Technology shocks, labor mobility and aggregate fluctuations

Daniela Hauser *

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Abstract

We provide evidence on the dynamic behavior of net labor flows across US states in response to a positive technology shock. Technology shocks are identified as disturbances that increase relative state productivity in the long run for 226 state-pairs encompassing 80 percent of labor flows across US states in the period 1976 - 2008. The data suggest heterogeneous responses of both employment and net labor flows across states conditional on a positive technology shock. We build a two region dynamic stochastic general equilibrium (DSGE) model with endogenous labor mobility and asymmetric shocks accounting for this evidence. We calibrate the model economy consistently with the observed differences in the degree of nominal rigidities across states and show that we replicate the different patterns of the responses in employment and net labor flows across states following a technology shock.

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*Universitat Autònoma de Barcelona. Contact: daniela.hauser@uab.cat
1 Introduction

Regional labor mobility within a country or labor flows across international boarders do not play any role in most of the theories explaining cyclical fluctuations of macroeconomic variables. Yet, according to a commonly held belief going back to Mundell (1961) labor mobility is an important mechanism of adjustment to asymmetric shocks; that is events that have diverse economic effects on different countries or on different regions within a given country. Labor mobility helps to balance the effects of asymmetric shocks in particular in the case conventional stabilization mechanisms are no longer available; for instance, in a monetary union with many regions and a single currency where monetary policy does no longer serve as stabilizing instrument for regional shocks. Only recently, some contributions emphasize that migration is not solely a long-run phenomenon. Rather, it is also relevant if one focuses on higher frequencies, typically between 6 and 34 quarters, which are commonly labeled as business cycle fluctuations. For example, Molloy and Wozniak (2011) show that internal migration rates within the US are strongly procyclical with respect to both the national and local business cycles. Moreover, from Herz and Van Rens (2011) we learn that labor mobility within the US is important in the sense that structural unemployment can not be explained by lacking mobility of workers across regions (but rather by a mismatch between available workers and jobs). In a counterfactual exercise they show that removing the costs associated to workers’ mobility would have reduced the 5%-point increase in unemployment in the Great Recession by only 0.1%-points. However, most of the evidence examines unconditional business cycle moments and the literature is missing a conditional analysis that would provide information about the direction of labor mobility in response to specific shocks. Conditional moments are crucial in evaluating the role of labor mobility as an alternative adjustment mechanism to asymmetric shocks and in determining the shocks that explain the observed labor flows.

The contribution of this paper to the literature is twofold: On one hand, we investigate the dynamic behavior of labor mobility conditional on state specific labor productivity shocks. The empirical estimates of labor flows and employment, resulting from a structural vector autoregression (SVAR) exhibit important differences between conditional and unconditional moments, and furthermore indicate essential heterogeneity in conditional moments across US states. On the other hand, we build a two region dynamic stochastic general equilibrium (DSGE) model with endogenous labor mobility, accounting for this evidence. We calibrate the model economy consistently with the observed differences in the degree of nominal rigidities across states and show that we replicate the different patterns of the responses in employment and net labor flows across states following a technology shock. The focus on technology shocks comes as a natural choice, given the relative attention this particular shock has attracted in the literature. Internal mobility within the boarders of the United States, as opposed to international labor movements, is very well documented and the US is widely known for its mobile labor force. According to Census 2000, over 22 million
people were internal migrants who changed their state of residence between 1995 and 2000 and over 40% of the US population lived in a state other than their state of birth.

For our SVAR specification we use available data about state-to-state migration in the US for the period 1976-2008 to identify a permanent shock to state specific technology. We use long run restrictions, following Galí (1999), and assume technology shocks to be the only shocks having a permanent effect on the level of productivity in a given state. In particular, we estimate the dynamic behavior of labor flows between a given pair of US states in response to a shock to labor productivity in one of the two states. The SVAR includes four endogenous variables, namely labor productivity in both states of a given pair, labor input in the state hit by the shock and net labor flows, defined as the difference between inflows and outflows between a given pair of states. An appropriate ordering of the four endogenous variables allows the identification of a technology shock for a given state such that technology in the other state remains unaffected. The SVAR exercise provides two interesting results: First, labor mobility exhibits significant dynamics in response to technology shocks. Technology shocks thus induce people to reallocate geographically, in a way that is different from unconditional labor mobility. And second, the conditional dynamic behavior of net labor flows and employment differs across US states. We distinguish between three groups of state-pairs: (a) Repelling states display a fall in both employment and net labor flows, (b) magnet states display the opposite (i.e. an increase in employment and labor flows), and (c) hybrid states exhibit an increase in net labor flows which goes along with a decline in employment. We show that state-pairs of a given group (repelling, magnet or hybrid states) do not display differences in business cycle moments, they do not belong to a specific region of the US, and they do not differ in terms of the distance between the states of a given pair. Rather the observed heterogeneity has to be seen in the context of state economies differing in their sectoral composition and in the light of the ample empirical evidence for differences in the frequency of price adjustments across sectors in the US economy. In a simple empirical exercise we show that the three groups of state-pairs differ in their degree of nominal rigidities. In particular, we show that repelling (magnet) states display a high (low) average price duration, whereas hybrid state-pairs are composed of states characterized by asymmetric degrees of price stickiness.

We develop a two region DSGE model, in the vein of Clarida, Galí and Gertler (2002), with endogenous labor mobility which replicates the observed heterogeneity in the dynamic behavior of labor flows and employment. We allow for labor mobility in the production sector assuming that firms hire both native and migrant workers, which are aggregated with a CES-function to total effective labor input for production. We assume that the representative household in each region consists of a continuum of family members, which can work in either one

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1 See for example Bernard and Jones (1996), U.S. Department of Labor (2011)
of the labor markets in the two regions. Households have a relative preference to work in the labor market of their region of nativity, such that working in the two regions entails different utility costs. Households in both regions take wages as given and optimally choose the composition of the aggregate labor supply, i.e. how many members to send to work in the domestic and the foreign labor market. The model predicts the dynamic behavior of labor mobility in response to region-specific technology shocks to depend crucially on the presence of nominal rigidities. This is essentially due to the respective differences in the adjustment of both the terms of trade and employment in the region hit by the productivity shock. When the shock occurs in a region where prices immediately adjust, the terms of trade depreciate such that demand for the region’s products increases. This, in turn, induces firms to increase employment which triggers a net inflow of workers. On the contrary, for the shock hitting a region characterized by sticky prices, the terms of trade and so demand schedules adjust only slowly over time. Firms therefore fall back on the only alternative margin of adjustment and reduce employment. Consequentially, workers flow out of the region hit by the shock.

Our model illustrates several interesting implications of labor mobility: Compared to a standard setup, allowing for labor mobility makes the Phillips curve of a given region to depend not only on its output gap but also on gaps related to labor markets in both regions. Hence, relaxing the assumption of a fixed labor force breaks the isomorphism between a closed and an open economy and gives rise to a direct link between the two economies through the mobile labor force. The spill-over effect of the region-specific productivity shock on the other region depends crucially on the direction of the resulting labor flows: When the productivity increase provokes an outflow of workers from the region where the shock occurs, employment in the other region increases such that we refer to a positive spill-over. A negative spill-over explains the opposite situation, i.e. labor flowing into the region hit by the shock and therefore inducing a reduction in the number of available workers in the other region. In conclusion, labor mobility consists in an important phenomenon to be taken into account for questions related to stabilization policies.

This paper relates to several contributions in the field: In a closed economy model Bentolila, Dolado and Jimeno (2008) study the implications of the presence of immigrants on the Phillips curve in Spain, assuming that native and migrant workers are assigned different labor market characteristics. They show that the presence of immigrants reduce labor costs which yields changes in both the slope and the intercept of the Phillips curve. In a more recent contribution Mandelman and Zlate (2012) examine the business cycle fluctuations of unskilled migration from Mexico to the US and the respective remittance flows, in a two-country DSGE model. Our work differs from those contributions in two respects: First, we explicitly study conditional business cycle moments. Second, a mobile labor force by nature has two ends such that a comprehensive understanding of labor mobility requires that in-depth attention be paid to both the origin and the destination locations in a general equilibrium approach. In our two-region model we therefore allow for labor flows in both directions. In line with the
relevant migration literature differences in equilibrium wages are the key trigger for workers’ mobility in our model: As it has been pointed out and empirically confirmed by many studies starting with Hicks (1932) and Greenwood (1975), respectively, differences in wages are key in explaining labor mobility.

The paper proceeds as follows: Section 2 presents the empirical evidence. In section 3 we develop the theoretical model and we study its dynamics. We make concluding remarks in section 4.

2 A structural VAR with labor mobility across US states

In this section we provide empirical evidence on the dynamic effects of a labor productivity shock on labor mobility across states within the United States. We use available data on state-to-state migration in the US for the period 1976-2008 to identify a permanent shock to state specific technology. Our long run identification scheme is based on Galí (1999). Specifically, we estimate the dynamic responses of net labor flows and employment for a given pair of US states after a shock to labor productivity in one of the two states.

2.1 Variable Definitions and Data

We specify the vector of observables for a given pair of states $i$ and $j$ as

$$ Y_t = [\Delta x_{i,t}, \Delta x_{j,t}, \Delta n_{j,t}, \Delta net_{ji,t}]' \quad (2.1) $$

As will be discussed in further detail, we define all state specific variables as logarithmic deviations from the respective aggregate US variable such that $\Delta x_{i,t}$ denotes the log-difference of labor productivity in state $i$ at time $t$, $X_{i,t}$, relative to aggregate US labor productivity, $X_{US,t}$:

$$ \Delta x_{i,t} = \log \left( \frac{X_{i,t}}{X_{US,t}} \right) - \log \left( \frac{X_{i,t-1}}{X_{US,t-1}} \right) $$

Equivalently, $\Delta x_{j,t}$ is the log-difference of labor productivity in state $j$ relative to aggregate US labor productivity, $\Delta n_{j,t}$ stands for the log-difference of employment in state $j$ relative to aggregate US employment and $\Delta net_{ji,t}$ is the log-difference of net labor flows from state $i$ to state $j$. In particular, $\Delta net_{ji,t}$ is defined as follows$^3$:

$$ \Delta net_{ji,t} = \Delta \log \left( \frac{Inflows_{ji,t}}{Outflows_{ji,t}} \right) $$

$^3$Note, that aggregate inflows (over all states) are equal to aggregate outflows, such that there is no need to define net flows relative to US aggregate. The estimated dynamic responses are robust to an alternative definition of net flows defining them relative to the respective state population.
Our data\(^4\) includes 48 states in the United States, excluding Alaska, the District of Columbia and Hawaii. The baseline series for labor productivity are constructed by subtracting the log of employment from the log of the gross state product for each state. Data on gross state products and employment are taken from the Bureau of Economic Analysis (BEA). Data on net labor flows across US states are obtained from the Internal Revenue Service (IRS) and are based on year-to-year address changes reported on individual income tax returns filed with the IRS, available from 1976 onwards. Net flows for a given state are defined as the difference between inflows and outflows, where inflows measures the number of families (including the tax filer, its spouse and all dependants) who moved to a state and where they migrated from, and outflows the number of families leaving a state and where they went. Our data for migration flows provides information about net labor flows for all 1128 possible state-pairs among the 48 states under consideration. We focus on 226 state-pairs encompassing up to the 80th percentile of aggregate labor flows over all 48 states and for the entire period of interest, and show that our results are robust to accounting for all possible state-pairs. For each of the 226 state-pairs we identify a labor augmenting technology shock in both states and study its effect on net labor flows, i.e. we consider 452 specifications.

The transformation of state specific variables into logarithmic deviations from the aggregate value of the same variable relates to our identification strategy. In order to identify state specific technology shocks we have to define state specific variables in an appropriate way. As suggested in Blanchard, Katz, Hall and Eichengreen (1992) we assume state specific variables to depend both on a common shock (related to the respective aggregate US variable) and on an idiosyncratic shock. Therefore, labor productivity in a given state \(i\) is defined as:

\[
\Delta X_{i,t} = \alpha_i + \beta_i \Delta X_{US,t} + \nu_{i,t}
\]

where \(\Delta X_{i,t}\) is the log-difference of labor productivity in state \(i\) at time \(t\) (not the log-difference of relative labor productivity in state \(i\), which we denoted \(\Delta x_{i,t}\) earlier), \(\Delta X_{US,t}\) is the log-difference of US labor productivity, and \(\nu_{i,t}\) is an idiosyncratic disturbance term. This equation is estimated using annual data from 1976-2008, for each state under consideration in order to determine to what extent states differ in their elasticity to common shocks. The estimates for the coefficient \(\beta_i\) are significantly different from one for 10 out of 48 states, only\(^5\). Given that for most states we can not reject that \(\beta_i = 1\) we use simple log-differences as measures of state specific variables, which is a common practice in the relevant literature.

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\(^4\)See Appendix C for a detailed discussion of data sources and definitions.

\(^5\)We consider the same regression for employment, \(N_{i,t}\) and the gross state product, \(Y_{i,t}\) and confirm the finding that the elasticity to common shocks in most of the states is not significantly different from one at the 5% level. It is worth mentioning that even though we are considering a different time period, our results for employment are very similar to the ones reported in Blanchard et al. (1992)
2.2 Bilateral SVAR

Following Galí (1999) we identify labor productivity shocks assuming them to be the only shock having a permanent effect on the level of productivity in a given state. Consider the following structural VAR:

\[ A_0 Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + \ldots + A_p Y_{t-p} + \epsilon_t \]  

(2.2)

where \( Y_t \) is the vector of observables, as defined in (2.1), matrix \( A_0 \) captures contemporaneous relationships between the variables and \( \epsilon_t \) is a vector of structural shocks which are uncorrelated across variables, such that the covariance matrix of \( \epsilon_t \) is diagonal, i.e. \( E_t(\epsilon_t \epsilon_t') = I \). We can rewrite the structural model, defined in (2.2), in a more general form:

\[ A(L) Y_t = \epsilon_t \]

where \( A(L) = A_0 - A_1 L^1 - \ldots - A_p L^p \) is a polynomial in the lag-operator. Assuming that the vector of observables can be expressed as a (possibly infinite) distributed lag of all disturbances, the structural model can be written as an MA(\( \infty \))

\[
\begin{bmatrix}
\Delta x_{i,t} \\
\Delta x_{j,t} \\
\Delta n_{j,t} \\
\Delta \text{net}_{ji,t}
\end{bmatrix} = \begin{bmatrix}
C^{11}(L) & C^{12}(L) & C^{13}(L) & C^{14}(L) \\
C^{21}(L) & C^{22}(L) & C^{23}(L) & C^{24}(L) \\
C^{31}(L) & C^{32}(L) & C^{33}(L) & C^{34}(L) \\
C^{41}(L) & C^{42}(L) & C^{43}(L) & C^{44}(L)
\end{bmatrix} \begin{bmatrix}
\epsilon^1_t \\
\epsilon^2_t \\
\epsilon^3_t \\
\epsilon^4_t
\end{bmatrix} = C(L) \epsilon_t
\]

where \( \{ \epsilon^1_t \} \) and \( \{ \epsilon^2_t \} \) denote, respectively, the sequence of technology shocks in the two states of a given pair. Our identification restriction is that the structural shocks \( \epsilon^3_t \) and \( \epsilon^4_t \) do not have permanent effects on labor productivity, employment and net flows which implies the matrix of long run multipliers, \( C(1) \), to be lower triangular, i.e. \( C^{12}(1) = C^{13}(1) = C^{14}(1) = C^{23}(1) = C^{24}(1) = C^{34}(1) = 0 \). Note, that given the ordering of the variables the technology shock in state \( i \), \( \epsilon^1_t \), affects both labor productivity in state \( i \), \( \Delta x_{i,t} \), and in state \( j \), \( \Delta x_{j,t} \). By contrast, \( \epsilon^2_t \) only affects labor productivity in state \( j \) and leaves labor productivity in state \( i \) unaffected. We therefore use the long run restrictions to identify a technology shock in state \( j \), \( \epsilon^2_t \), for each state-pair. Note that our previously discussed definition of state specific variables, as log-differences from the respective aggregate variable, excludes the possibility that the structural shocks are driven by movements related to the aggregate US economy.

We imposing the long run identification restrictions in a standard way: First

\[ \Delta x_{i,t} = \Delta x_{j,t} \]

We test for cointegration of labor productivity in state \( i \) and \( j \) for each state-pair under consideration. We use both the Johansen Test and the Engle-Granger test. 3 out of 226 state-pairs are tested positively for cointegration of \( x_{i,t} \) and \( x_{j,t} \) using Johansens’ Test; 1 out of 225 state-pair is tested positively for cointegration of \( x_{i,t} \) and \( x_{j,t} \) using the Engler-Granger test. Only one state-pair displays cointegration of labor productivities for both tests. We thus conclude that generally cointegration between \( x_{i,t} \) and \( x_{j,t} \) is not an issue.

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\[ \Delta x_{i,t} = \Delta x_{j,t} \]

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\[ \Delta x_{i,t} = \Delta x_{j,t} \]

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\[ \Delta x_{i,t} = \Delta x_{j,t} \]
we define the reduced form model corresponding to our structural VAR. Assuming the matrix of contemporaneous relationships, $A_0$, to be invertible allows to pre-multiply both sides of the structural VAR model defined by (2.2) with $A_0^{-1}$:

$$Y_t = A_0^{-1}A_1Y_{t-1} + A_0^{-1}A_2Y_{t-2} + ... + A_0^{-1}A_pY_{t-p} + A_0^{-1}\varepsilon_t$$

Defining $\phi_i = A_0^{-1}A_i$ for all $i \in [1, p]$ and establishing the relationship between structural and reduced form shocks, $A_0^{-1}\varepsilon_t = u_t$, we define our reduced form model:

$$Y_t = \phi_1Y_{t-1} + \phi_2Y_{t-2} + ... + \phi_pY_{t-p} + u_t$$

Second, we orthogonalize the reduced form shocks by Cholesky decomposition, i.e. $(A_0^{-1})(A_0^{-1})^t = E_t(u_t u_t^t)$. We estimate the reduced form model by ordinary least squares (OLS) in order to get consistent estimates for the coefficient $\phi_1$ and the variance-covariance matrix of the reduced form error terms. According to the standard information criterion$^7$ the optimal number of lags is equal to one, such that we set $p = 1$. The long run effect of a given reduced form shock $u_t$ is defined by

$$E\left[\sum_{s=0}^{\infty} Y_t \mid u_t\right] = \left[1 + \phi_1 + \phi_1^2 + ... + \phi_1^\infty\right] u_t = (I - \phi_1)^{-1}u_t$$

Using the relation between structural and reduced form shocks we recover the matrix of long run multipliers corresponding to the vector of structural shocks on which we impose our identifying assumptions:

$$C(1) = (I - \phi_1)^{-1}A_0^{-1}$$

Our results are robust to changing the order of employment and net labor flows. Furthermore, we consider an alternative vector of observables including employment of the other state of a given pair. We therefore augment the four variable structural VAR with an additional variable measuring employment in state $i$ for each state pair under consideration. This alternative specification allows the study of the effects on a labor productivity shocks of a given state $j$ on employment in state $i$. More details about the augmented SVAR can be found in Appendix D.

2.3 Results

Table 1 reports estimates of aggregate unconditional correlations between employment, the gross state product (GSP), labor productivity and net labor flows.

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$^7$We test the appropriate lag length using the Akaike information criterion, the Schwarz/Bayesian criterion and the Hannan-Quinn information criterion. All three criteria suggest $p = 1$ to be the optimal number of lags.
We compute aggregate unconditional correlations as simple average over correlations for all 48 states. All correlations are significant at the 5% level for all states under consideration. The signs of the estimated correlations are consistent with the relevant empirical literature, as for instance Molloy and Wozniak (2011). In particular we confirm the finding of internal migration being procyclical, i.e. net labor flows tend to be lower during downturns in a given state's economy.

Table 2 reports correlations between employment, the gross state product (GSP), labor productivity and net labor flows conditional on labor productivity shocks. Conditional correlations are computed as weighted average over all 452 specifications, where the weight is given by the respective share in aggregate labor flows of a given state-pair (but using the simple average gives almost identical results). For 448 out of 452 specifications under consideration we have all conditional correlations to be significant at the 5% level. Aggregate conditional moments of employment and labor productivity are consistent with the findings in Galí (1999), i.e. the conditional correlation between labor productivity and employment are large and negative. Interestingly, when considering conditional moments we have net labor flows across US states to be negatively correlated with both GSP and labor productivity. This implies that after a technology shock net labor flows tend to be lower, such that we observe relatively more outflows and relatively less inflows compared to normal times. Hence, comparing conditional with unconditional moments yields the exact opposite picture of labor flows.

Even though Table 2 apparently provides a uniform picture for the aggregate conditional moments across US states we observe important heterogeneity in the estimated impulse response functions at the state-pair level. In particular, we distinguish three patterns for the estimated impact behavior of both net flows and employment to a positive technology shock: First, 133 state-pairs representing 34% of aggregate labor flows across all 48 states between 1976 and 2008 display a negative impact reaction of both net flows and employment. The second pattern we identify is an estimated positive impact reaction of both net flows and employment, which we observe in 155 state-pairs capturing 15% of aggregate labor flows. The third pattern in the estimated dynamic behavior consists in a positive impact reaction of net flows and a negative impact reaction of employment. 123 state-pairs encompassing 26% of aggregate labor flows across all 48 states between 1976 and 2008 display these dynamics.

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8 Note, that our state level data is consistent with the findings in Galí (1999). In particular, aggregating our state level data and running the same bivariate SVAR as in Galí (1999) yields almost identical results, even though the time period considered in this paper is different.

9 For each state-pair we have data on the total number of net moves, such that we can compute the share of labor flows of a given state-pair to total number of moves. For example, the state-pair Florida - New York captures 1.73% of total aggregate labor flows for the period 1976-2008. Summing up the shares of all state-pairs displaying the same pattern yields the total share of aggregate labor flows for the period 1976-2008.

10 For the remaining 41 state-pairs capturing less than 5% of aggregate labor flows in the period of interest, the estimated impact responses to a technology shock are positive for employment and negative for net flows. Along with the small number of state-pairs belonging to this group we have none out of the 41 state-pairs displaying significant impact reactions of both employment and net
As we have mentioned before the focus on all state-pairs within the 80th percentile of aggregate state-to-state labor flows is not affecting the results. In particular, the relative size of the groups, measured either in terms of the number of state-pairs or in terms of aggregate labor flows, remains unaffected when enlarging the analysis to all possible state-pairs. The 226 state-pairs under consideration are therefore to be considered a good representation of the state-to-state labor flows in the United States between 1976 and 2008.

The insights we gain from the structural VAR exercise lead to two conclusions: First, labor mobility exhibits significant dynamics in response to technology shocks. Technology shocks thus induce people to reallocate geographically, in a way that is different from unconditional labor mobility. And second, the conditional dynamic behavior of net labor flows and employment differs across US states. In what follows we analyze in further detail the impact response of employment and net flows for each of the three identified patterns, exemplified through the respective state-pair with the biggest fraction in aggregate labor flows.

2.3.1 Repelling States

For 133 state-pairs we estimate a fall in both employment and net labor flows in the state hit by the productivity shock. The productivity shock repels workers from the labor market in the state where the shock is observed such that inflows decrease and/or outflows increase. The impulse responses to the identified labor productivity shock for the state-pair Florida - New York are illustrated in Figure 1. We show the impact of one standard error increase in labor productivity in New York relative to aggregate US labor productivity along with 68% bootstrapped confidence intervals for a horizon of 10 years. Migration between Florida and New York consists in the largest state-to-state migration flow between 1976 and 2008, amounting to 1.73% of aggregate labor flows for the same period. In response to a positive technology shock in New York labor productivity increases by 1.2 percent\(^{11}\), eventually stabilizing at a level somewhat higher than before the shock. Output also experiences a permanent increase, with the initial increase of 1.1 percent to be more gradual than that of productivity. The gap between the initial increase in labor productivity and the smaller increase in output is reflected in a significant fall in employment (-0.1 on impact). The fall in employment in New York goes along with a significant fall in net flows between Florida and New York of 4.36 percent on impact. The technology shock in New York thus implies a fall of 4.36 percent in the ratio of inflows to outflows.

\(^{11}\) Note, that given our specification of state-level variables relative to the US aggregate, impulse response functions have to be interpreted as the reaction of the state specific variable relative to the US aggregate. In the present example, labor productivity in New York relative to aggregate US labor productivity increases by 1.2 percent in response to a one standard deviation shock to relative labor productivity in New York.
from New York to Florida, which can be interpreted as a fall in inflows and/or an increase in outflows.

Considering the estimated dynamics of the augmented SVAR discussed in Appendix D allows to draw conclusions about the spill-over effect of the technology shock identified in a given state $j$ on employment in state $i$. Figure 2 shows the estimated impulse response functions of the augmented SVAR for the state-pair New York - Florida. The spill-over effect of the technology shock in New York on employment in Florida is significantly positive. Over all state-pairs classified as repelling states 71% display a positive spill-over effect to state $j$'s employment.

The group of repelling states consists of the most important group in terms of total significant impact responses of net flows and employment (73 out of 133), as shown in Table 3. Furthermore, with 34% in aggregate labor flows repelling states represent an important part of state-to-state migration in our sample period.

### 2.3.2 Magnet States

Opposite to repelling states where we observe a fall in both labor input and net flows, for 155 state-pairs we estimate an increase in both employment and net labor flows in the state for which we identify the shock. The productivity shock attracts workers to the labor market of the state hit by the technology shock such that inflows increase and/or outflows decline. Figure 3 displays the estimated impulse responses for the state-pair Texas - Ohio, which constitutes the 14th largest state-to-state migration flow between 1976 and 2008, accounting for 0.72% of aggregate labor flows. In response to a positive technology shock labor productivity in Ohio increases by 1.65 percent on impact. Output also increases, with the impact response of 1.84 percent to be slightly more persistent than the one of labor productivity. The difference between the two impact responses is due to an increase in employment of 0.19 percent on impact. Alongside the persistent increase in employment in Ohio net flows with Texas increase by 3.24 percent on impact. After a positive technology shock in Ohio we thus observe an increase in the ratio between inflows and outflows with Texas of 3.24 percent, which can be interpreted as an increase in inflows and/or a fall in outflows.

According to the augmented SVAR the spill-over of the technology shock in a given state $j$ on employment in the other state ($i$) of a given pair is negative for 72% of all state-pairs classified as magnet states. Figure 4 shows a significantly negative spill-over effect of a positive productivity shock in Ohio on employment in Texas.

Even though the number of state-pairs included in the group of magnet states is higher than the one of repelling states, magnet states account for a lower but still important share of aggregate state-to-state flows between 1976 and 2008 (15%). As indicated in Table 4 out of 155 state-pairs 63 display a significant impact response of both employment and labor flows, versus only 9 state-pairs for which we estimate non-significant increases in both variables.
### 2.3.3 Hybrid States

Additionally to the previously discussed patterns where the impact response for employment and labor flows display the same sign we identify a third pattern where the dynamic reaction of employment and labor flows go in opposite directions. For 123 state-pairs we estimate an increase in net labor flows and a fall in employment in the state experiencing a productivity shock. The significance of the impact responses of net flows and employment for all hybrid state-pairs are summarized in Table 5. Despite a fall in employment the productivity shock attracts more workers, such that inflows rise and/or outflows decrease. Hence, states displaying these dynamics become relatively more attractive after the technology shock, even though employment is reduced. Figure 5 displays the estimated impulse responses for the state-pair Texas - California, which with 1.70% of aggregate labor flows captures the second largest state-to-state migration flow between 1976 and 2008. After a positive technology shock in California labor productivity increases by 0.68 percent on impact. Output increases by slightly less, 0.51 percent on impact. The difference between the two impact responses is due to a fall in employment by -0.17 percent on impact. The ratio of inflows to outflows between California and Texas increases by 7.82 percent on impact. In 85% of the cases of state-pairs classified as hybrid the spill-over effect of a technology shock in state \( j \) on state \( i \)'s employment is negative, according to the augmented SVAR. Figure 6 documents the significantly negative spill-over of a technology shock in California on employment in Texas.

### 2.4 Regional and Structural Differences as possible explanation for the observed heterogeneity

One possible explanation that naturally lends itself to account for the observed heterogeneity in labor flows are regional or structural differences causing economies of given states behaving differently across the business cycle and therefore also exhibiting different dynamics of labor flows. We therefore consider aggregate (unconditional) business cycle moments for each of the three groups of states (repelling, magnet and hybrid states) and show that they do not significantly differ in terms of business cycle moments: Table 6 shows that the three groups are not characterized by differences in volatilities. For all three groups we find a positive correlation between employment and net labor flows (ranging from 0.38 to 0.43), between employment and gross state product (ranging from 0.58 to 0.65) and between gross state product and net labor flows (ranging from 0.21 to 0.27). The correlation between productivity and GSP is positive and high for all three groups, whereas the correlation between productivity and net flows is positive but rather low. The only difference across groups lies in the correlation between productivity and employment, which is very small and slightly negative for repelling and hybrid states, respectively. For magnet states the unconditional correlation of labor input and productivity is small, but slightly positive. These values are in line with the near-zero correlation found in the literature. Over-
all we conclude that differences in business cycle moments do not explain the observed heterogeneity in the dynamics after a labor augmenting productivity shocks.

Figures 7, 8, and 9 provide a graphical summary of all state-pairs belonging to the three groups defining the different dynamic reactions of a given state’s economy after a labor augmenting productivity shock. This simple graphical exercise makes clear that states belonging to each of the three groups are spread over the entire United States, such that geographical differences can be ruled out as explanation for the observed heterogeneity in the dynamics after a technology shock. Moreover, we consider the proposed classification of states according to Blanchard et al. (1992) in order to further analyze the possibility of regional trends being the cause of the observed heterogeneity. In particular, we consider the following clusters of states\textsuperscript{12}: New England, Middle Atlantic and coal countries, Rust Belt, Sun Belt, Farm States and Oil States. In addition, we consider states with a high level of defense dependency, according to Ellis, Barff and Markusen (1993). We find that all farm states are classified as magnet states. For all other state clusters under consideration we do not find any intersection with any of the three groups defining the differences in the dynamic behavior in response to a labor augmenting productivity shock.

Finally, distance plays an important role in migration decisions and is usually referred to as a serious deterrent to migration. In order to rule out different groups reflecting state-pairs with larger or smaller distances between them we consider the share of state-pairs within each group being neighbor states. We find that this share is remarkably similar across the three groups. Namely, 29% of the state-pairs classified as repelling states are neighbor states. For magnet and hybrid states this share is found to be 25% and 28% respectively.

\subsection*{2.5 Price Duration of States}

As we have documented in section 2.3 the three groups of state-pairs differ in their dynamic responses of both net labor flows and employment to the state-specific productivity shock. From Galí (1999) we learn that nominal rigidities are crucial in explaining the responses of labor input after a positive technology shock. There is ample evidence that the frequency of price adjustments differs substantially across industries in the US economy\textsuperscript{13}. Moreover, different states rely more or less on different industries\textsuperscript{14}. As a consequence the aggregate degree of nominal rigidities differs across US states. We empirically explore these two dimensions, i.e. the differences in average price duration per industry and the different sectoral composition of a given state’s economy and show that state-
pairs being classified as repelling (magnet) are characterized by rather high (low) price duration in both states, and that hybrid state-pairs contain states exhibiting different degrees of price stickiness.

Ideally, we would use data on labor mobility across states at the industry level. Given the lack of such data we are missing information about the relative contribution of a given industry to total labor flows into and out of a given state. We therefore assume that labor flows across a given pair of states take place proportionally to the importance of a given industry in a given state, i.e. more important industries exhibit bigger labor flows. In order to define the relative importance of a given industry in a particular state we use four different measures, based on employment, wages, the number of establishments and the value added at the industry level, defined according to the American Industry Classification System (NAICS 2007). Table 8 provides a detailed description of all four measures. We use all industries included in the 75th percentile\textsuperscript{15} for each of the four measures as an approximation of the most important industries in a given state. For example, using observations for the number of employees per industry and state we define the industries lying in the 75th percentile of all industries in a given state, i.e. the most employee intensive industries in each state. Our assumption thus implies labor flows to take place predominantly across industries, which are relatively more employee intensive than others\textsuperscript{16}. As a practical example, we look at the state-pair capturing the biggest labor flows for our period of interest, namely Florida - New York. For all four measures under consideration the most important industries in Florida are Real Estate and Rental Leasing, Arts, Entertainment, and Recreation, and Administrative-, Support-, Waste Management, Remediation Services. For New York we identify Educational Services, Information, Real Estate and Rental Leasing, and Finance and Insurance as the most important industries across all four measures.

In order to compute the average price duration of a given industry we use data from Nakamura and Steinsson (2008), providing the median price duration for a wide range of product categories included in the CPI-basket over the time period 1998-2005. We match the roughly 270 product categories to one or several of total 19 industries, according to the North American Industry Classification System (NAICS 2007)\textsuperscript{17}. We use the same weights per product category as the ones used in Nakamura and Steinsson (2008), i.e. the respective weight of a given category in the CPI basket, to compute the median price duration over a given industry, which ranges from 0.6 months for Mining up to 22.4 months for Retail

\textsuperscript{15}Note, that our results are robust to considering the 50th percentile industries.

\textsuperscript{16}One possible alternative way of defining the most important industries is considering volatilities rather than averages. For example, instead of using annual average employment per industry and state to total GDP in the same state (measure 1 in Table 8) we consider the standard deviation of the latter. Overall, the results are similar when using volatilities of our four measures for the most important industries.

\textsuperscript{17}For example, according to the NAICS the product category ”potatoes” appears in both industries Agriculture, Forestry, Fishing, Hunting and in Manufacturing, such that the median price duration of potatoes will be taken into account for both industries.
Trade. Table 9 provides a summary for the computed price durations over all industries.

For each state we match the most important industries, defined according to one out of the four available measures, with the respective price durations and then compute the aggregate price duration of a given state. We calculate the aggregate price duration as the weighted average of the price duration for the most important industries in each state, with the weight being defined according to one of the four measures. For Florida the average price duration of the above mentioned industries weighted by their relative importance ranges from 8.7 to 11.4 months. Equivalently, for New York we get weighted average price durations over the most important industries of 9.2 to 11.4 months.

Given the aggregate price duration in each state under consideration we define the average price duration of the most important industries over all states and use it as a threshold price duration in order to classify states as either sticky or flexible\textsuperscript{18}. States for which the average price duration of the most important industries lies above (below) the threshold price duration are classified as sticky (flexible) states. Whenever the average price duration of a given state is more than one standard deviation above (below) the threshold level, we refer to the state as clearly sticky (flexible). For both Florida and New York, for all four measures we use to define the most important industries, the respective price duration is more than one standard deviation above the corresponding threshold values, such that both states are considered clearly sticky.

We distinguish between state-pairs where both states are defined as (clearly) sticky, state-pairs with both states being classified as (clearly) flexible, and between asymmetric state-pairs composed of one (clearly) flexible and one (clearly) sticky state. We identify a clear pattern across the three groups, as summarized in Table 10: For all four measures between 60-75% of repelling state-pairs are classified as (clearly) sticky. The remaining 25-40% are either state-pairs where both states are (clearly) flexible or state-pairs with asymmetric price duration. For magnet states we find that, according to the measure used to define the most important industries, between 61-85% of state-pairs are defined as (clearly) flexible. Hybrid states are composed of state-pairs with asymmetric price durations, with the share varying between 69-83%.

The respective state-pairs with the biggest fraction in aggregate labor flows, analyzed in section 2.3, are classified accordingly, independently of the measure used to define the most important industries: The state-pair Florida - New York is classified as clearly sticky, Ohio - Texas is a flexible state-pair and our example state-pair for hybrid states consists of California, which is classified as sticky and Texas, which is clearly flexible according to the data. We therefore conclude that the observed heterogeneity in the dynamics of employment and net labor flows after a technology shock go along with differences in the state level aggregate price duration.

\textsuperscript{18}Note that results are robust to using alternative definitions of the threshold price duration. In particular, we consider median price duration or the weighted average price duration of the most important industries over all states, where the weight is defined by the GDP of a given state.
2.6 Conclusions for the empirical exercise

The insights we gain from the empirical exercise lead to several conclusions: Technology shocks induce people to relocate geographically in a way that is different across US states. The differences in the dynamic responses of employment and net labor flows in the state hit by the shock and the spillover effect on employment in the other state of a given pair go along with differences in the degree of nominal price rigidities in the state-pairs. In particular, the majority of repelling (magnet) state-pairs for which we estimate a fall (rise) in both employment and net labor flows consist of states with high (low) price duration. Hybrid state-pairs are mostly composed of two states with asymmetric state pairs. In the following section we build a theoretical model consistent with the evidence presented in this section.

3 A two country model with labor mobility

In this section we build a theoretical model consistent with the empirical evidence provided in the previous section. We consider a stochastic two region model with endogenous labor mobility. The model consists of two regions that belong to a monetary union. We refer to the regions as Home ($i$) and Foreign ($j$). The representative household in each of the two regions consists of a continuum $[0, 1]$ of family members. Each member can supply labor in either the domestic or the foreign labor market, with the respective fractions of family members to be decided at the household level. Working in the domestic and the foreign labor market are assumed to entail different utility costs, i.e. households have a relative preference to work in the labor market of their region of nativity. Wages and returns from savings are pulled together and redistributed equally among members so that they all enjoy an identical level of consumption. Together with labor supply decisions, consumption and savings are defined at the household level\footnote{See Andolfatto (1996) and Merz (1995) as general references, and Binyamini and Razin (2008) as an example for a an application of the big household assumption in a framework with labor mobility.}, i.e. among family members of the same nativity but possibly active in different labor markets.

The economy features two production sectors producing intermediate and final goods respectively. Each of the two sectors is characterized by a continuum of firms selling a differentiated good under monopolistic competition. Firms are assumed to set prices in a staggered fashion, as in in Calvo (1983). We consider different scenarios of nominal price rigidities in the two production sectors. Final goods producers assemble domestically produced and imported intermediate goods into a non-traded final good. Intermediate goods producers employ native and migrant workers as sole production factor. Our general setup allows migrant and native born workers to be substitutable and possibly unequally productive in the production of intermediate goods. Given our focus on the US economy we calibrate the respective parameter values such that workers from different
states are attached equal productivity and are considered perfect substitutes in production\textsuperscript{20}. We consider two production sectors in order to be able to separate labor mobility and nominal rigidities. As we will show, our results do not rely on this separation and therefore also hold in a one sector setup.

### 3.1 Households’ Problem

In each region there is a household consisting of a unit mass of infinitely lived family members, that obtain utility from consuming the final consumption good and disutility from supplying hours of labor in either of the two labor markets, i.e. some of the household’s members are working in the domestic labor market as native workers and some are sent to work in the foreign labor market as migrant workers. Households choose aggregate consumption, savings and relative labor supply in both labor markets in order to maximize the expected lifetime utility:

\[
U_o^i = E_0 \sum_{t=0}^{\infty} \beta^t \left[ \frac{(C_i)^{1-\sigma}}{1-\sigma} \frac{(N_i)^{1+\varphi}}{1+\varphi} \right]
\]

where \(C_i, N_i\) denote, respectively, consumption and hours worked, \(E_0\) stands for the rational expectations operator using information up to time \(t = 0\), \(\beta \in [0, 1)\) is the discount factor, and \(i \in [H, F]\) denotes the two regions, Home and Foreign, respectively. More precisely, \(C_i\) is an index of region \(i\)’s final goods consumption, (i.e. goods supplied by final goods producers in region \(i\) itself), given by the CES function

\[
C_i^j = \left[ \int_0^1 C_i^j(k) \frac{\varepsilon-1}{\varepsilon} dk \right]^{\frac{\varepsilon}{\varepsilon-1}}
\]

where \(k \in [0, 1]\) denotes the type of good within the set produced in region \(i\) and \(\varepsilon > 1\) defines the elasticity of substitution between varieties produced within any given region, independently of the producing region.

We allow for labor mobility in the following sense: Some household members will offer their labor services to domestic firms while others are sent to work in the foreign labor market. Aggregate labor supply, as appearing in the household’s utility function, is assumed to be a CES-aggregator of family members’ labor supply in the domestic and in the foreign labor market, defined as \(N_{ii}^i\) and \(N_{ij}^i\) respectively:

\[
N_i^i = \left[ (1 - \alpha_1)^{\frac{1}{\nu_1}} (N_{ii}^i)^{\frac{\nu_1-1}{\nu_1}} + (\alpha_1)^{\frac{1}{\nu_1}} (N_{ij}^i)^{\frac{\nu_1-1}{\nu_1}} \right]^{\frac{\nu_1}{\nu_1-1}}
\]

where \(\nu_1 < 0\) is a measure of the elasticity of substitution of working as a native in the domestic labor market and working as a migrant in the foreign labor

\textsuperscript{20}This assumption implies that for production in a given state, say Texas, workers from Texas are equally productive as workers from New York or any other state. Moreover, workers from any other state are considered to be perfect substitutes for native workers from Texas.
market, and $\alpha_1$ captures differences in the disutility attached to working in the home versus the foreign labor market.

Maximization of equation (3.1) is subject to a sequence of budget constraints:

$$\int_{1}^{0} P_i^t(k)C_i^t(k)dk + E_t \{Q_{t,t+1}D_{t+1}^i\} \leq D_t^i + W_t^{ii}N_t^{ii} + W_t^{ij}N_t^{ij} - T_t^i \quad (3.4)$$

for $t = 0, 1, 2, \ldots$, where $P_i^t(k)$ is the price of final good $k$ produced in region $i$, expressed in units of the single currency. $W_t^{ii}N_t^{ii}$ is nominal labor income of family members working in the domestic labor market, $W_t^{ij}N_t^{ij}$ is nominal labor income of all members working in the foreign labor market and $T_t^i$ contains profits.

We assume that households have access to a complete set of contingent claims, traded across the monetary union. $Q_{t,t+1}$ is the stochastic discount factor for one-period ahead nominal payoffs which is common across regions. $E_t \{Q_{t,t+1}\}R_t^{-1} = 1$, where $R_t$ is the gross nominal return on a riskless one-period bond paying off one unit of the common currency in $t + 1$ or, for short, the gross nominal interest rate. Below, we assume that the union’s central bank uses that interest rate as its main instrument for monetary policy.

We assume risk and consumption to be pooled among all members of a given household such that consumption is equal across all members of a given household\(^\text{21}\). The optimal allocation of any given expenditure on the final goods produced in a given region yields the demand function

$$C_i^t(k) = \left( \frac{P_i^t(k)}{P_t^i} \right)^{-\epsilon} C_t^i \quad (3.5)$$

for $i \in [H, F]$ and $k \in [0, 1]$. $P_t^i \equiv \left[ \int_{0}^{1} P_i^t(k)^{1-\epsilon}dk \right]^{\frac{1}{1-\epsilon}}$ represents region $i$’s CPI-price index. Given the optimal allocation of expenditures the period budget constraint reads as

$$P_t^iC_t^i + E_t \{Q_{t,t+1}D_{t+1}^i\} \leq D_t^i + W_t^{ii}N_t^{ii} + W_t^{ij}N_t^{ij} - T_t^i \quad (3.6)$$

Households’ optimality conditions are the domestic labor supply condition,

$$\frac{W_t^{ii}}{P_t^i} = (C_t^i)^{\sigma}(N_t^i)^{\varphi}\left(\frac{N_t^{ii}}{N_t^i}\right)^{-\frac{1}{\sigma}}(1-\alpha_1)\frac{1}{\sigma_1} \quad (3.7)$$

the condition for labor supply in the foreign labor market, which equivalently states

$$\frac{W_t^{ij}}{P_t^i} = (C_t^i)^{\sigma}(N_t^i)^{\varphi}\left(\frac{N_t^{ij}}{N_t^i}\right)^{-\frac{1}{\sigma}}(\alpha_1)^{\frac{1}{\sigma_1}} \quad (3.8)$$

\(^{21}\)Note, that our setup implies native and migrant workers of the same household to consume the same bundle of goods. Assuming absence of home bias in the final goods sector implies consumption to be equal across households in both regions, and therefore also between native and migrant workers of a given region $i$. 

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Compared to a standard labor supply condition allowing for labor mobility implies that, for given aggregate labor supply, $N_t$, households optimally choose the composition of the latter, i.e. how many member to send to work in the domestic vs. the foreign labor market.

The remaining optimality condition for the household’s problem is the standard intratemporal optimality condition, given by

$$\beta R_t E_t \left\{ \left( \frac{C_i^t}{C_{t+1}^i} \right)^\sigma \left( \frac{P_i^t}{P_{t+1}^i} \right) \right\} = 1 \quad (3.9)$$

It is useful to note that household’s optimality conditions (3.7), (3.8) and (3.9) can be respectively written as log-linear deviations from the symmetric steady state:

$$w_{it}^{ii} - p_i^t = \sigma c_i^t + \varphi n_i^t - \frac{1}{\nu_1} (n_{it}^{ii} - n_i^t) \quad (3.10)$$

$$w_{it}^{ij} - p_i^t = \sigma c_i^t + \varphi n_i^t - \frac{1}{\nu_1} (n_{it}^{ij} - n_i^t) \quad (3.11)$$

$$c_i^t = E_t \{ c_{t+1}^i \} - \frac{1}{\sigma} [r_t + E_t \{ \pi_{t+1}^i \}] \quad (3.12)$$

where lower case letters denote log-deviations from the steady state value of the respective variable, i.e. $z_t = \log(Z_t) - \log(Z)$, and $\pi_i^t \equiv p_i^t - p_{t-1}^i$ is CPI inflation in region $i$. Note, that labor mobility in our setup will affect the intertemporal, but not the intratemporal choices of consumers. Labor supply in the domestic and in the foreign labor market crucially depend on the value of $\nu_1$:

$$w_{it}^{ii} - w_{it}^{jj} = - \frac{1}{\nu_1} (n_{it}^{ii} - n_{it}^{ij})$$

Higher values of the elasticity of substitution between working in the domestic vs. the foreign labor market, $\nu_1$, imply labor supply for both types of workers to be more sensitive to changes in relative wages across the two regions.

### 3.2 International Risk Sharing

Under the assumption of complete markets for state-contingent assets across regions, the Euler condition holds in both regions, as stated in (3.9). Combining the two, together with the definition of the relative price of final goods in both regions, $Q_i^t \equiv \frac{P_i^t}{P_j^t}$, it follows (after iterating) that

$$C_i^t = \vartheta C_j^t \left( Q_i^t \right)^{\frac{1}{\sigma}}$$

for all $t$, where $\vartheta$ is a constant which will generally depend on initial conditions. Henceforth, and without loss of generality, we assume symmetric initial conditions (zero net foreign asset holdings, combined with an ex-ante identical environment) such that $\vartheta = 1$. 

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3.3 Intermediate goods producers

We assume that there is a continuum of monopolistically competitive firms producing each of them a different variety of the traded intermediate good, indexed by \( s \) on the unit interval \([0, 1]\). All firms have access to the same constant return to scale production technology linking aggregate labor input and the level of region-specific technology to output in the intermediate sector:

\[
X_i^*(s) = A_i^* L_i^*(s)
\]

where region-specific productivity denoted by \( A_i^* \) is assumed to follow an AR(1) process:

\[
a_i^* = \rho a_{i-1}^* + \varepsilon_t^a
\]

with \( a_i^* = \log(A_i^*) \), \( \rho_a \in [0, 1] \) and \( \varepsilon_t^a \) being white noise. Note that the production technology (3.13) by definition satisfies the identification restrictions used in the empirical part.

We allow for labor mobility in the production sector as in Ottaviano and Peri (2012), i.e. we assume that firms hire both native and migrant workers for production, which are aggregated with a CES-function to total effective labor input for production of variety \( s \):

\[
L_i^*(s) = \left[ (1 - \alpha_3) \frac{1}{\nu_3} \left( N_{ii}^*(s) \right)^{\frac{1-\nu_3}{\nu_3}} + (\alpha_3) \frac{1}{\nu_3} \left( N_{ji}^*(s) \right)^{\frac{1-\nu_3}{\nu_3}} \right]^{\frac{\nu_3}{1-\nu_3}}
\]

where \( \alpha_3 \) captures possible differences in the relative productivity of native and migrant workers and \( \nu_3 > 0 \) measures the aggregate elasticity of substitution between native and migrant workers in production\(^{22}\).

The first order conditions for cost minimization determining intermediate firms’ demand for both native and migrant workers are:

\[
N_{ii}^*(s) = \frac{X_i^*(s)}{A_i^*} \left\{ (\alpha_3) \frac{1}{\nu_3} \left( \frac{1 - \alpha_3}{\alpha_3} \right)^{\frac{1-\nu_3}{\nu_3}} \left( \frac{W_j^i}{W_i^i} \right)^{1-\nu_3} + (1 - \alpha_3) \frac{1}{\nu_3} \right\}^{\frac{\nu_3}{1-\nu_3}}
\]

\[
N_{ji}^*(s) = \frac{X_j^*(s)}{A_j^*} \left\{ (1 - \alpha_3) \frac{1}{\nu_3} \left( \frac{\alpha_3}{1 - \alpha_3} \right)^{\frac{1-\nu_3}{\nu_3}} \left( \frac{W_i^j}{W_j^j} \right)^{1-\nu_3} + (\alpha_3) \frac{1}{\nu_3} \right\}^{\frac{\nu_3}{1-\nu_3}}
\]

Combining the labor demand conditions as log-linear deviations from the symmetric steady state yields the following relationship between native and migrant workers:

\[
w_{ii}^* - w_{ji}^* = -\frac{1}{\nu_3} (n_{ii}^* - n_{ji}^*)
\]

\(^{22}\)Assuming native and migrant workers to be perfect substitutes in production yields equality of their respective wages, i.e. \( W_i^{ii} = W_j^{ji} \). But when assuming the two types of workers being perfectly substitutable there are two corner solutions which need to be taken into account: \( W_i^{ii} > W_j^{ji} \) with \( N_{ii}^* = 0 \) and \( L_i = N_j^* \), and \( W_i^{ii} < W_j^{ji} \) with \( N_{jj}^* = 0 \) and \( L_j = N_i^* \), respectively. It is easy to show that when assuming imperfect substitutability of labor supply in the domestic vs. the foreign labor market in the Households’ problem we can exclude these two corner solutions.

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Assuming the two types of workers to be perfectly substitutable implies labor demand for both types of workers to be rather sensitive to changes in relative wages.

The real marginal cost of production expressed in terms of intermediate goods prices will be common across firms and is defined as

$$\text{RMC}_{i,x,t}(s) = (1 - \tau^i_x) \left( \frac{P^i_t}{P^i_{x,t}} \right) \left[ \frac{W^{ii}_t}{P^i_t A^i_t} \left( \frac{N^{ii}_t(s)}{(1 - \alpha_3) L^i_t(s)} \right)^{\frac{1}{\nu_3}} + \frac{W^{jj}_t}{P^i_t A^i_t} \left( \frac{N^{jj}_t(s)}{\alpha_3 L^i_t(s)} \right)^{\frac{1}{\nu_3}} \right]$$

(3.19)

where $\frac{P^i_t}{P^i_{x,t}}$ denotes the relative price of intermediate to final consumption goods in region $i$. Note, that intermediate firms can costlessly adjust either factor of production. Thus, the static first-order conditions for cost minimization imply that all firms have identical marginal cost per unit of output. Equation (3.19) can be rewritten in log-linear terms

$$rmc^i_{x,t} = \eta_1 \left[ w^{ii}_t - p^i_t - a^i_t + \frac{1}{\nu_3} \left( n^{ii}_t - l^i_t \right) - (p^i_{x,t} - p^i_t) \right] + \eta_2 \left[ w^{jj}_t - p^i_t - a^i_t + \frac{1}{\nu_3} \left( n^{jj}_t - l^i_t \right) - (p^i_{x,t} - p^i_t) \right]$$

(3.20)

where $\eta_1$ and $\eta_2$ depend on steady state values and on $\tau^i_x$, which is an employment subsidy neutralizing all distortions present in the intermediate sector, but the one related to nominal rigidities. In Appendix E we compute the employment subsidy for the intermediate sector, $\tau^i_x$, and show that it depends on the markup of intermediate goods producers, as in a standard setup without labor mobility.

When assuming nominal rigidities to be present in the intermediate production sector, we suppose that firms set prices in a staggered fashion, as in Calvo (1983). Hence, a measure $(1 - \theta^i_x)$ of randomly selected firms in $i$ sets new prices each period, with an individual firm’s probability to re-optimize in any given period being independent of the time elapsed since it last reset its price. As in a standard model without labor mobility, inflation of intermediate goods prices can be expressed as a function of marginal costs:

$$\pi^i_{x,t} = \beta E_t \{ \pi^i_{x,t+1} \} + \lambda x rmc^i_{x,t}$$

(3.21)

where $\lambda x \equiv \frac{(1-\theta^i_x)(1-\theta^i_x)}{\theta^i_x}$ and $rmc^i_{x,t}$ is the log deviation of real marginal costs from its steady state value $mc^i = -\log \left( \frac{\epsilon_x}{\epsilon_x - 1} \right)$.

In presence of labor mobility the standard relation linking inflation to firms’ real marginal cost of production still holds, with the latter to be defined differently. In particular, the real marginal cost of production depends on wages of both native and migrant workers in the labor market of region $i$, with each of them weighted by the relative share in overall labor input for production. The real marginal cost of production is therefore positively related to wages, negatively to productivity, and furthermore depends (inversely) on the relative price
of intermediate to final goods. Hence, the channel through which labor mobility affects inflation of intermediate goods prices is by its effect on the marginal cost of production of intermediate goods producers.

Given that the fiscal authority in both regions fully neutralize the distortions associated with firms’ market power by means of a constant employment subsidy, \( \tau_i \), we define the output gap in the intermediate sector \( \tilde{x}_it \) as the deviation of (log) output \( x_{it} \), from its natural level \( \bar{x}_it \), where the latter is in turn defined as the equilibrium level of output in the absence of nominal rigidities. Combining (3.20) and (3.21) gives rise to the New Keynesian Phillips curve of the intermediate goods sector:

\[
\pi_{x,t}^i = \beta E_t \{ \pi_{x,t+1}^i \} + \lambda_x^i \left\{ \left( \frac{\nu_3 - 1}{\nu_3} \right) \tilde{x}_it + \eta \left[ \left( \varphi + \frac{1}{\nu_1} \right) (\bar{n}_it + \bar{n}_jt) + \gamma (\bar{n}_it + \bar{n}_jt) \right] \right\}
\]

where \( \eta \) depends on steady state values, \( \gamma \equiv \left( \frac{\nu_3 - \nu_1}{\nu_1 \nu_3} \right) \), \( \bar{n}_it \) is the labor supply gap in region \( i \) and \( \bar{n}_jt \) the labor input gap of labor supplied by household members from region \( i \) employed in production in region \( i \). The Phillips curve of intermediate goods producers in region \( i \) thus depends on gaps related to both labor inputs used in production of intermediate goods, i.e. on gaps linked to labor provided by both native and migrant workers (\( \bar{n}_it \) and \( \bar{n}_jt \), respectively). The labor used in production of the two types of workers will in turn depend on the aggregate labor supply of households in both region \( i \) and \( j \) (\( \bar{n}_it \) and \( \bar{n}_jt \), respectively).

When comparing the Phillips curve of the intermediate sector in region \( i \), (3.22), with the one corresponding to a setup without labor mobility

\[
\pi_{x,t}^i = \beta E_t \{ \pi_{x,t+1}^i \} + \lambda_x^i (1 + \varphi)\tilde{x}_it
\]

it becomes evident that when allowing for labor mobility the isomorphism between a closed and an open economy is broken. In particular, the Phillips curve of a given region \( i \) does not only depend on its output gap but also on gaps related to both the domestic and the foreign labor inputs and thus (via the mobile labor force) to the foreign economy. The presence of labor mobility furthermore affects both the intercept and the slope: the slope will depend on the elasticity of substitution between the two types of workers, \( \nu_3 \), but will always be strictly smaller than the slope of the Phillips curve corresponding to an intermediate goods sector with a fixed labor force. Allowing for labor mobility provides intermediate goods producers with an additional margin of adjustments, such that the effect of changes in the output gap on domestic inflation are reduced, i.e. the Phillips curve becomes flatter.

### 3.4 Final good producers

In each region there are infinitely many monopolistically competitive final goods producers that are indexed by \( k \) on the unit interval. All final goods producers
have access to the same constant elasticity of substitution technology combining domestic and foreign intermediate goods to output in the final goods sector:

\[ Y_t^i(k) = \left( 1 - \alpha_2 \right)^{\frac{1}{\nu_2}} \left( X_t^{ii}(k) \right)^{\frac{\nu_2 - 1}{\nu_2}} + \left( \alpha_2 \right)^{\frac{1}{\nu_2}} \left( X_t^{ij}(k) \right)^{\frac{\nu_2 - 1}{\nu_2}} \]  

(3.24)

where \( X_t^{ii}(k) \) stands for the demand of the final goods producer of variety \( k \) for the domestically produced intermediate good and \( X_t^{ij}(k) \) with \( j \in [H, F] \) and \( j \neq i \), denotes the demand of the same producer for the imported intermediate good. \( X_t^{ii}(k) \) is given by the constant elasticity of substitution function:

\[ X_t^{ii}(k) = \left[ \int_0^1 X_t^{ii}(k, s) \frac{\varepsilon_x - 1}{\varepsilon_x} ds \right]^{\frac{\varepsilon_x}{\varepsilon_x - 1}} \]

where \( s \in [0, 1] \) denotes the variety of intermediate goods. Equivalently, \( X_t^{ij}(k) \) is an index of imported intermediate goods:

\[ X_t^{ij}(k) = \left[ \int_0^1 X_t^{ij}(k, s) \frac{\varepsilon_x - 1}{\varepsilon_x} ds \right]^{\frac{\varepsilon_x}{\varepsilon_x - 1}} \]

\( \varepsilon_x > 1 \) denotes the elasticity of substitution between varieties of intermediate goods produced within a given region, which is assumed to be equal for domestically produced and imported goods. The elasticity of substitution between domestically produced and imported intermediate goods is denoted by \( \nu_2 \) and \( (1 - \alpha_2) \) measures the home bias in absorption of intermediate goods such that \( \alpha_2 \in [0, 1] \) serves as a natural index of the degree of openness of a given region. Given our focus on different states or groups of states in the US we consider the particular case where \( \alpha_2 = 0.5 \), i.e. absence of home bias; that is, for any given relative price, final goods producers in both regions will demand the same quantities of the domestic good. But, as we will show below, our results do not rely on this particular case.

The optimal allocation of expenditure on each variety, \( k \), yields final goods producers' demand function for a given variety \( s \) of domestically produced and imported intermediate goods, respectively

\[ X_t^{ii}(k, s) = \left( \frac{P_{x,t}^i(s)}{P_{x,t}^i} \right)^{-\varepsilon_x} X_t^{ii}(k) \]  

(3.25)

\[ X_t^{ij}(k, s) = \left( \frac{P_{x,t}^j(s)}{P_{x,t}^j} \right)^{-\varepsilon_x} X_t^{ij}(k) \]  

(3.26)

where \( P_{x,t}^i \equiv \left[ \int_0^1 P_{x,t}^i(s)^{1-\varepsilon_x} ds \right]^{\frac{1}{1-\varepsilon_x}} \) denotes the price index of domestically produced intermediate goods and \( P_{x,t}^j \equiv \left[ \int_0^1 P_{x,t}^j(s)^{1-\varepsilon_x} ds \right]^{\frac{1}{1-\varepsilon_x}} \) is a price index of imported intermediate goods.

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Cost minimization yields the following demand functions for domestically produced and imported intermediate goods

\[ X_{ii}^i(k) = (1 - \alpha_2) \left( \frac{P^i_{x,t}}{P^i_t} \right)^{-\nu_2} Y_i^i(k) \] (3.27)

\[ X_{ij}^i(k) = \alpha_2 \left( \frac{P^j_{x,t}}{P^i_t} \right)^{-\nu_2} Y_i^i(k) \] (3.28)

where \( P^i_t = \left[ (1 - \alpha_2)(P^i_{x,t})^{1-\nu_2} + \alpha_2(P^j_{x,t})^{1-\nu_2} \right]^{\frac{1}{1-\nu_2}} \) denotes the consumer price index, i.e. the aggregate price index of final, non-traded goods.

Real marginal costs of final goods producers in region \( i \), expressed in terms of prices of the final consumption good, \( P^i_t \), is defined as

\[ RMC^i_t(k) = (1 - \tau^i) \left[ \frac{P^i_{x,t}}{P^i_t} \left( \frac{X_{ii}^i(k)}{(1 - \alpha_2)Y_i^i(k)} \right)^{1 \over \nu_2} + \frac{P^j_{x,t}}{P^i_t} Q^i_t \left( \frac{X_{ij}^i(k)}{\alpha_2 Y^i_i(k)} \right)^{1 \over \nu_2} \right] \] (3.29)

with \( \tau^i \) being an employment subsidy exactly offsetting the effect of market power distortions in the final goods sector, and thus rendering the flexible price equilibrium allocation optimal. In appendix E we compute the employment subsidy, \( \tau^i \), and show that it is not affected by labor mobility, i.e. simply depending on final goods producers’ market power.

Equation (3.29) can be rewritten in log-linear terms

\[ rmc^i_t = \eta_3 \left[ p^i_{x,t} - p^i_t + \frac{1}{\nu_2} (x^i_t - y^i_t) \right] + \eta_4 \left[ p^j_{x,t} - p^j_t + q^i_t + \frac{1}{\nu_2} (x^j_t - y^i_t) \right] \] (3.30)

where \( \eta_3 \) and \( \eta_4 \) depend on steady state values. When assuming nominal rigidities to be present in the final goods sector, we suppose that firms set prices in a staggered fashion, as in Calvo (1983), with a measure of \( (1 - \theta^i) \) of randomly selected final goods producers setting new prices each period. Combining the optimal pricing condition with the aggregate price dynamics yields the standard relation between inflation and real marginal costs in the final goods sector of region \( i \):

\[ \pi^i_t = \beta E_t \left\{ \pi^i_{t+1} + \lambda^i rmc^i_t \right\} \] (3.31)

where \( \lambda^i \equiv \frac{(1 - \theta^i)(1 - \theta^i)}{\theta^i} \) and \( rmc^i_t \) is the log deviation of real marginal costs from its steady state value \( mc = -\log \left( \frac{\epsilon}{\epsilon - 1} \right) \).

The Phillips curve of the final goods sector can be derived combining real marginal costs, (3.30), with inflation dynamics, (3.31):

\[ \pi^i_t = \beta E_t \left\{ \pi^i_{t+1} \right\} + \lambda^i \left\{ \eta_3 \left[ \tilde{p}^i_{x,t} - \tilde{p}^i_t + \frac{1}{\nu_2} (\tilde{x}^i_t - \tilde{y}^i_t) \right] \right. \\
+ \eta_4 \left[ \tilde{p}^j_{x,t} - \tilde{p}^j_t + \frac{1}{\nu_2} (\tilde{x}^j_t - \tilde{y}^i_t) \right] \right\} \] (3.32)
Inflation of final goods in region $i$ is linked to the foreign economy via trade in intermediate goods, and will thus not be affected directly by labor mobility.

### 3.5 Market clearing

The clearing of the market for variety $s$ of intermediate goods produced in region $i$ requires

$$X^i_t(s) = X^{ii}_t(s) + X^{ji}_t(s)$$  \hspace{1cm} (3.33)

with $X^{ii}_t(s)$ denoting domestic absorption, i.e. the fraction of total intermediate production of region $i$ which is consumed domestically, and $X^{ji}_t(s)$ determining exports from region $i$ to region $j$. Combining (3.33) with the respective demand functions (3.25) - (3.28), together with the law of one price for traded intermediate goods yields total demand that a given intermediate producer $s$ in region $i$ faces:

$$X^i_t(s) = \left( \frac{P^i_{x,t}(s)}{P^i_t} \right)^{-\varepsilon_x} \left( \frac{P^i_{x,t}}{P^i_t} \right)^{-\nu_2} Y^i_t \{(1 - \alpha_2) + \alpha_2(Q^i_t)^{\nu_2-1}\}$$

for all $s \in [0,1]$ and all $t$. Using the previous condition in the definition of region $i$’s aggregate output in the intermediate goods sector, $X^i_t \equiv \int_0^1 X^i_t(s) \frac{\varepsilon_{x-1}}{\varepsilon_x} ds$, yields the aggregate intermediate goods market clearing condition for region $i$:

$$X^i_t = \left( \frac{P^i_{x,t}}{P^i_t} \right)^{-\nu_2} Y^i_t \{(1 - \alpha_2) + \alpha_2(Q^i_t)^{\nu_2-1}\}$$  \hspace{1cm} (3.34)

The clearing of the market for variety $k$ of final non-traded goods produced in region $i$ requires

$$Y^i_t(k) = C^i_t(k)$$

which, given aggregate output in the final goods sector being defined as $Y^i_t \equiv \int_0^1 Y^i_t(k) \frac{\varepsilon_{x-1}}{\varepsilon_x} dk$ states as

$$Y^i_t = C^i_t$$  \hspace{1cm} (3.35)

Finally we can combine (3.35) with the household’s log-linear Euler equation to derive the following relationship between output of final consumption goods and the real interest rate in region $i$:

$$y^i_t = E_t\{y^i_{t+1}\} - (r_t - E_t\{\pi^i_t\})$$  \hspace{1cm} (3.36)

By solving (3.36) forward, it is easy to see that the level of output in region $i$ is negatively related to current and anticipated domestic real interest rates, but independent of output in region $j$. Labor mobility in the given setup does therefore not affect the standard form of the IS-curve.
3.6 Monetary Policy

We consider the two regions $i$ and $j$ to form a monetary union. The central monetary authority sets the union-wide interest rate such as to stabilize a weighted average of CPI-inflation in the two regions.

$$R_t = \beta^{-1} \left[ \chi \pi_i^t + (1 - \chi) \pi_j^t \right]^\phi$$  \hspace{1cm} (3.37)

where $\chi \in [0, 1]$ defines the weight the monetary authority of the union assigns to stabilization of CPI-inflation in Home relative to Foreign, and $\phi$ measures the aggressiveness of the monetary authority in stabilizing the weighted average of inflation rates in both regions.

3.7 Dynamics after an asymmetric labor productivity shock

In this section we analyze the dynamics in the theoretical economies after an asymmetric technology shock. We choose parameter values, as defined in Table 11, to mimic the structure of the economy of the United States. Some comments with respect to the calibration are in order: The utility cost of working in the foreign labor market, $\alpha_1$, is chosen such as to match the average steady state share of state level inflows to total labor input, $\frac{N_{ji}}{L_i}$, which according to our US state level data is 10.7 percent on average\(^{23}\). The value for the elasticity of substitution between domestic and foreign labor supply, $\nu_1$, is chosen such as to match the average volatility of net flows over all states\(^{24}\).

The value of the elasticity of substitution between domestically produced and imported intermediate goods in final goods production, $\nu_2$, is worth some discussion. Elasticities of import- and export substitution have been extensively estimated for international trade, but limited information is available on elasticities of substitution for regional trade. A common assumption is that the elasticities for international trade are to be considered as lower bound for regional trade, mainly based on the argument of lower trade restrictions for regional-compared to international trade. Bilgic, King, Lusby and Schreiner (2002) provide an overview of the literature on regional trade elasticities and report values between 1.5 and 3.5 for the US. Morgan, Mutti and Partridge (1989), using US data, estimate an inter-regional trade elasticity of 3. We set $\nu_2 = 3$ and provide extensive sensitivity analysis.

The degree of price stickiness in both the intermediate and the final goods sector is discussed in detail in what follows. All remaining parameter values are chosen consistent with the values used in the literature. We focus on a symmet-

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\(^{23}\)Over all 48 states under consideration we have this share to vary between 2-12%. As we will show our results are not sensitive to changes in $\alpha_1$ within this range.

\(^{24}\)The percentage standard deviation of net labor flows relative to GDP ranges from 1.62 to 7.70. On average over all 48 states under consideration it takes value 4.04.
ric steady states where the share of native and migrant workers is equal across regions. Considering an asymmetric steady state does not alter the results.

3.7.1 High vs. Low degree of nominal rigidities in the intermediate goods sector

We first consider the case of nominal rigidities to be present only in the intermediate goods sector, i.e. $\theta_i = \theta_j = \theta^{26}$. Figure 10 describes the dynamics after a positive productivity shock in the intermediate goods sector in the Home economy, for a degree of price stickiness implying an average price duration of four quarters ($\theta_x^i = \theta_x^j = 0.75$). In the region hit by the shock production of intermediate goods increases as a direct consequence of the raise in productivity. The presence of nominal rigidities prevents intermediate producers to perfectly adjust prices such that they will make use of the only alternative margin of adjustment, namely labor demand. Consequentially labor input in intermediate goods production in the region hit by the shock falls.

Given the common monetary policy union-wide interest rates will be downward adjusted, in response to the productivity shock in region $i$. As it becomes evident from the IS-curve, (3.36), consumption and production of final goods will increase in the economy of region $j$ which has not been directly hit by the shock. Demand for intermediate goods produced in $j$ will thus be increasing, which translates directly into an increase in labor demand in the same region. Households in both economies, observing the fall in labor demand in region $i$ and the increase in labor demand in $j$, will thus optimally send more members to work in the labor market in region $j$. As a consequence net flows in region $i$ will be falling in response to the productivity shock, i.e. workers flow out of the economy directly hit by the shock, given that the latter offers less employment.

The impact response of employment and of net labor flows in region $i$ crucially depends on two opposing effects: First, prices for intermediate goods produced in the region hit by the shock are relatively lower and thus induce a demand substitution of intermediate goods across the two regions, i.e. final goods producers in both regions demand relatively more of the relatively cheaper intermediate goods.

25In particular, we considered differences in labor income taxes across the two regions, which gives rise to an asymmetric steady state with different shares of native to migrant workers across regions. Assuming labor income taxes to be relatively higher in region $i$ leads to a smaller amount of labor used in production of intermediate goods in region $i$, and thus a strictly smaller steady state output of final goods. Nevertheless, an asymmetric labor income tax does not have an important impact on the dynamics in response to a technology shock and does therefore not account for the observed heterogeneity in the dynamics documented in section 2.

26Assuming the presence of the employment subsidy eliminating distortions related to market power, $\tau$, the final goods sector operates in a perfectly competitive environment, where final goods producer assemble domestically produced and imported goods to the final, non-traded consumption good. Alternatively, we can think of households’ utility to depend on consumption of both imported and domestically produced goods, such that consumption of final goods in the utility function (3.1) is defined according to equation (3.24). In the latter case, we can think of the economy as being characterized by one production sector only.
This effect is referred to as expenditure switching effect. As a direct consequence of the increasing demand for intermediate goods produced in region \( i \) firms in this sector have an incentive to hire more workers. The expenditure switching effect therefore induces an upward pressure on employment in region \( i \). The second effect is linked to the presence of nominal rigidities. As we have discussed above, the impossibility of adjusting prices immediately after the shock induces intermediate producers in region \( i \) to reduce employment. Consequently, the presence of nominal rigidities acts as a downward pressure on employment in region \( i \). For a moderate to high degree of nominal rigidities we have the downward pressure on employment resulting from price stickiness to be more pronounced than the upward pressure due to the expenditure switching effect. Labor input in region \( i \) thus falls in response to the productivity shock. Given the increase in intermediate goods production and labor input in region \( j \) we therefore observe labor to flow from region \( i \) to region \( j \), i.e. a decrease in net labor flows in the region hit by the shock.

We then consider the case of a low degree of nominal rigidities in the intermediate goods sector in both regions. Figure 11 displays the dynamics in response to a positive productivity shock in region \( i \) for \( \theta^i_x = \theta^j_x = 0.3 \), corresponding to an average price duration of roughly four months. Clearly, in this case we have the expenditure switching effect to be stronger, i.e. employment in region \( i \) increases in response to the shock. The relative fall in prices for intermediate goods produced in \( i \) is more pronounced compared to the previous case such that the increase in demand for and production of intermediate goods is bigger. The subsequent increase in employment more than offsets the reduction of the workforce due to an incomplete adjustment in prices. For region \( j \) the decrease in demand for its intermediate goods induces a fall in production and employment. Households in both economies will therefore observe an increase in labor demand in region \( i \), a fall in labor demand in \( j \) and therefore send more household members to work in the labor market in \( i \). Net labor flows in region \( i \) will therefore increase after the positive technology shock, i.e. workers flow into the economy directly hit by the shock, given that the latter offers relatively more employment after the productivity shock.

The dynamics in net labor flows and employment in the economy hit by the technology shock are very robust to the value of key parameters: Figures 13 and 15 display the impact impulse response functions for net labor flows and employment over a range of reasonable values of all three elasticities of substitution, \( \nu_1, \nu_2, \) and \( \nu_3 \), for high and low degrees of nominal rigidities, respectively. Furthermore, as it becomes clear from Figures 14 and 16, the impact dynamics are robust to all three share-parameters, \( \alpha_1, \alpha_2, \) and \( \alpha_3 \). Consequentially, some strong assumptions that we have made for our model economy can be relaxed without affecting the dynamics quantitatively: First of all, our assumption of the two types of workers being perfectly substitutable in production induces labor demand to adjust quickly in response to changes in relative wages. As it comes out in Figures 13 and 15 relaxing this assumption and allowing the two types of workers to be imperfect substitutes still generates a fall in both net flows and
employment for high degrees of nominal rigidities, and an increase for low average price durations. The magnitude of the impact response is negatively related to the degree of substitutability of the two types of workers. Hence, other than on the degree of price rigidities, the qualitative impact response of net flows does not hinge on the assumption of perfect substitutability between the two types of workers.

Secondly, assuming native and migrant workers to be attached a different productivity, i.e. $\alpha_3 \neq 0.5$, does yield the same qualitative dynamics after a positive technology shock. Figures 14 and 16 illustrate this point in showing the impact response of net labor flows for different values of $\alpha_3^{27}$. Thirdly, both the value for the elasticity of substitution between domestic and imported intermediate goods, $\nu_2$, and the degree of openness of the intermediate goods sector, $\alpha_2$, clearly affect the size of the expenditure switching effect. The higher the value of $\nu_2$ the bigger this effect, whereas the presence of some home bias will make the effect smaller. But as it becomes clear from Figures 13 to 16 the dynamics are robust to changes within the range of admissible values for both parameters.

Combining the empirical evidence with the theoretical predictions of the model presented in this section thus suggests that the dynamic behavior of labor flows in response to an asymmetric productivity shock depends primarily on the adjustment of employment in the two regions and thus on the degree of nominal rigidities in the sector where labor mobility is observed. In particular, according to our economic model labor flows for repelling state-pairs are primarily between production sectors displaying high degrees of nominal rigidities, whereas labor flows between magnet states take place primarily between industries characterized by low price durations. Moreover, in our model economy the two groups differ in terms of their implied spill-over effect on the labor market of region $j$, which has not been directly hit by the productivity shock. Whenever prices adjust slowly the expenditure switching effect is rather small such that production of intermediate goods and so employment in region $j$ will be increasing. The increase in employment in $j$ after the asymmetric productivity shock in $i$ is referred to as a positive spill-over. On the contrary, when prices adjust rapidly the spill-over effect on region $j$’s economy will be negative due to an important demand substitution of intermediate goods produced in $j$ with goods produced in $i$. Both production of intermediate goods and employment in region $j$ are therefore falling. These theoretical predictions are consistent with the empirical evidence presented in section 2.

27Note, that assuming both types of workers to be perfectly substitutable makes the impact response of labor input independent of $\alpha_3$. Relaxing both of our working assumptions, i.e. the two types of workers being imperfectly substitutable and unequally productive does not alter our results qualitatively.
3.7.2 Asymmetric degrees of nominal rigidities in the intermediate goods sector

One of the underlying assumptions of the economy presented in the previous section is that labor flows between production sectors characterized by symmetric degrees of nominal rigidities. There is ample evidence that the frequency of price adjustments differs substantially across sectors in the US economy\textsuperscript{28}. Given that the economies of different US states are more or less dependent on particular sectors\textsuperscript{29}, labor flows affect sectors with different degrees of nominal rigidities. In the previous section we have taken one possible extreme view, namely that the degree of price rigidity is the same for both regions. In the alternative setup presented in this section we analyze the implications of labor flowing between sectors with asymmetric price durations. Figure 12 describes the dynamic effects of a positive technology shock to the intermediate goods sector in region $i$, assuming $\theta^i_x = 0.6$ and $\theta^j_x = 0.3$. All remaining parameters are set as in Table 11. Intermediate goods produced in region $i$ become relatively cheaper after the shock such that respective demand from final goods producers of both regions increases. Production of intermediate goods in region $i$ thus raises. But given that intermediate producers in $i$ can not immediately adjust prices they optimally reduce employment. The size of the expenditure switching effect affecting employment in $i$ is therefore smaller than the size of the effect linked to the presence of nominal rigidities. For the labor market in $j$ the opposite is true: Given the relatively short average price duration of approximately 3 months the size of the negative effect on employment due to sticky prices is rather small. At the same time, intermediate goods producers increase their prices relatively quickly, such that the size of the expenditure switching effect is relatively big. Consequently, employment in region $j$ falls.

Whenever the degree of price rigidity is higher in the economy hit by the shock, i.e. $\theta^i_x > \theta^j_x$, the fall in employment in $j$ is strictly bigger that the reduction in employment in $i$. Observing the relative worsening of labor market conditions in region $j$ induces households in both regions to reduce labor supply in $j$, such that net flows in region $i$ increase in response to the shock.

Figure 17 provides an overview of the impact responses of net labor flows and employment in both states, respectively, when varying the degree of price rigidity in the intermediate goods sector in both regions\textsuperscript{30}. As we have concluded before, for high values of both $\theta^i_x$ and $\theta^j_x$ the expenditure switching effect is always stronger than the effect linked to price stickiness. Consequentially, employment falls in region $i$, increases in $j$ such that labor flows out of $i$ and into $j$. These

\textsuperscript{28}See for example Blinder et al. (1998), Bils and Klenow (2004), Nakamura and Steinsson (2008)

\textsuperscript{29}See for example Bernard and Jones (1996), U.S. Department of Labor (2011)

\textsuperscript{30}We group the observed patterns in the impact responses of both net labor flows and employment in the region hit by the shock accordingly to the classification used in the empirical section: Repelling states represent negative impact responses in both employment and net labor flows, magnet states encompass positive impact responses in both variables, and hybrid states refer to a positive impact response in net labor flows and a negative impact response in employment
dynamics correspond to what we have previously referred to as repelling states. On the contrary, for low values of both $\theta^i_x$ and $\theta^j_x$ the opposite is true: Employment increases in region $i$, falls in region $j$ and labor flows into the region hit by the shock $i$ (magnet states). In between these two clear cut cases we have an intermediate case, replicating the empirical evidence of state-pairs we have previously classified as hybrid. For our calibration, when $\theta^i_x \in [0.55, 0.68]$ and $\theta^j_x < \theta^i_x$ the theoretical model generates a fall in employment in both region $i$ and region $j$, with the latter being bigger than the former. Labor therefore flows out of region $j$ into $i$. Note, that the range of values for $\theta^i_x$ reproducing the estimated dynamics of hybrid states depends on the calibration. In particular, lower values for $\nu_2$ imply a slightly bigger and strictly lower range of values for $\theta^i_x$, i.e. setting $\nu_2 = 1.5$ implies an admissible range of $\theta^i_x$ between $[0, 0.34]$. For given price duration, lower values of $\nu_2$ imply a smaller expenditure switching effect. In region $i$ this implies a more pronounced fall in employment, whereas in region $j$ employment falls by less or even increases. In order for employment to fall by more in region $j$ we need prices to adjust slightly faster in $i$ such as to enlarge the impact of the expenditure switching effect on employment in $j$. In other words, we need the negative effect on employment in region $i$ linked to nominal rigidities to be smaller.

Other than affecting the range of admissible values for the degree of price rigidities in region $i$, as for the setup with symmetric degrees of nominal rigidities, the qualitative dynamics of the model economy replicating the empirical evidence of hybrid states does not rely on our calibration.

To sum up, as in the setup with symmetric nominal rigidities in the intermediate goods sector we have labor to flow to the economy with relatively better labor market conditions after the shock. Combining the theoretical predictions of the model presented in this section with the empirical evidence thus leads to the conclusion that labor flows between hybrid states primarily take place between states with moderate, but unequal degrees of price rigidities. The direction of the flows is determined by the relative price duration across the two states. These theoretical predictions are consistent with the empirical evidence presented in section 2.

3.7.3 Nominal rigidities in the final goods sector

So far we have assumed perfectly flexible prices in the final goods sector. Relaxing this assumption does not affect the previously discussed results in any important way, given that the underlying mechanism of adjustment remains the same. The presence of price stickiness in the final goods sector most of all reduces the size of the expenditure switching effect: Given the presence of nominal rigidities final goods producers are no longer able to perfectly adjust their prices in response to a shock and therefore make adjustments in their demand for intermediate goods. Figure 18 represents impact responses of net labor flows and employment in both regions, respectively, when varying the degree of price rigidity in the intermediate goods sector, assuming the degree of price stickiness in the final
sector to be relatively high, i.e. $\theta^i = \theta^j = 0.75$. For our given calibration, assuming prices in the final goods sector to be sticky does therefore still allow to replicate the respective dynamic behavior of repelling, magnet and hybrid states that we have observed in the data.

3.8 The Role of a mobile labor force on the spill-over of an asymmetric shock

Previously we have concluded that allowing for labor mobility gives rise to an additional transmission channel between the two regions in our model economy. Specifically, we have seen that the Phillips curve depends on gaps related to labor market variables in the other region. Our theoretical model replicates the estimated spill-over effects in the data: After a positive productivity shock in state $i$ employment in state $j$ increases when both states’ intermediate sector displays some degree of nominal rigidities (repelling states). For both magnet and hybrid states the data indicates a positive spill-over effect on the other state’s employment. In our model economy employment in state $j$ falls when both states display a low or asymmetric degree of nominal rigidities.

One important issue we have not addressed so far is the impact of a mobile labor force on the propagation of the asymmetric shock. In order to isolate the effects of labor mobility on the transmission of a productivity shock in region $i$ we consider the following counterfactual exercise: We shut down trade in intermediate goods between the two regions and compare the effects of the productivity shock in region $i$ with and without labor mobility. Figure 19 displays the corresponding impulse response functions, for perfectly flexible prices in both sectors and regions. On the one hand, in a closed economy without migration the only effect the productivity shock in region $i$ has on the economy in $j$ is an increase in prices of both goods. The spill-over effect on the economy not directly hit by the shock therefore does not imply any real effects. In a closed economy with labor mobility, on the other hand, we observe a clear spill-over effect on both sectors of the economy in $j$, where the sign of the spill-over crucially depends on the degree of nominal rigidities in the intermediate goods sector. As we know from Backus, Kehoe and Kydland (1992) in a baseline two-country model with a fixed labor force technology spill-overs crucially depend on the correlation of the shocks across countries. Hence, in their model there is no endogenous channel inducing positive spill-over effects which allow to match the observed co-movement of output and consumption in the data. From this exercise we can thus conclude that labor mobility provides an endogenous transmission channel of productivity shocks in an otherwise standard two-country model.

4 Conclusions

The first part of this paper provides empirical evidence on the dynamic behavior of labor flows across US states in response to state specific labor productivity
shocks. References to the cyclicality of internal migration have appeared before in the literature, but have not analyzed conditional moments of migration rates which are important for a thorough understanding of labor mobility as an alternative adjustment mechanism. We use data on state-to-state migration in the US for the period 1976 to 2008 to identify labor productivity shocks for 226 state-pairs representing 80 percent of aggregate labor flows in the same period. We find no uniform pattern describing the dynamic behavior of economic variables in response to the technology shock. The crucial difference in the conditional behavior across state-pairs lies in the dynamic responses of both employment and net labor flows.

In the second part of this paper we provide a new open economy model with endogenous labor mobility consistent with the established empirical evidence. We use this model to show that an explanation consistent with the observed heterogeneity in the dynamic behavior of labor flows is a varying degree of nominal rigidities in the sector affected by labor mobility. We discuss the differences in the dynamics of the model economy with high (low) degrees of nominal rigidities, compared to a two-region economy with asymmetric price durations across regions. In particular, we show that whenever the degree of nominal rigidities is high (low) and firms adjust prices rather slowly (quickly), states experiencing a labor augmenting productivity shock become less (more) attractive to workers. Namely, labor market condition will be relatively worse (better) in the region hit by the shock, such that labor will flow out of (in to) the region hit by the shock. For states with clearly asymmetric degrees of nominal rigidities labor will be flowing into the state with relatively better labor market conditions.

Finally, we show with a simple empirical exercise that the provided theoretical explanation for the observed heterogeneity in the dynamics of labor flows across US states is confirmed in the data.

The present paper offers (at least) two interesting extensions: First of all, our theoretical model provides a starting point in order to analyze the optimal monetary policy in an environment with labor mobility. In particular, it would be interesting to study to what extent labor mobility affects the attractiveness of coordination of monetary policies across countries. Secondly, skills endowments have an important influence in the direction of internal migration flows, as it has been pointed out by Borjas, Bronars and Trejo (1992). One promising extension would thus be to analyze to what extent the differences in workers’ skills account for the observed heterogeneity in labor flows across states.
References


## A Tables

### Table 1: Aggregate unconditional correlations

<table>
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<th>Productivity</th>
<th>Net Flows</th>
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<td>GSP</td>
<td>0.6256</td>
<td>0.8100</td>
<td>0.2713</td>
</tr>
<tr>
<td>Employment</td>
<td>0.0821</td>
<td>0.4385</td>
<td></td>
</tr>
<tr>
<td>Productivity</td>
<td></td>
<td>0.0238</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2: Aggregate correlations conditional on labor productivity shocks

<table>
<thead>
<tr>
<th></th>
<th>Employment</th>
<th>Productivity</th>
<th>Net Flows</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSP</td>
<td>-0.8766</td>
<td>0.7330</td>
<td>-0.2345</td>
</tr>
<tr>
<td>Employment</td>
<td>-0.4132</td>
<td>0.3392</td>
<td></td>
</tr>
<tr>
<td>Productivity</td>
<td></td>
<td>-0.4115</td>
<td></td>
</tr>
</tbody>
</table>

### Table 3: Repelling States (133 state pairs, 34% of aggregate labor flows)

<table>
<thead>
<tr>
<th>Impact Response Net Flows</th>
<th>Impact Response Employment</th>
<th>State Pairs</th>
</tr>
</thead>
<tbody>
<tr>
<td>- and significant</td>
<td>- and significant</td>
<td>73</td>
</tr>
<tr>
<td>- and significant</td>
<td>- but non significant</td>
<td>38</td>
</tr>
<tr>
<td>- but non significant</td>
<td>- and significant</td>
<td>17</td>
</tr>
<tr>
<td>- but non significant</td>
<td>- but non significant</td>
<td>5</td>
</tr>
</tbody>
</table>

### Table 4: Magnet States (155 state pairs, 15% of aggregate labor flows)

<table>
<thead>
<tr>
<th>Impact Response Net Flows</th>
<th>Impact Response Employment</th>
<th>State Pairs</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ and significant</td>
<td>+ and significant</td>
<td>63</td>
</tr>
<tr>
<td>+ and significant</td>
<td>+ but non significant</td>
<td>54</td>
</tr>
<tr>
<td>+ but non significant</td>
<td>+ and significant</td>
<td>29</td>
</tr>
<tr>
<td>+ but non significant</td>
<td>+ but non significant</td>
<td>9</td>
</tr>
</tbody>
</table>

### Table 5: Hybrid States (123 state pairs, 26% of aggregate labor flows)

<table>
<thead>
<tr>
<th>Impact Response Net Flows</th>
<th>Impact Response Employment</th>
<th>State Pairs</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ and significant</td>
<td>- and significant</td>
<td>48</td>
</tr>
<tr>
<td>+ and significant</td>
<td>- but non significant</td>
<td>41</td>
</tr>
<tr>
<td>+ but non significant</td>
<td>- and significant</td>
<td>25</td>
</tr>
<tr>
<td>+ but non significant</td>
<td>- but non significant</td>
<td>9</td>
</tr>
</tbody>
</table>
Table 6: Percentage Standard Deviations across groups

<table>
<thead>
<tr>
<th></th>
<th>Repelling States</th>
<th>Hybrid States</th>
<th>Magnet States</th>
<th>All States</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \sigma_Y )</td>
<td>1.84</td>
<td>1.70</td>
<td>2.19</td>
<td>1.99</td>
</tr>
<tr>
<td>( \sigma_N^Y )</td>
<td>0.63</td>
<td>0.62</td>
<td>0.56</td>
<td>0.60</td>
</tr>
<tr>
<td>( \sigma_A^Y )</td>
<td>0.79</td>
<td>0.81</td>
<td>0.77</td>
<td>0.79</td>
</tr>
<tr>
<td>( \sigma_{NET}^Y )</td>
<td>4.57</td>
<td>4.31</td>
<td>3.92</td>
<td>4.04</td>
</tr>
</tbody>
</table>

Average standard deviations are computed as a simple average over standard deviations for all states within a given group.

Table 7: Unconditional correlations across groups

<table>
<thead>
<tr>
<th></th>
<th>Repelling States</th>
<th>Employment</th>
<th>Productivity</th>
<th>Net Flows</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSP</td>
<td>0.6126</td>
<td>0.7733</td>
<td>0.2119</td>
<td></td>
</tr>
<tr>
<td>Employment</td>
<td></td>
<td>0.0019</td>
<td>0.3885</td>
<td></td>
</tr>
<tr>
<td>Productivity</td>
<td></td>
<td></td>
<td>0.0422</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Hybrid States</th>
<th>Employment</th>
<th>Productivity</th>
<th>Net Flows</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSP</td>
<td>0.5843</td>
<td>0.7817</td>
<td>0.2491</td>
<td></td>
</tr>
<tr>
<td>Employment</td>
<td></td>
<td>-0.0235</td>
<td>0.3761</td>
<td></td>
</tr>
<tr>
<td>Productivity</td>
<td></td>
<td></td>
<td>0.0230</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Magnet States</th>
<th>Employment</th>
<th>Productivity</th>
<th>Net Flows</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSP</td>
<td>0.6497</td>
<td>0.8266</td>
<td>0.2737</td>
<td></td>
</tr>
<tr>
<td>Employment</td>
<td></td>
<td>0.1389</td>
<td>0.4297</td>
<td></td>
</tr>
<tr>
<td>Productivity</td>
<td></td>
<td></td>
<td>0.0483</td>
<td></td>
</tr>
</tbody>
</table>

Average correlations are computed as a simple average over correlations for all states belonging to a given group. All correlations are significant at the 5% level.
Table 8: Four measures for the most important industries per state

<table>
<thead>
<tr>
<th>Measure</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Annual average employment per industry and state to total GDP in the same state, relative to aggregate annual average employment per industry (over all states) to US GDP</td>
</tr>
<tr>
<td>2</td>
<td>Annual average number of establishments per industry and state to total GDP in the same state, relative to aggregate annual average number of establishments per industry (over all states) to US GDP</td>
</tr>
<tr>
<td>3</td>
<td>Gross Operating Surpluses per industry and state relative to aggregate US Gross Operating Surpluses in the same industry</td>
</tr>
<tr>
<td>4</td>
<td>Compensation of Employees per industry and state relative to aggregate US compensation of employees per industry</td>
</tr>
</tbody>
</table>

Table 9: Median Price Duration (in months) per industry (according to 2007 NAICS classification)

<table>
<thead>
<tr>
<th>Industry (according to 2007 NAICS classification)</th>
<th>Median Price duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mining, Quarrying, Oil- and Gas Extraction</td>
<td>0.60</td>
</tr>
<tr>
<td>Utilities</td>
<td>1.83</td>
</tr>
<tr>
<td>Real Estate and Rental Leasing</td>
<td>1.97</td>
</tr>
<tr>
<td>Administrative-, Support-, Waste Management, Remediation Services</td>
<td>2.11</td>
</tr>
<tr>
<td>Management of Companies and Enterprises</td>
<td>2.01</td>
</tr>
<tr>
<td>Agriculture, Forestry, Fishing, Hunting</td>
<td>2.34</td>
</tr>
<tr>
<td>Wholesale Trade</td>
<td>2.68</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>3.57</td>
</tr>
<tr>
<td>Information</td>
<td>4.06</td>
</tr>
<tr>
<td>Transportation and Warehousing</td>
<td>8.19</td>
</tr>
<tr>
<td>Other Services</td>
<td>12.31</td>
</tr>
<tr>
<td>Finance and Insurance</td>
<td>13.25</td>
</tr>
<tr>
<td>Health Care and Social Assistance</td>
<td>15.25</td>
</tr>
<tr>
<td>Accommodation and Food Services</td>
<td>15.48</td>
</tr>
<tr>
<td>Educational Services</td>
<td>16.15</td>
</tr>
<tr>
<td>Arts, Entertainment, and Recreation</td>
<td>16.20</td>
</tr>
<tr>
<td>Construction</td>
<td>16.43</td>
</tr>
<tr>
<td>Professional-, Scientific-, and Technical Services</td>
<td>20.49</td>
</tr>
<tr>
<td>Retail Trade</td>
<td>22.38</td>
</tr>
</tbody>
</table>

Table 10: Price duration across state-pairs according to the four measures for the relative importance of a given industry in a given state

<table>
<thead>
<tr>
<th>Measure</th>
<th>Repelling States</th>
<th>Magnet States</th>
<th>Hybrid States</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Both (clearly) sticky</td>
<td>Other</td>
<td>Both (clearly) flexible</td>
</tr>
<tr>
<td>1</td>
<td>60.47</td>
<td>39.53</td>
<td>71.43</td>
</tr>
<tr>
<td>2</td>
<td>75.56</td>
<td>24.44</td>
<td>85.71</td>
</tr>
<tr>
<td>3</td>
<td>63.04</td>
<td>36.96</td>
<td>75.68</td>
</tr>
<tr>
<td>4</td>
<td>71.43</td>
<td>28.57</td>
<td>61.54</td>
</tr>
</tbody>
</table>
Table 11: Parameter Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mnemonic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utility Cost of working abroad</td>
<td>$\alpha_1$</td>
<td>0.107</td>
</tr>
<tr>
<td>Elasticity of Substitution Labor Supply ($N_{it}^a$ vs. $N_{it}^u$)</td>
<td>$\nu_1$</td>
<td>-15</td>
</tr>
<tr>
<td>Home-Bias</td>
<td>$\alpha_2$</td>
<td>0.5</td>
</tr>
<tr>
<td>Elasticity of Substitution Domestic vs. Foreign Goods</td>
<td>$\nu_2$</td>
<td>3</td>
</tr>
<tr>
<td>Relative Productivity Native vs. Foreign Workers</td>
<td>$\alpha_3$</td>
<td>0.5</td>
</tr>
<tr>
<td>Elasticity of Substitution Labor Demand ($N_{it}^H$ vs. $N_{it}^P$)</td>
<td>$\nu_3$</td>
<td>10'000</td>
</tr>
<tr>
<td>Discount Factor</td>
<td>$\beta$</td>
<td>0.99</td>
</tr>
<tr>
<td>Labor Supply Elasticity</td>
<td>$\frac{1}{\varphi}$</td>
<td>$\frac{1}{3}$</td>
</tr>
<tr>
<td>Elasticity of Substitution among varieties</td>
<td>$\varepsilon=\varepsilon_x$</td>
<td>6</td>
</tr>
<tr>
<td>Relative weight Monetary Authority</td>
<td>$\chi$</td>
<td>0.5</td>
</tr>
<tr>
<td>Inflation Reaction Coefficient</td>
<td>$\phi$</td>
<td>1.5</td>
</tr>
<tr>
<td>Persistence Technology Shock</td>
<td>$\rho_a$</td>
<td>0.85</td>
</tr>
<tr>
<td>Degree of Nominal Rigidities (Final Goods Sector)</td>
<td>$\theta^H = \theta^R$</td>
<td>0 (0.75)</td>
</tr>
</tbody>
</table>
B Figures

Figure 1: Estimated impulse response functions for labor productivity, employment, GSP and net labor flows, for the repelling state-pair New York - Florida

Figure 2: Estimated impulse response functions of the augmented SVAR for the repelling state-pair New York - Florida
Figure 3: Estimated impulse response functions for labor productivity, employment, GSP and net labor flows, for the magnet state-pair Ohio - Texas

Figure 4: Estimated impulse response functions of the augmented SVAR for the magnet state-pair Ohio - Texas
Figure 5: Estimated impulse response functions for labor productivity, employment, GSP and net labor flows, for the hybrid state-pair California - Texas

Figure 6: Estimated impulse response functions of the augmented SVAR for the hybrid state-pair California - Texas
Figure 7: 133 state pairs displaying an estimated fall in employment and net labor flows in response to a positive productivity shock (*Repelling States*).

Red dots denote the state where the productivity shock is identified, and black dots denote the respective partner state for a given pair.

Figure 8: 155 state pairs displaying an estimated increase in both employment and net labor flows in response to a positive productivity shock (*Magnet States*).

Green dots denote the state where the productivity shock is identified, and black dots denote the respective partner state for a given pair.
Figure 9: 123 state pairs displaying an estimated fall in employment and an increase in net labor flows in response to a positive productivity shock (*Hybrid States*)

Blue dots denote the state where the productivity shock is identified, and black dots denote the respective partner state for a given pair.
Figure 10: Theoretical impulse response functions to a productivity shock in the intermediate goods sector in the Home economy, assuming high price duration in the intermediate goods sector ($\theta^i_x = \theta^j_x = 0.75$), and perfectly flexible prices in the final goods sector ($\theta^i = \theta^j = 0$).

Figure 11: Theoretical impulse response functions to a productivity shock in the intermediate goods sector in the Home economy, assuming low price duration in the intermediate goods sector ($\theta^i_x = \theta^j_x = 0.3$), and perfectly flexible prices in the final goods sector ($\theta^i = \theta^j = 0$).
Figure 12: Theoretical impulse response functions to a productivity shock in the intermediate goods sector in the Home economy, assuming asymmetric price duration in the intermediate goods sector of the two regions ($\theta^i_x = 0.6$ and $\theta^j_x = 0.3$), and perfectly flexible prices in the final goods sector ($\theta^i = \theta^j = 0$).
Figure 13: Sensitivity of the impact response of net labor flows and employment to the elasticity of substitution between domestic and foreign labor supply, $\nu_1$, between domestic and foreign intermediate goods, $\nu_2$, and between native and migrant workers in intermediate production, $\nu_3$, assuming high price duration in the intermediate goods sector ($\theta^i_x = \theta^j_x = 0.75$), and perfectly flexible prices in the final goods sector ($\theta^i = \theta^j = 0$).
Figure 14: Sensitivity of the impact response of net labor flows and employment to the utility cost of moving, $\alpha_1$, the degree of openness in the intermediate goods sector, $\alpha_2$, and the relative productivity of native versus migrant workers, $\alpha_3$, assuming high price duration in the intermediate goods sector ($\theta^i_x = \theta^j_x = 0.75$), and perfectly flexible prices in the final goods sector ($\theta^i = \theta^j = 0$).
Figure 15: Sensitivity of the impact response of net labor flows and employment to the elasticity of substitution between domestic and foreign labor supply, $\nu_1$, between domestic and foreign intermediate goods, $\nu_2$, and between native and migrant workers in intermediate production, $\nu_3$, assuming low price duration in the intermediate goods sector ($\theta^i_x = \theta^j_x = 0.3$), and perfectly flexible prices in the final goods sector ($\theta^i = \theta^j = 0$).
Figure 16: Sensitivity of the impact response of net labor flows and employment to the utility cost of moving, $\alpha_1$, the degree of openness in the intermediate goods sector, $\alpha_2$, and the relative productivity of native versus migrant workers, $\alpha_3$, assuming low price duration in the intermediate goods sector ($\theta^i_x = \theta^j_x = 0.3$), and perfectly flexible prices in the final goods sector ($\theta^i = \theta^j = 0$)
Figure 17: Theoretical patterns in the impact impulse responses of net labor flows and employment to a technology shock in the intermediate goods sector in the Home economy, for different degrees of price rigidities in the intermediate goods sector of the two regions, and assuming flexible prices in the final goods sector.

Figure 18: Theoretical patterns in the impact impulse responses of net labor flows and employment to a technology shock in the intermediate goods sector in the Home economy, for different degrees of price rigidities in the intermediate goods sector of the two regions, and assuming sticky prices in the final goods sector.
Figure 19: Counterfactual Exercise: Closed Economy with and without labor mobility assuming prices to be perfectly flexible in both sectors and regions.
C Data sources and definitions

C.1 Data used for the VAR-exercise in Section 2

The data set used for the structural VAR estimation consists of US data series for gross state product, employment and net flows for 48 states in the United States at a yearly frequency from 1976-2008. We exclude Alaska, District of Columbia and Hawaii.

**Gross State Product (GSP):** Obtained from Bureau of Economic Analysis (BEA). GDP by state is the value added in production by the labor and capital located in a state, originating in all industries in a state (including all private industries and government). GDP by state is the state counterpart of the nation’s gross domestic product (GDP).

**Employment:** Obtained from Bureau of Economic Analysis (BEA). The BEA employment series for states and local areas comprises estimates of the number of jobs, full-time plus part-time, by place of work. Full-time and part-time jobs are counted at equal weight. Employees, sole proprietors, and active partners are included, but unpaid family workers and volunteers are not included.

**Labor Productivity:** Consistent with Galí (1999) we construct the baseline series for labor productivity for each state by subtracting the log of employment from the log of GDP.

**Net Flows:** Obtained from Internal Revenue Service (IRS), US Population Migration Data. Internal migration data for the United States are based on year-to-year address changes reported on individual income tax returns filed with the IRS. IRS data include records from the domestic tax forms 1040, 1040A and 1040EZ as well as the foreign tax forms 1040NR, 1040PR, 1040VI and 1040SS and contains about 95 to 98 percent of all returns filed during any given tax year, within the mentioned categories. We focus on the data capturing migration patterns by state for the entire United States. Net flows for a given state are defined as the difference between inflows and outflows, where inflows measures the number of individuals who moved to a state and where they migrated from, and outflows the number of individuals leaving a state and where they went.

C.2 Industry-level data used for the empirical exercise in Section 4

**Annual average employment per industry and state:** Obtained from Bureau of Labor Statistics (BLS), Quarterly Census of Employment and Wages. Data is available at a yearly frequency from 2001-2007. The series include reported monthly employment data representing the number of covered workers who worked during, or received pay for, the pay period which included the 12th day of the month. The annual average employment is an average of the monthly employment levels.

**Annual average number of establishments per industry and state:** Obtained from
Bureau of Labor Statistics (BLS), Quarterly Census of Employment and Wages. Data is available at a yearly frequency from 2001-2007. The series include reported number of establishments representing the number of establishments whose activities were reported to the unemployment insurance system for the quarter. An establishment is an economic unit, such as a farm, mine, factory, or store, which produces goods or provides services. It is typically at a single physical location and engaged in one, or predominantly one, type of economic activity for which a single industrial classification may be applied. The annual average number of establishments is an average of the corresponding quarterly number of establishment levels.

*Gross Operating Surpluses per industry and state*: Obtained from Bureau of Economic Analysis (BEA), Regional Economic Accounts. Data is available at a yearly frequency from 1997-2008. The value is derived as a residual after subtracting total intermediate inputs, compensation of employees, and taxes on production and imports less subsidies from total industry output. Gross operating surplus includes consumption of fixed capital, proprietors’ income, corporate profits, and business net current transfer payments. Prior to 2003 this series was referred to as value added or property-type income.

*Compensation of Employees per industry and state*: Obtained from Bureau of Economic Analysis (BEA), Regional Economic Accounts. Data is available at a yearly frequency from 1997-2008. The series includes the sum of employee wages and salaries and supplements to wages and salaries. Wages and salaries are measured on an accrual, or “when earned” basis.

### D Augmented structural VAR

In this section of the appendix we describe in further detail the augmented, five-variable structural VAR. Compared to the structural VAR discussed in section 2, we additionally include employment in state $i$. Therefore, the vector of observables for a given pair of states $i$ and $j$ is defined as

$$Y_t = [\Delta x_{i,t}, \Delta x_{j,t}, \Delta n_{i,t}, \Delta n_{j,t}, \Delta net_{ji,t}]'$$

(D.1)

where all variables are defined as in section 2. The corresponding bilateral structural VAR, written as an $MA(\infty)$ states as

$$\begin{bmatrix}
\Delta x_{i,t} \\
\Delta x_{j,t} \\
\Delta n_{i,t} \\
\Delta n_{j,t} \\
\Delta net_{ji,t}
\end{bmatrix} =
\begin{bmatrix}
C^{11}(L) & C^{12}(L) & C^{13}(L) & C^{14}(L) & C^{15}(L) \\
C^{21}(L) & C^{22}(L) & C^{23}(L) & C^{24}(L) & C^{25}(L) \\
C^{31}(L) & C^{32}(L) & C^{33}(L) & C^{34}(L) & C^{35}(L) \\
C^{41}(L) & C^{42}(L) & C^{43}(L) & C^{44}(L) & C^{45}(L) \\
C^{51}(L) & C^{52}(L) & C^{53}(L) & C^{54}(L) & C^{55}(L)
\end{bmatrix}
\begin{bmatrix}
\varepsilon^1_t \\
\varepsilon^2_t \\
\varepsilon^3_t \\
\varepsilon^4_t \\
\varepsilon^5_t
\end{bmatrix} = C(L)\varepsilon_t$$

Our identification restriction is that the structural shocks $\varepsilon^3_t$, $\varepsilon^4_t$, $\varepsilon^5_t$ do not have permanent effects on labor productivity, employment and net flows. This implies
that the matrix of long run multipliers, \( C(1) \), is lower triangular. As in section 2 of the paper, we use these long-run restrictions to identify a technology shock in state \( j, \delta_j^2 \), for each state-pair under consideration. Note, that the results of the augmented SVAR are robust to changing the order of employment in either state, and net labor flows.

### E Optimality of flexible price equilibrium

In the present appendix we study the implications of labor mobility on the efficient allocation and in particular on the employment subsidy implementing the latter. In the economy of both regions \( i \) and \( j \) we have various distortions to be present which yield suboptimality of the equilibrium allocation. The present distortions are three: Market power of firms, terms of trade externality, and nominal rigidities. For the particular case of log-utility and unitary elasticity of substitution between domestically produced and imported goods, \( \nu_2 = 1 \), we can derive analytically the employment subsidy that exactly offsets the combined effects of market power and the terms of trade distortions, and thus rendering the flexible price equilibrium allocation optimal. As we are showing in this appendix, the employment subsidy is not affected by the presence of labor mobility such that it takes the same form as in a standard two country model with a fixed labor force.

#### E.1 Efficient allocation

The social planner in the two sector economy maximizes a weighted average of the utility function in both countries subject to the technological constraints in both sectors, (3.13) and (3.24), and the market clearing conditions for both intermediate and final goods, (3.33) and (3.35). The first order conditions under the assumption of equal weight given to welfare in both countries are defined by

\[
N_{ii}^t = \gamma_1 \left( \frac{L_i^t}{N_i^t} \right)^{\gamma_2} \gamma_3
\]  
(E.1)

where

\[
\gamma_1 \equiv \left( \frac{1 - \alpha_3}{\nu_3} \right)^{\frac{\nu_1 \nu_3}{\nu_1 - \nu_3}}, \quad \gamma_2 \equiv \frac{\nu_1 (1 - \nu_3)}{\nu_1 - \nu_3}, \quad \gamma_3 \equiv \left( \varphi + \frac{1}{\nu_1} \right) \left( \frac{\nu_1 \nu_3}{\nu_1 - \nu_3} \right).
\]

Equation E.1 defines the optimal amount of domestic labor in region \( i \) as a function of aggregate domestic labor input, \( L_i^t \), and aggregate domestic labor supply, \( N_i^t \).

\[
N_{ji}^t = \gamma_4 \left( \frac{L_i^t}{N_i^t} \right)^{\gamma_2} \gamma_3
\]  
(E.2)

with

\[
\gamma_4 \equiv \left( \frac{\alpha_3}{\alpha_1} \right)^{\frac{\nu_1 \nu_3}{\nu_1 - \nu_3}} \left( \frac{\nu_1 \nu_3}{\nu_1 - \nu_3} \right)
\]

defines the optimal amount of migrant labor used in production in region \( i \), as a function of aggregate domestic labor input, \( L_i^t \), and
aggregate labor supply in the foreign region $j$.

\[
\frac{X_{ii}^j}{X_{jj}^j} = \frac{1 - \alpha_2}{\alpha_2}
\]  

(E.3)

defines the optimal amount of domestically produced vs. imported intermediate goods in production of final goods in region $i$.

**E.2 Decentralization of the efficient allocation in the intermediate sector**

We know that the flexible price equilibrium satisfies

\[
\frac{\varepsilon_x - 1}{\varepsilon_x} = RMC_{x,t}^i
\]  

(E.4)

Using (3.19) together with (3.7), (3.8), (3.13) and (3.34) we can rewrite (E.4) as follows:

\[
\frac{\varepsilon_x - 1}{\varepsilon_x} = (1 - \tau_x^i) \left( L_i^i \right)^{\frac{\nu_3 - 1}{\nu_3}} \left[ \gamma_5 \left( N_{ii}^i \right)^{\nu_1 + \frac{1}{\nu_1}} \left( N_{ij}^i \right)^{\frac{1}{\nu_1} - \frac{1}{\nu_1}} + \gamma_6 \left( N_{ji}^j \right)^{\nu_1 + \frac{1}{\nu_1}} \left( N_{jj}^j \right)^{\frac{1}{\nu_1} - \frac{1}{\nu_1}} \right]
\]  

(E.5)

where \( \gamma_5 \equiv \left( \frac{1 - \alpha_1}{\alpha_1} \right)^{\frac{1}{\nu_1}} \) and \( \gamma_6 \equiv \left( \frac{1 - \alpha_3}{\alpha_3} \right)^{\frac{1}{\nu_3 - 1}} \).

Combining the first order conditions of the social planners problem, (E.1) and (E.2) for both regions $i$ and $j$, with the two labor aggregation functions (3.3) and (3.15), and equation (E.5) yields:

\[
\frac{\varepsilon_x - 1}{\varepsilon_x} = (1 - \tau_x^i)
\]  

(E.6)

such that the employment subsidy in the intermediate goods sector, $\tau_x^i$, implementing the optimal allocation under flexible prices is equal to $\frac{1}{\varepsilon_x}$. Allowing for labor mobility in the present setup makes the employment subsidy to be defined as a function of the markup of monopolistic producers as in the standard model with a fixed labor force.

**E.3 Decentralization of the efficient allocation in the final goods sector**

We know that the flexible price equilibrium satisfies

\[
\frac{\varepsilon - 1}{\varepsilon} = RMC_t^i
\]  

(E.7)

Combining (E.7) with (3.7), (3.8), (3.13), (3.24), (3.16), (3.17), (3.33), and (3.35) yields

\[
\frac{\varepsilon - 1}{\varepsilon} = (1 - \tau_x^i) \left( L_i^i \right)^{\frac{\nu_3 - 1}{\nu_3}} \left( N_{ii}^i \right)^{\nu_1 + \frac{1}{\nu_1}} \left( N_{ij}^i \right)^{\frac{1}{\nu_1} - \frac{1}{\nu_1}} \gamma_7
\]  

(E.8)
where \( \gamma_7 \equiv \left( \frac{(1-\alpha_1)^{\frac{1}{\pi_1}}}{(1-\alpha_2)^{\frac{1}{\pi_3}}} \right) \).

Combining (E.8) with the first order conditions of the social planner yields:

\[
\frac{\varepsilon - 1}{\varepsilon} = (1 - \tau^i)
\]  

(E.9)

such that the employment subsidy implementing the efficient allocation is the same as in a standard two-country model with a fixed labor force.