}_{t-1}^* - \gamma \Delta V_{t}^* \right),
\end{align*}
\]

where $n$ denotes the share of workers that stay in the small economy in steady state. In the limiting case of a small open economy, the small country is sufficiently small that it has no influence over economic variables in the rest of the world. We also consider the limiting case as $\beta \to 0$. That is,

\[
\begin{align*}
\Delta V_t &= n \ddot{w}_t \\
\ddot{N}_t &= \gamma \ddot{w}_t + n \left( \ddot{N}_{t-1} - \gamma \Delta V_t \right).
\end{align*}
\]

Taken together, this yields

\[\ddot{N}_t = (1 - n^2) \gamma \ddot{w}_t + n \ddot{N}_{t-1}.\]

This corresponds to equation (i) in the Lemma, with \[\dot{\gamma} = (1 - n^2) \gamma.\]

We now log linearize the remaining equations.
1. Price index final good

\[ P_t = \left( \frac{P_t^M}{Z_t} \right)^{\omega} \left( P_t^T \right)^{1-\omega} \]

\[ \tilde{P}_t = \omega \left( \tilde{P}_t^M - \tilde{Z}_t \right) + (1 - \omega) \tilde{P}_t^T \]

2. Price index of the traded good

\[ (P_t^T)^{-\theta} = \tilde{\Gamma}^{-\theta} \left( Z (p_t^M)^{-\theta} + Z^* \left( \frac{p_t^{M,s}}{E_t^s} \right)^{-\theta} \right) \]

\[ \tilde{P}_t^T = \omega \tilde{p}_t^M - (1 - \omega) \tilde{E}_t \]

3. Balanced trade

\[ \frac{E_t p_t^M N_t}{v_t} = \text{const.} \left( E_t^2 p_t^M P_t^T \right)^{-\theta} \]

\[ \tilde{E}_t + \tilde{p}_t^M + \tilde{N}_t = \frac{d\omega_t}{1 - \omega} - \vartheta \left( \tilde{P}_t^T + \tilde{p}_t^M + 2 \tilde{E}_t \right) \]

4. Labor demand / Phillips curve

\[ 1 = \theta (p_t^M)^{\psi_m^{-1}} + (1 - \theta) \left( \frac{W_t}{p_t^M} \right)^{1-\psi_m} \]

\[ 0 = \theta \tilde{p}_t^M + (1 - \theta) \left( \tilde{W}_t - \tilde{p}_t^M \right) \]

5. Price dispersion

\[ v_t = \theta (p_t^M)^{\psi} + (1 - \theta) \left( \frac{W_t}{p_t^M} \right)^{-\psi} \]

\[ \frac{1}{\psi_m} \tilde{v}_t = \theta \tilde{p}_t^M + (1 - \theta) \left( \tilde{W}_t - \tilde{p}_t^M \right) \]

We simplify these equations as follows. First, the labor demand equation can be written
as

\[ 0 = \theta \hat{p}^M_t + (1 - \theta) \left( \hat{W}_t - \hat{p}^M_t \right) \]

\[ = (1 - \theta)\hat{W}_t - \hat{p}^M_t \]

\[ = (1 - \theta)\hat{w}_t + (1 - \theta)\hat{P}_t - \hat{p}^M_t \]

\[ \hat{w}_t = -\hat{P}_t + \frac{1}{1 - \theta}\hat{p}^M_t \]

\[ = -\left( \omega \left( \hat{p}^M_t - \hat{Z}_t \right) + (1 - \omega)\hat{P}^T_t \right) + \frac{1}{1 - \theta}\hat{p}^M_t \]

\[ = -\left( \omega \left( \hat{p}^M_t - \hat{Z}_t \right) + (1 - \omega) \left( \omega \hat{p}^M_t - (1 - \omega)\hat{E}_t \right) \right) + \frac{1}{1 - \theta}\hat{p}^M_t \]

\[ \hat{w}_t = \omega \hat{Z}_t - (1 - \omega)(1 - \omega)\hat{E}_t + \left( \frac{1}{1 - \theta} - \omega + (1 - \omega)\omega \right)\hat{p}^M_t \]

This corresponds to equation (iii) in Lemma 1, with \( \Psi_2 = \frac{1}{1 - \theta} - \omega + (1 - \omega)\omega \). Second, the balanced trade equation can be written as

\[ \hat{E}_t + \hat{p}^M_t + \hat{N}_t = \frac{d\omega_t}{1 - \omega} - \vartheta \left( \hat{P}^T_t + \hat{p}^M_t + 2\hat{E}_t \right) \]

\[ \hat{N}_t = - \left( \hat{E}_t + \hat{p}^M_t \right) + \frac{d\omega_t}{1 - \omega} - \vartheta \left( \omega \hat{p}^M_t - (1 - \omega)\hat{E}_t + \hat{p}^M_t + 2\hat{E}_t \right) \]

\[ \hat{N}_t = - \left( \hat{E}_t + \hat{p}^M_t \right) + \frac{d\omega_t}{1 - \omega} - \vartheta (1 + \omega) \left( \hat{p}^M_t + \hat{E}_t \right) \]

\[ \hat{N}_t = - (1 + \vartheta (1 + \omega)) \left( \hat{E}_t + \hat{p}^M_t \right) + \frac{d\omega_t}{1 - \omega} \]

This corresponds to equation (ii) in Lemma 1, with \( \Psi_1 = 1 + \vartheta (1 + \omega) \).

Finally, we derive a second-order approximation of the price dispersion term. We can write the distortion term as

\[ v_t = \theta \left( p^M_t \right)^{\psi_m} + (1 - \theta) \left( \xi_t \right)^{-\psi_m}, \]

with \( \xi_t = \frac{w}{p_t} \). The (second order) log linear version of this expression is

\[ dv_t = \bar{v}_t + \frac{1}{2} \left\{ \theta \psi_m \left( \psi_m - 1 \right) \left( dp^M_t \right)^2 + \psi_m \left( \psi_m + 1 \right) (1 - \theta) \left( d\xi_t \right)^2 \right\}. \]

From above, we know that the first order term in the expression is zero so in the end the
efficiency losses are only the second order term

\[ dv_t = \frac{1}{2} \left\{ \theta \psi_m (\psi_m - 1) (\tilde{p}_t^M)^2 + \psi_m (\psi_m + 1) (1 - \theta) (\tilde{\xi}_t)^2 \right\}, \]

so that

\[ v_t \approx 1 + \frac{\psi_m}{2} \left\{ \theta (\psi_m - 1) (dp_t^M)^2 + (\psi_m + 1) (1 - \theta) (d\xi_t)^2 \right\} \]

\[ = 1 + \frac{\psi_m}{2} \frac{\theta}{1 - \theta} (\psi_m - 1 + 2\theta) (\tilde{p}_t^M)^2, \]

where the second equality uses \( \theta \tilde{p}_t^M = (1 - \theta)\tilde{\xi}_t \). This establishes equation (iv) in Lemma 1, with \( \Theta_v = \frac{\psi_m}{2} \frac{\theta}{1 - \theta} (\psi_m - 1 + 2\theta) \).  

We re-state the proposition from the main body of the text and provide the proof below. 

**Proposition 1 (Cost of currency union)**

The expected cost of the currency union is

\[ \Theta_v \frac{\sigma^2_\omega + (\tilde{\gamma}_\omega)^2 \sigma^2_Z}{(\Psi_1 + \tilde{\gamma}_\Psi_2)^2}, \]

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

\[ \frac{\Psi_1}{\Psi_2} \tilde{\gamma}_\omega^2 < \frac{\sigma^2_\omega}{\sigma^2_Z}. \]

**Proof.** We assume that, under independent monetary policy, the central bank conducts an optimal monetary policy that eliminates any price dispersion such that there are no losses from nominal rigidities.

With a fixed exchange rate \( (\tilde{E}_t = 0) \), the first two equations of the lemma yield

\[ \tilde{\gamma}_\omega \tilde{E}_t = -\Psi_1 \tilde{p}_t^M + \tilde{\omega}_t. \]

Solving out:

\[ \tilde{p}_t^M = \frac{\tilde{\omega}_t - \tilde{\gamma}_\omega \tilde{Z}_t}{\Psi_1 + \tilde{\gamma}_\Psi_2}. \]

To calculate the losses associated with nominal rigidities, we assume that the demand shocks
and productivity shocks are uncorrelated and have variances $\sigma_\omega^2$, and $\sigma_Z^2$. Then, using equation (iv) of the lemma, the loss is equal to

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

The cost of the union is therefore higher for lower trade elasticities ($\vartheta$ small), higher import shares ($\varpi$ big), stronger price rigidity ($\theta$ big). The cost of the union is increasing in labor mobility $\hat{\gamma}$ if

$$2\gamma\omega^2\sigma_Z^2(\Psi_1 + \hat{\gamma}\Psi_2)^2 < 2\left(\sigma_\omega^2 + (\hat{\gamma}\omega)^2 \sigma_Z^2\right)(\Psi_1 + \hat{\gamma}\Psi_2)\Psi_2$$

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

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

Inserting the expressions for $\Psi_1$ and $\Psi_2$:

$$\hat{\gamma}\omega^2 \frac{1 + \vartheta(1 + \varpi)}{\frac{1}{1-\theta} - \omega + (1 - \omega)\varpi} < \frac{\sigma_\omega^2}{\sigma_Z^2}$$

Migration therefore reduces the cost of the currency union if demand shocks are sufficiently prevalent compared to supply shocks, i.e. $\frac{\sigma_\omega^2}{\sigma_Z^2}$ should be large, prices are particularly rigid, i.e. $\theta$ should be large, and / or the trade elasticity is low, i.e. $\vartheta$ is small.

The role of the import share of traded goods, $1 - \varpi$, is ambiguous: If the trade elasticity is high, a higher import share makes migration more likely to reduce the cost of the currency union. If the trade elasticity is low, a lower import share is more likely to support Mundell’s hypothesis. (The threshold for the trade elasticity is $\vartheta = (1 - \omega)\frac{1-\theta}{\theta}$.)
References


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<td>2019</td>
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Table A2: Availability of Migration Data

| Country               | adj in | adj out | 95 | 96 | 97 | 98 | 99 | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|-----------------------|-------|---------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| **Part A: Euro area sample** |       |         |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Belgium               | 1.20  | 1.21    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Germany               | 1.79  | 2.61    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Estonia               | 0.45  | 0.42    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Ireland               | -     | -       |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Greece                | -     | -       |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Spain                 | 1.24  | 1.03    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| France                | -     | -       |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Italy                 | 0.99  | 0.97    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Cyprus                | -     | -       |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Latvia                | 1.00  | 1.00    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Lithuania             | -     | -       |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Malta                 | -     | -       |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Netherlands           | 1.24  | 1.14    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Austria               | 1.45  | 1.73    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Portugal              | -     | -       |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Slovenia              | 1.00  | 1.00    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Slovakia              | 1.00  | 1.00    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Finland               | 1.00  | 1.00    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| **Part B: Other European countries** |       |         |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Bulgaria              | 1.00  | 1.00    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Czech Republic        | 0.84  | 0.48    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Denmark               | 1.31  | 1.24    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Croatia               | -     | -       |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Luxembourg            | -     | -       |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Hungary               | -     | -       |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Poland                | -     | -       |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Romania               | -     | -       |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Sweden                | 1.00  | 1.00    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| United Kingdom        | 0.91  | 0.92    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Iceland               | 1.28  | 1.52    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Norway                | 1.10  | 1.34    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Switzerland           | 1.19  | 1.00    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

Notes: Table displays aggregate (unilateral) migration data based on either the national definition (grey) or the Eurostat definition (black). The adjustment factor is used to transform migration data based on national definitions into migration data based on the Eurostat definition. It is calculated as the ratio of migration data based on the national definition to migration data based on the Eurostat definition, averaged over all time periods where data from both sources overlap.
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<td>New Hampshire</td>
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<td>2.4</td>
<td>96.3</td>
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<td>96.1</td>
<td>0.55</td>
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<td>96.3</td>
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<td>94.9</td>
<td>0.26</td>
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<tr>
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<td>3.8</td>
<td>97.2</td>
<td>0.46</td>
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<td>95.6</td>
<td>0.33</td>
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<tr>
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<td>0.87</td>
<td>Oklahoma</td>
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<td>3.6</td>
<td>95.9</td>
<td>0.79</td>
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<tr>
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<td>2.1</td>
<td>96.6</td>
<td>0.23</td>
<td>Oregon</td>
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<td>0.60</td>
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<td>97.8</td>
<td>0.32</td>
<td>Pennsylvania</td>
<td>12.3</td>
<td>1.8</td>
<td>96.7</td>
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<td>2.5</td>
<td>97.9</td>
<td>0.44</td>
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<td>3.0</td>
<td>96.6</td>
<td>0.39</td>
</tr>
<tr>
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<td>3.8</td>
<td>96.0</td>
<td>0.24</td>
<td>South Carolina</td>
<td>3.9</td>
<td>3.5</td>
<td>96.2</td>
<td>0.33</td>
</tr>
<tr>
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<td>2.8</td>
<td>96.6</td>
<td>0.26</td>
<td>South Dakota</td>
<td>0.8</td>
<td>3.6</td>
<td>97.1</td>
<td>0.47</td>
</tr>
<tr>
<td>Louisiana</td>
<td>4.4</td>
<td>2.7</td>
<td>96.3</td>
<td>0.91</td>
<td>Tennessee</td>
<td>5.5</td>
<td>3.2</td>
<td>97.7</td>
<td>0.30</td>
</tr>
<tr>
<td>Maine</td>
<td>1.3</td>
<td>2.8</td>
<td>96.7</td>
<td>0.37</td>
<td>Texas</td>
<td>20.4</td>
<td>2.6</td>
<td>94.4</td>
<td>0.52</td>
</tr>
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<td>3.1</td>
<td>95.1</td>
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<td>Utah</td>
<td>2.2</td>
<td>3.4</td>
<td>97.2</td>
<td>0.56</td>
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<td>95.3</td>
<td>0.29</td>
<td>Vermont</td>
<td>0.6</td>
<td>3.3</td>
<td>97.6</td>
<td>0.30</td>
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<tr>
<td>Michigan</td>
<td>9.6</td>
<td>1.7</td>
<td>96.3</td>
<td>0.34</td>
<td>Virginia</td>
<td>6.9</td>
<td>4.0</td>
<td>92.5</td>
<td>0.29</td>
</tr>
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<td>Minnesota</td>
<td>4.8</td>
<td>2.0</td>
<td>97.3</td>
<td>0.22</td>
<td>Washington</td>
<td>5.6</td>
<td>3.5</td>
<td>94.5</td>
<td>0.51</td>
</tr>
<tr>
<td>Mississippi</td>
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<td>3.0</td>
<td>97.0</td>
<td>0.23</td>
<td>West Virginia</td>
<td>1.8</td>
<td>2.7</td>
<td>98.5</td>
<td>0.47</td>
</tr>
<tr>
<td>Missouri</td>
<td>5.5</td>
<td>2.8</td>
<td>97.3</td>
<td>0.22</td>
<td>Wisconsin</td>
<td>5.2</td>
<td>1.8</td>
<td>97.7</td>
<td>0.25</td>
</tr>
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<td>Montana</td>
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<td>4.1</td>
<td>97.4</td>
<td>0.72</td>
<td>Wyoming</td>
<td>0.5</td>
<td>6.1</td>
<td>97.7</td>
<td>1.59</td>
</tr>
</tbody>
</table>

Notes: Table displays average population (pop, in millions), the average migration rate (migr), the share of internal migration in total migration (dom), and the standard deviation across time of the net migration rate (sd(netm)).

Time period: 1977-2018
Table A4: MIGRATION STATISTICS: EUROPE

<table>
<thead>
<tr>
<th>Country</th>
<th>pop</th>
<th>migr</th>
<th>dom</th>
<th>sd(netm)</th>
<th>pop</th>
<th>migr</th>
<th>dom</th>
<th>sd(netm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>10.7</td>
<td>0.8</td>
<td>59.5</td>
<td>0.15</td>
<td>Malta</td>
<td>0.4</td>
<td>1.9</td>
<td>–</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>7.7</td>
<td>1.0</td>
<td>53.7</td>
<td>0.47</td>
<td>Netherlands</td>
<td>16.4</td>
<td>0.6</td>
<td>49.0</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>10.4</td>
<td>0.4</td>
<td>–</td>
<td>0.24</td>
<td>Austria</td>
<td>8.3</td>
<td>0.8</td>
<td>50.9</td>
</tr>
<tr>
<td>Denmark</td>
<td>5.5</td>
<td>0.8</td>
<td>53.2</td>
<td>0.13</td>
<td>Poland</td>
<td>38.2</td>
<td>0.6</td>
<td>–</td>
</tr>
<tr>
<td>Germany</td>
<td>82.0</td>
<td>0.6</td>
<td>47.5</td>
<td>0.29</td>
<td>Portugal</td>
<td>10.4</td>
<td>0.3</td>
<td>–</td>
</tr>
<tr>
<td>Estonia</td>
<td>1.4</td>
<td>0.5</td>
<td>71.9</td>
<td>0.23</td>
<td>Romania</td>
<td>21.1</td>
<td>0.9</td>
<td>–</td>
</tr>
<tr>
<td>Ireland</td>
<td>4.3</td>
<td>1.4</td>
<td>63.7</td>
<td>0.73</td>
<td>Slovenia</td>
<td>2.0</td>
<td>0.6</td>
<td>32.7</td>
</tr>
<tr>
<td>Greece</td>
<td>10.9</td>
<td>0.7</td>
<td>–</td>
<td>0.34</td>
<td>Slovakia</td>
<td>5.4</td>
<td>0.2</td>
<td>114.3</td>
</tr>
<tr>
<td>Spain</td>
<td>43.9</td>
<td>0.8</td>
<td>43.2</td>
<td>0.59</td>
<td>Finland</td>
<td>5.3</td>
<td>0.4</td>
<td>60.3</td>
</tr>
<tr>
<td>France</td>
<td>63.4</td>
<td>0.4</td>
<td>40.8</td>
<td>0.05</td>
<td>Sweden</td>
<td>9.3</td>
<td>0.7</td>
<td>47.1</td>
</tr>
<tr>
<td>Italy</td>
<td>58.5</td>
<td>0.4</td>
<td>40.5</td>
<td>0.22</td>
<td>United Kingdom</td>
<td>61.5</td>
<td>0.7</td>
<td>39.8</td>
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<tr>
<td>Cyprus</td>
<td>0.8</td>
<td>1.5</td>
<td>–</td>
<td>1.17</td>
<td>Iceland</td>
<td>0.3</td>
<td>1.6</td>
<td>79.2</td>
</tr>
<tr>
<td>Latvia</td>
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<td>0.7</td>
<td>44.8</td>
<td>0.36</td>
<td>Norway</td>
<td>4.8</td>
<td>0.8</td>
<td>56.8</td>
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<tr>
<td>Lithuania</td>
<td>3.2</td>
<td>0.9</td>
<td>57.1</td>
<td>0.58</td>
<td>Switzerland</td>
<td>7.6</td>
<td>1.3</td>
<td>60.5</td>
</tr>
<tr>
<td>Hungary</td>
<td>10.1</td>
<td>0.4</td>
<td>–</td>
<td>0.09</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: Table displays average population (pop, in millions), the average migration rate (migr), the share of internal migration in total migration (dom), and the standard deviation across time of the net migration rate (st(netm)). Time period: 1995-2018

Table A5: MIGRATION STATISTICS

<table>
<thead>
<tr>
<th>Nb.</th>
<th>Ave pop</th>
<th>Migr rate</th>
<th>Internal migr</th>
<th>Net migr rate (std dev)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit</td>
<td>#</td>
<td>m</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>US</td>
<td>48</td>
<td>5.65</td>
<td>3.24</td>
<td>3.12</td>
</tr>
<tr>
<td>Euro</td>
<td>18</td>
<td>18.30</td>
<td>0.75</td>
<td>0.23</td>
</tr>
<tr>
<td>Europe</td>
<td>29</td>
<td>17.44</td>
<td>0.78</td>
<td>0.43</td>
</tr>
<tr>
<td>Eurocore</td>
<td>11</td>
<td>28.54</td>
<td>0.64</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Notes: Table displays the number of regions (States / Provinces / Countries) for the United States, Canada and three European samples, their average population (in millions), their average migration rate, the average internal migration rate, and the average standard deviation across time of the net-migration rate. Migration is the average of inmigration and outmigration. Values are simple averages across regions and time ('77-'18 for North America and '95-'18 for Europe).
Table A6: UNEMPLOYMENT AND NET MIGRATION

<table>
<thead>
<tr>
<th></th>
<th>US</th>
<th>Euro</th>
<th>Europe</th>
<th>Eurocore</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>-0.261</td>
<td>-0.080</td>
<td>-0.068</td>
<td>-0.078</td>
</tr>
<tr>
<td></td>
<td>(0.028)</td>
<td>(0.011)</td>
<td>(0.012)</td>
<td>(0.009)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.24</td>
<td>0.24</td>
<td>0.18</td>
<td>0.51</td>
</tr>
<tr>
<td>No. Obs.</td>
<td>2,016</td>
<td>379</td>
<td>586</td>
<td>247</td>
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</table>

Table A7: UNEMPLOYMENT AND NET MIGRATION

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<th></th>
<th>US</th>
<th>Euro</th>
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</thead>
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<tr>
<td><strong>Baseline</strong></td>
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<td></td>
</tr>
<tr>
<td>$\beta$</td>
<td>-0.261</td>
<td>-0.080</td>
</tr>
<tr>
<td></td>
<td>(0.028)</td>
<td>(0.011)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.24</td>
<td>0.28</td>
</tr>
<tr>
<td>No. Obs.</td>
<td>2,016</td>
<td>379</td>
</tr>
<tr>
<td><strong>Time dummies</strong></td>
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<tr>
<td>$\beta$</td>
<td>-0.262</td>
<td>-0.080</td>
</tr>
<tr>
<td></td>
<td>(0.026)</td>
<td>(0.012)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.11</td>
<td>0.34</td>
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<tr>
<td><strong>NAWRU</strong></td>
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<tr>
<td>$\beta$</td>
<td>-0.262</td>
<td>-0.085</td>
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<td>(0.026)</td>
<td>(0.011)</td>
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<tr>
<td>$R^2$</td>
<td>0.24</td>
<td>0.17</td>
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<tr>
<td>No. Obs.</td>
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<td>374</td>
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<td><strong>Baxter-King</strong></td>
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<tr>
<td>$\beta$</td>
<td>-0.259</td>
<td>-0.102</td>
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<tr>
<td></td>
<td>(0.033)</td>
<td>(0.013)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.18</td>
<td>0.25</td>
</tr>
<tr>
<td>No. Obs.</td>
<td>1,632</td>
<td>235</td>
</tr>
<tr>
<td><strong>Including wages</strong></td>
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<td></td>
</tr>
<tr>
<td>$\beta$</td>
<td>-0.257</td>
<td>-0.079</td>
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<tr>
<td></td>
<td>(0.028)</td>
<td>(0.010)</td>
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<tr>
<td>$\gamma$</td>
<td>0.007</td>
<td>0.002</td>
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<tr>
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<tr>
<td>$R^2$</td>
<td>0.25</td>
<td>0.28</td>
</tr>
<tr>
<td>No. Obs.</td>
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<td>235</td>
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</table>

*Notes:* Table displays regression results with alternative filters and a regression that includes wages.
## Table A8: IMPUTATION OF BILATERAL MIGRATION FLOWS

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<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
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</thead>
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<td>0.28</td>
<td>-0.01</td>
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</tr>
<tr>
<td></td>
<td>(0.11)</td>
<td>(0.09)</td>
<td>(0.08)</td>
<td></td>
</tr>
<tr>
<td>Contiguity</td>
<td>0.52</td>
<td>-0.24</td>
<td>-0.13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.19)</td>
<td>(0.13)</td>
<td>(0.12)</td>
<td></td>
</tr>
<tr>
<td>Common language</td>
<td>-0.11</td>
<td>-0.19</td>
<td>-0.10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.24)</td>
<td>(0.17)</td>
<td>(0.15)</td>
<td></td>
</tr>
<tr>
<td>Euro</td>
<td>-0.30</td>
<td>-0.27</td>
<td>-0.13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.15)</td>
<td>(0.10)</td>
<td>(0.10)</td>
<td></td>
</tr>
<tr>
<td>EU</td>
<td>0.57</td>
<td>-0.07</td>
<td>0.21</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.39)</td>
<td>(0.28)</td>
<td>(0.26)</td>
<td></td>
</tr>
<tr>
<td>Migrant Stock(_{i,j})</td>
<td>0.46</td>
<td>0.43</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>(0.04)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Migrant Stock(_{j,i})</td>
<td>0.34</td>
<td>0.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>(0.04)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>gdp(_i) – gdp(_j)</td>
<td>0.68</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.06)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Country FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>R(^2)(_\text{partial})</td>
<td>0.73</td>
<td>0.77</td>
<td>0.89</td>
<td>0.91</td>
</tr>
<tr>
<td>No. Obs.</td>
<td>814</td>
<td>814</td>
<td>784</td>
<td>784</td>
</tr>
</tbody>
</table>

**Notes:** Table displays the regression coefficients of

\[
\ln v_{i,j} = \beta_i + \beta_j + \beta z_{i,j} + \varepsilon_{i,j}.
\]

Dependent variable is average log migration from country \(j\) to country \(i\). Explanatory variables are the log of the population-weighted distance, a contiguity dummy, common official language, the euro, membership in the European Union, the log long-run migration stocks of people born in \(j\) living in \(i\) and people born in \(i\) living in \(j\), and the absolute log difference in GDP per capita between country \(j\) and \(i\). Specification (4) is our main specification.
Table A9: Bilateral Migration Matrix

<table>
<thead>
<tr>
<th>To</th>
<th>BEL</th>
<th>BGR</th>
<th>CZE</th>
<th>DK</th>
<th>FRA</th>
<th>HUN</th>
<th>AUT</th>
<th>POL</th>
<th>SVK</th>
<th>NOR</th>
<th>CHE</th>
<th>RoW</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEL</td>
<td>0.993</td>
<td>0.004</td>
<td>0.008</td>
<td>0.009</td>
<td>0.014</td>
<td>0.013</td>
<td>0.011</td>
<td>0.011</td>
<td>0.014</td>
<td>0.013</td>
<td>0.011</td>
<td>0.014</td>
<td>0.011</td>
</tr>
<tr>
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Notes: Table displays the bilateral migration matrix estimated from the table. Each cell displays the share of people from the country at the top of the column that move to the country at the beginning of the row. Values in each column sum to 100. Values are based on averages between 1995 and 2015.
Table A10: COUNTRY-SPECIFIC STEADY-STATES VALUES

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Notes: Table displays the 18 euro area countries plus the Rest of the World in our sample. Averages for the euro area are displayed in the last column. Population is measured relative to the euro area. GDP per capita of the euro area is normalized to 1. The trade share is imports over GDP. The gross migration rate is expressed in percent. The labor force is in percent of the overall population. Government purchases are in percent of GDP.
## Table A11: BILATERAL TRADE MATRIX FOR MODEL CALIBRATION

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Notes: Table displays values for $c_{ij}$. The value in a cell is country 'row's expenditure on traded goods produced in country 'row', as a share of all expenditure on country 'row's traded goods. Values are in percent. Each column sums to 100. See Section C.5 for the derivation of this Table.
Table A12: BILATERAL MIGRATION MATRIX FOR MODEL CALIBRATION

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Notes: Table displays values for \( n_i^j \). Each cell display the share of people from the country at the top of the column that move to the country at the beginning of the row. Values in each column sum to 1. Values are in percent. Each column sums to 100. Table is derived from Table A9 and is adjusted following the procedure outlined in C.5.
Note: The figure plots the migration-to-population ratio against population for US States, Canadian Provinces, European and core euro area countries. Migration is measured as the average of immigration and emigration. Values are averages over 1995 - 2015. The 'core euro area' sample is a subset of the 'Europe' sample.
Figure A2: Migration Rates over Time

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

Figure A3: Cross-Sectional Standard Deviations in Unemployment Rates

*Note:* The figure plots cross-sectional standard deviation in demeaned unemployment rates, $\bar{\sigma}_{i,t}$, for four regions: US states, Canadian provinces, European countries and core euro countries. The dotted lines are the respective time averages. See the text for the definition of demeaned unemployment rates.
Figure A4: Local Projections

Notes: Figure displays the estimated coefficients (and standard errors) from local projection regressions (see equation (3.4)) for the U.S. (panel (a)), Canada (panel (b)), Europe (panel (c)) and the Euro core (panel (d)). The first set displays the coefficients from regressing the demeaned unemployment rate at time $t+h$, $\tilde{u}_{t,t+h}$, on the demeaned unemployment rate at time $t$, $\tilde{u}_{t,t}$ controlling for two lags $\tilde{u}_{t,t-1}$ and $\tilde{u}_{t,t-2}$. The second set regresses the demeaned net migration rate at time $t+h$, $\tilde{m}_{t,t+h}$, on the demeaned unemployment rate at time $t$, $\tilde{u}_{t,t}$ controlling for two lags $\tilde{u}_{t,t-1}$ and $\tilde{u}_{t,t-2}$. The estimated population response at horizon $h$ is calculated from the estimated coefficients as $\left(\sum_{k=0}^{h}(1 + \beta_k^h)\right) - 1$ of the net migration regression.
Figure A5: Net Migration vs. Unemployment: Repeated Cross Sections

Note: The figure displays the coefficients from regressions of demeaned state / country net migration rates vs. demeaned state / country unemployment rates (see equation (3.5)). Every coefficient corresponds to a single year. Confidence intervals are $\hat{\beta} \pm 1.96\text{stderr}$, where standard errors are regular standard errors.
Figure A6: Migration Rates vs. Surface Area

Note: The figure plots the migration-to-population ratio against population (a) and surface area (b) for US States, Canadian Provinces, and Western European countries. Migration is measured as the average of immigration and emigration. Values are averages over 1995 - 2015.