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Abstract

We provide evidence regarding the dynamic behaviour of net labour flows across U.S. 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 per cent of labour flows across U.S. states in the 1976–2008 period. The data suggest heterogeneous responses of both employment and net labour flows across states, conditional on a positive technology shock. We build a two-region dynamic stochastic general equilibrium (DSGE) model with endogenous labour mobility and region-specific shocks to account 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 labour flows across states following a technology shock.

JEL classification: E24, E32, J61
Bank classification: Business fluctuations and cycles; Labour markets

Résumé

Nous analysons le comportement dynamique des flux nets de main-d’œuvre aux États-Unis induit par un choc technologique positif. Dans notre étude, les chocs technologiques désignent des perturbations menant à une hausse à long terme de la productivité relative dans un État, eu égard à un ensemble de 226 paires d’États qui rendent compte de 80 % des flux de main-d’œuvre enregistrés à l’intérieur des frontières américaines de 1976 à 2008. Selon les données utilisées, un choc technologique positif suscite des réactions hétérogènes en ce qui concerne l’emploi et les flux nets de main-d’œuvre interétatiques. Pour refléter cette observation, nous construisons un modèle d’équilibre général dynamique et stochastique à deux régions où la mobilité des travailleurs est endogène et les chocs ont une spécificité régionale. Nous étalonnons ce modèle en tenant pleinement compte des écarts relevés dans les niveaux de rigidité nominale entre États. Nous montrons que le modèle reproduit les divers types de réactions de l’emploi et des flux nets de main-d’œuvre causées par un choc technologique.

Classification JEL : E24, E32, J61
Classification de la Banque : Cycles et fluctuations économiques; Marchés du travail

1 Introduction

Regional labour mobility within a country or labour flows across international borders 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), factor mobility, and in particular labour mobility, is an important adjustment mechanism for region- or country-specific shocks. These asymmetric shocks are understood as economically relevant events that have diverse effects on different countries or different regions within a country. Labour mobility helps to balance the effects of asymmetric shocks in particular when conventional stabilization mechanisms are no longer available; for instance, in a monetary union with many regions and a single currency where monetary policy no longer serves as a stabilizing instrument for regional shocks. Internal mobility within the borders of the United States, as opposed to international labour movements, is very well documented, and the United States is widely known for its mobile labour force. According to the Statistical Abstract of the United States: 2010, over 36 million people migrated internally, changing their state of residence between 2009 and 2010, and over 40 per cent of the U.S. population lived in a state other than their state of birth.

Only recently have some contributions emphasized that migration is not strictly a long-run phenomenon. Rather, it is also relevant if one focuses on higher frequencies, typically between 6 and 34 quarters, which are commonly labelled as business cycle fluctuations. For example, Molloy and Wozniak (2011) document that internal migration rates within the United States are strongly procyclical with respect to both the national and local business cycles. Moreover, Herz and Van Rens (2011) show that allowing for perfect labour mobility would have reduced U.S. unemployment in the Great Recession by only 0.1 percentage point.

Most of the existing evidence is based on the study of unconditional business cycle moments. We investigate the dynamic behaviour of labour mobility, conditional on state-specific labour productivity shocks. The focus on technology shocks is a natural choice, given the attention this particular shock has attracted in the literature. The empirical estimates of labour flows and employment, resulting from a structural vector autoregression (SVAR), lead to two interesting results. First, labour 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 labour mobility: after a technology shock labour flows either increase or decrease, when unconditionally they are always procyclical. Second, the conditional dynamic behaviour of both employment and labour mobility differs across U.S. states.

We build a two-region dynamic stochastic general equilibrium (DSGE) model with endogenous labour mobility to account 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 labour flows across states following a technology shock.

For our SVAR specification we use available data on state-to-state migration in the United States for the 1976–2008 period, 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 that have a permanent effect on the level of productivity in a given state. In particular, we estimate the dynamic behaviour of labour flows between a given pair of U.S. states in response to a shock to labour productivity in one of the two states. The benchmark SVAR includes four endogenous variables: labour productivity in both of a given pair of states; labour input in the state hit by the shock; and net labour 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, leaving technology in the other state unaffected.

The SVAR exercise documents important differences between conditional and unconditional moments, and also indicates essential heterogeneity in conditional moments across U.S. states. We distinguish between three groups of state pairs: (a) repelling states display a fall in both employment and net labour flows in the state where the shock occurs; (b) magnet states display the opposite effect (i.e., an increase in employment and net labour flows in the state hit by the shock); and (c) hybrid states exhibit an increase in net labour flows as well as a decline in employment. We show that state pairs of a given group (repelling, magnet or hybrid states) do not display differences in unconditional business cycle moments, they do not belong to a specific region of the United States, 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 the differing sectoral composition of state economies[1], and in the light of the ample empirical evidence of differences in the frequency of price adjustments across sectors in the U.S. economy[2]. 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 labour mobility. The model predicts that the dynamic behaviour of labour mobility in response to region-specific technology shocks depends crucially on the presence of nominal rigidities. This is essentially because of 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, thus increasing demand for the region's products. This, in turn, induces firms to increase employment, triggering a net inflow of workers. In contrast, when a shock hits a region characterized by sticky prices, the terms of trade and thus the 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 provides additional interesting implications for the relevant literature. We show that relaxing the assumption of a fixed labour force breaks the isomorphism between a closed and an open economy (see Clarida, Galí and Gertler (2002) for a detailed discussion), and gives rise to a direct link between the two economies through

[1]See, for example, Autor, Dorn and Hanson (2013), Bernard and Jones (1996), and U.S. Department of Labor (2011).

[2]See, for example, Blinder et al. (1998), Bils and Klenow (2004), and Nakamura and Steinsson (2008).

the mobile labour force. The spillover effect of the region-specific productivity shock on the other region depends crucially on the direction of the resulting labour flows: when the productivity increase provokes an outflow of workers from the region where the shock occurs, employment in the other region increases, which in turn stimulates production. We refer to this as a positive spillover. A negative spillover explains the opposite situation, i.e., labour flowing into the region hit by the shock and therefore reducing the number of available workers in the other region. In conclusion, labour mobility is an important phenomenon to be taken into account for questions regarding stabilization policies.

This paper relates to several contributions in the field. While most of the empirical macroeconomic literature evaluating the effect of technology shocks focuses on the analysis of aggregate data, some contributions provide evidence of the conditional dynamics of employment at a more disaggregated level, concluding that the contractionary effect of technology shocks is much stronger for firms or industries with stickier prices (e.g., Chang and Hong (2006), Marchetti and Nucci (2005), and Franco and Philippon (2007)). The empirical analysis in this paper, using state-level macro data, confirms this evidence. 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 (1963) and Greenwood (1975), respectively, differences in wages are key in explaining labour mobility. More recently, some theoretical contributions have examined the implications of immigration at business cycle frequencies: Mandelman and Zlate (2012) analyze the business cycle fluctuations of unskilled migration from Mexico to the United States, while Bentolila, Dolado and Jimeno (2008) study the implications of the presence of immigrants on the New Keynesian Phillips curve in Spain. This paper differs from those contributions in two respects: first, a mobile labour force by nature has two ends such that a comprehensive understanding of labour 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 labour flows in both directions. Second, we explicitly study conditional business cycle moments.

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

2 A SVAR with Labour Mobility

In this section we provide empirical evidence of the dynamic effects of state-specific labour productivity shocks on labour mobility across U.S. states, using available annual data on state-to-state migration for the 1976–2008 period. We identify permanent shocks to state-specific technology, falling back on the long-run identification scheme in Galí (1999). Specifically, we estimate the dynamic responses of net labour flows and employment for a given pair of U.S. states after a shock to labour productivity in either of the two states.

2.1 Variable Definitions and Data

The vector of observables for a given pair of states i and j is given by

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

All variables are defined in log differences. Furthermore, and as we will discuss in further detail, state-specific employment and output are defined as logarithmic deviations from the respective aggregate U.S. variable. Consequentially, $\Delta x_{i,t}$ denotes labour productivity in state i at time t relative to aggregate U.S. labour productivity, and $\Delta n_{j,t}$ stands for employment in state j relative to aggregate U.S. employment. $\Delta net_{ji,t}$ captures net labour flows from state i to state j[3]:

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

Our data include 48 states in the United States, excluding Alaska, the District of Columbia and Hawaii. The baseline labour productivity series for each state are constructed by subtracting the log of employment from the log of the gross state product. Data on gross state products and employment are taken from the Bureau of Economic Analysis (BEA). Data on net labour flows across U.S. 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. Net flows for a given state pair are defined as the difference between inflows and outflows. Inflows measure the number of families (including the tax filer, its spouse and all dependants) who moved from a given state i to state j, and outflows the number of families leaving state i for state j. Our data for migration flows provide information about net labour flows for all 1,128 possible state pairs among the 48 states under consideration. We focus on 226 state pairs encompassing up to the 80th percentile of aggregate labour 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 labour-augmenting technology shock, separately in each state, and study its effect on net labour 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. The appropriate definition of state-specific variables is important for the identification of state-specific technology shocks. As suggested in Blanchard et al. (1992), we assume that state-specific variables depend both on a common shock (related to the respective aggregate U.S. variable) and on an idiosyncratic shock. Therefore, labour productivity in a given state i follows

$$\Delta X_{i,t} = \alpha_i + \beta_i \Delta X_{US,t} + v_{i,t}$$

where $\Delta X_{i,t}$ is the log difference of labour productivity in state i at time t (not the log difference of relative labour productivity in state i, which we denoted $\Delta x_{i,t}$ earlier),

[3]Aggregate inflows are equal to aggregate outflows, thus defining net flows for a given state pair relative to aggregate net flows is superfluous. Our results are robust to an alternative specification, defining net flows relative to the corresponding state population.

$\Delta X_{US,t}$ is the log difference of U.S. labour productivity, and $\upsilon_{i,t}$ is an idiosyncratic disturbance term. We use annual data from 1976–2008 for each state under consideration to determine the extent that states differ in their elasticity to common shocks. For most states, we cannot reject that $\beta_i = 1$, such that we use simple log differences as a measure for state-specific variables[4].

2.2 Bilateral SVAR

Following Galí (1999), we identify a labour productivity shock in a given state i, based on the assumption that only this shock can have a permanent effect on the level of labour productivity in i. Consider the following SVAR:

$$A_0 Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + ... + A_p Y_{t-p} + \varepsilon_t \tag{2.2}$$

where Y_t is the vector of observables as defined in (2.1); matrix A_0 captures contemporaneous relationships between the variables; and ε_t is a vector of structural shocks with a diagonal covariance matrix, i.e., $E_t(\varepsilon_t \varepsilon_t') = I$. The structural model (2.2) can be rewritten in a more general form:

$$A(L)Y_t = \varepsilon_t$$

where $A(L) = A_0 - A_1 L^1 - ... - A_p L^p$ 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 $MA(\infty)$:

$$\begin{bmatrix} \Delta x_{i,t} \\ \Delta x_{j,t} \\ \Delta n_{j,t} \\ \Delta net_{ji,t} \end{bmatrix} = \begin{bmatrix} C^{11}(L) & C^{12}(L) & C^{13}(L) & C^{14}(L) \\ C^{21}(L) & C^{22}(L) & C^{23}(L) & C^{24}(L) \\ C^{31}(L) & C^{32}(L) & C^{33}(L) & C^{34}(L) \\ C^{41}(L) & C^{42}(L) & C^{43}(L) & C^{44}(L) \end{bmatrix} \begin{bmatrix} \varepsilon_t^1 \\ \varepsilon_t^2 \\ \varepsilon_t^3 \\ \varepsilon_t^4 \end{bmatrix} = C(L)\varepsilon_t$$

where $\{\varepsilon_t^1\}$ and $\{\varepsilon_t^2\}$ denote, respectively, the sequence of technology shocks in the two states of a given pair[5]. Our identification restriction is that the structural shocks $\{\varepsilon_t^3\}$ and $\{\varepsilon_t^4\}$ do not have permanent effects on labour productivity, employment and net flows, thus the matrix of long-run multipliers, $C(1)$, is lower triangular, i.e., $C^{12}(1) = C^{13}(1) = C^{14}(1) = C^{23}(1) = C^{24}(1) = C^{34}(1) = 0$.[6] For each state pair, we identify the structural shock[7] $\{\varepsilon_t^2\}$ that affects only labour productivity in state

[4]Considering the same regression for employment and the gross state product, we confirm the finding that the elasticity to common shocks in most of the states is not significantly different from one (at the 5 per cent significance level).

[5]Our results are robust to changes in the order of employment and net labour flows.

[6]The specification of our SVAR is based on the assumption that labour productivity is integrated of order one, so that first-differencing is necessary to achieve stationarity. This assumption is motivated by the outcome of standard augmented Dickey Fuller tests that do not reject the null of a unit root in the levels, but reject the same null when applied to the first-differences (at the 5 per cent significance level).

[7]To ensure that we identify the same shock for a given state, independently of the corresponding partner state, we compute the correlation among all labour productivity shocks that we have identified for a given state. For the vast majority of states, the mean correlation over all identified shocks lies between 0.81 and 0.99. The state with the lowest mean correlation (0.61) is Indiana.

j and leaves labour productivity in state i unaffected in the long run. The employed definition of state-specific variables excludes the possibility of these structural shocks being driven by movements related to the aggregate U.S. economy[8].

We impose the long-run identification restrictions in a standard way: First, we define the reduced-form model corresponding to our SVAR. Assuming the matrix of contemporaneous relationships, A_0, to be invertible allows the pre-multiplication of both sides of the SVAR model, (2.2), by A_0^{-1}. Defining $\phi_p = A_0^{-1}A_p$ for for a given lag length p, and establishing the relationship between structural and reduced-form shocks, $A_0^{-1}\varepsilon_t = u_t$, the reduced-form model states

$$Y_t = \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + ... + \phi_p Y_{t-p} + u_t$$

Second, we orthogonalize the reduced-form shocks by Cholesky decomposition, i.e., $\left(A_0^{-1}\right)\left(A_0^{-1}\right)' = E_t(u_t u_t')$. According to the standard information criteria[9], the optimal number of lags, p, is equal to one. We estimate the reduced-form model by ordinary least squares (OLS). The long-run effect of u_t,

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

together with the relation between structural and reduced-form shocks, allows us to recover the matrix of long-run multipliers, on which we impose our identifying assumptions:

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

2.3 Results

Table 1 reports estimates of aggregate correlations between employment, the gross state product (GSP), labour productivity and net labour flows. The estimated unconditional correlations are consistent with the relevant empirical literature. In particular, as emphasized in Molloy and Wozniak (2011), we confirm that internal migration is procyclical. Aggregate conditional moments of employment and labour productivity are consistent with the findings in Galí (1999): the conditional correlation between labour productivity and employment is large and negative[10]. Interestingly, technology

[8] We test for cointegration of labour productivity in states i and j for all state pairs under consideration. We use both the Johansen Test and the Engle-Granger test. Out of 226 state pairs, 3 are tested positively for cointegration of $x_{i,t}$ and $x_{j,t}$ using the Johansens' Test; 2 out of 226 state pairs are tested positively for cointegration of $x_{i,t}$ and $x_{j,t}$ using the Engler-Granger test. Only one state pair displays cointegration of labour productivities for both tests. We thus conclude that generally cointegration between $x_{i,t}$ and $x_{j,t}$ is not an issue.

[9] 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.

[10] 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.

shocks induce people to relocate geographically in a way that is different from unconditional moments of labour mobility. In particular, aggregate conditional moments reveal that, after a technology shock, aggregate labour flows tend to be lower, whereas unconditionally net flows comove with labour productivity and GSP. Thus, comparing conditional and unconditional moments yields the exact opposite picture of labour flows, which provides an additional motive for studying unconditional moments.

To assess the role of the identified technology shocks in state-specific fluctuations, we perform a variance decomposition. Figure 1 (a) reports the percentage of forecast error variance due to technology shocks over all state pairs, at horizons of 1 to 10 years. Roughly 60 per cent of the one-step-ahead forecast error variance in GSP is accounted for by state-specific technology shocks. In contrast, these shocks account for a much smaller percentage of the one-step-ahead forecast error variance in employment and net labour flows (15 and 10 per cent, respectively).

Even though the presented evidence apparently provides a uniform picture for aggregate conditional moments across U.S. 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 behaviour of both net flows and employment in the state hit by a positive technology shock[11]:

- Repelling states: negative impact reaction of net flows and employment
- Magnet states: positive impact reaction of net flows and employment
- Hybrid states: positive impact reaction of net flows, negative impact reaction of employment

In what follows, we analyze the impact responses of employment and net flows for each of the three identified patterns, exemplified through the respective state pair capturing the biggest fraction in total state-to-state moves during the 1976–2008 period.

2.3.1 Repelling States

For 133 state pairs representing 34 per cent of total moves across all 48 states between 1976 and 2008, we estimate a negative impact reaction of both net flows and employment in the state hit by the productivity shock. The impulse response functions to the identified labour productivity shock for the state pair Florida and New York are illustrated in Figure 2 (a). In response to a positive technology shock in New York, labour productivity increases by 1.2 per cent, eventually stabilizing at a level somewhat higher than before the shock. GSP also experiences a permanent increase, with the initial increase of 1.1 per cent to be more gradual than that of productivity. The gap between the initial increase in labour productivity and the smaller increase in GSP is reflected in a significant fall in employment (-0.1 per cent on impact). The fall in employment in New York coincides with a significant fall in net flows between Florida

[11]The focus on all state pairs within the 80th percentile of aggregate state-to-state labour flows does not affect 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 labour flows, remains unaffected when expanding 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 labour flows in the United States between 1976 and 2008.

and New York of 4.36 per cent on impact. The technology shock in New York thus implies a fall of 4.36 per cent in the ratio of inflows to outflows from New York to Florida, which can be interpreted as a fall in inflows and/or an increase in outflows. The productivity shock in New York repels workers from the labour market in New York such that inflows from Florida decrease and/or outflows to Florida increase.

2.3.2 Magnet States

The second pattern we observe is an estimated positive impact reaction of both net flows and employment in the state where we identify the shock. These dynamics are observed in 155 state pairs capturing 15 per cent of total state-to-state moves. Figure 2 (b) displays the estimated impulse response functions for the state pair Texas and Ohio. In response to a positive technology shock, labour productivity in Ohio increases by 1.65 per cent on impact. GSP also increases, with the impact response of 1.84 per cent to be slightly more persistent than the one of labour productivity. The difference between the two impact responses is the result of an increase in employment of 0.19 per cent on impact. In addition to the persistent increase in employment in Ohio, net flows from Texas increase by 3.24 per cent on impact. After the productivity shock, the labour market in Ohio becomes relatively more attractive such that inflows from Texas increase and/or outflows to Texas decline.

2.3.3 Hybrid States

Finally, we identify a third pattern where the dynamic reactions of employment and labour flows go in opposite directions. For 123 state pairs encompassing 26 per cent of total state-to-state moves between 1976 and 2008, we estimate an increase in net labour flows and a fall in employment in the state experiencing a productivity shock[12]. Figure 2 (c) displays the estimated impulse responses for the state pair Texas and California. After a positive technology shock in California, labour productivity increases by 0.68 per cent on impact. GSP increases by slightly less, 0.51 per cent on impact. The difference between the two impact responses is the result of a fall in employment by -0.17 per cent on impact. Despite the significant fall in employment, the productivity shock attracts more workers, such that inflows from Texas rise and/or outflows to Texas decrease.

2.4 Regional and Structural Differences

One explanation that naturally lends itself to account for the observed heterogeneity in labour flows is that regional or structural differences cause economies of given states to behave differently along the business cycle. When comparing (unconditional) business

[12]For the remaining 41 state pairs, representing less than 5 per cent of aggregate labour 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, none out of the 41 state pairs displays significant impact reactions of both employment and net flows. This fourth group can therefore be considered negligible both quantitatively and qualitatively. We abstract from it for the rest of the paper.

cycle moments across the three groups (repelling, magnet and hybrid states), we do not find any significant differences. Table 2 shows that the three groups are not characterized by differences in volatilities. As shown in the results presented in Table 3, all three groups are characterized by a positive correlation between employment and net labour flows (ranging from 0.38 to 0.43), between employment and GSP (ranging from 0.58 to 0.65) and between GSP and net labour flows (ranging from 0.21 to 0.27). 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 labour input and productivity is small, but slightly positive. These values are in line with the near-zero correlation found in the literature. Finally, we do not find significant differences in terms of the variance decomposition across the three groups (see Figures 1 (b)–(d)). Overall, we conclude that differences in business cycle moments do not explain the observed heterogeneity in the dynamics after a state-specific labour-augmenting productivity shock.

Regardless of structural differences, one might think of the geographical location of the states in a given pair as a possible explanation for the documented differences in the dynamics. Figures 3 (a)–(c) provide a graphical summary of all state pairs per group. This simple graphical exercise illustrates that states belonging to each of the three groups are spread across the entire United States, allowing geographical differences to be ruled out as an explanation for the observed heterogeneity in the dynamics after a technology shock. Moreover, we consider the proposed classification of states in Blanchard et al. (1992) to further analyze the possibility that regional trends are the cause of the observed heterogeneity. In particular, we consider the following clusters of states: 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. Other than that, for all other state clusters under consideration, we do not find any concentration in any of the three groups.

Finally, distance plays an important role in migration decisions and is usually referred to as a serious deterrent to migration. To rule out different groups reflecting differences in the distance between origin and destination state, we consider the share of state pairs within each group that are neighbour states. We find that this share is remarkably similar across the three groups: 29 per cent of the state pairs classified as repelling states are neighbour states, and for magnet and hybrid states, this share is 25 per cent and 28 per cent, respectively.

2.5 Price Duration of States

From Galí (1999) we learn that nominal rigidities are crucial in explaining the responses of labour input after a positive technology shock. For our state-level analysis, two additional facts may play an important role. First, there is ample evidence that the frequency of price adjustments differs substantially across industries in the U.S.

economy[13]. And second, different states rely more or less on different industries[14]. Combining these two facts leads to the assertion that the aggregate degree of nominal rigidities possibly differs across U.S. states. We empirically explore these two dimensions, the differences in average price duration per industry and the different sectoral compositions across state economies, and show that states classified as repelling (magnet) form part of a pair in which both states are characterized by rather high (low) price duration, and that hybrid states belong to pairs exhibiting asymmetries in the degree of price stickiness.

Ideally, we would use data on labour mobility across states at the industry level. Since such data are not available, we are missing information about the relative contribution of a given industry to total labour flows into and out of a given state. Our working assumption is that labour flows across a given pair of states are proportional to the importance of a given industry in a given state, i.e., more important industries amount to bigger labour flows. 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 2007 North American Industry Classification System (NAICS). Table 4 provides a detailed description of all four measures. For each of the four measures, we consider all industries up to the 75th percentile 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 within the 75th percentile of all industries in a given state, i.e., the most employee-intensive industries in each state. Our assumption thus implies that labour flows take place predominantly across industries that are relatively more employee-intensive than others[15].

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 1998–2005 period. We match the roughly 270 product categories to one or several of a total 19 industries, according to the 2007 NAICS[16]. We use the weight of a given product category in the CPI basket to compute the median price duration for a given industry. Table 5 provides a summary for the computed price durations over all industries, which range from 0.6 months for Mining up to 22.4 months for Retail Trade[17].

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[13]See, for example, Blinder et al. (1998), Bils and Klenow (2004), and Nakamura and Steinsson (2008).

[14]See, for example, Autor, Dorn and Hanson (2013), Bernard and Jones (1996), and U.S. Department of Labor (2011).

[15]One possible alternative way of defining the most important industries is by considering volatilities rather than averages. For example, instead of using the ratio of annual average employment per industry and state, and total GSP in the same state (Measure 1 in Table 4), we consider the standard deviation of the latter. Overall, when using volatilites of our four measures for the most important industries, the results are not affected qualitatively.

[16]For example, according to the 2007 NAICS, the product category "potatoes" appears in both the Agriculture, Forestry, Fishing and Hunting, and Manufacturing industries, thus the median price duration of potatoes is taken into account for both industries.

[17]Chang and Hong (2006) do a similar exercise with data for the Manufacturing industry only. They use data from Bils and Klenow (2004), whereas we base our calculations on data from Nakamura and Steinsson (2008). Nevertheless, Chang and Hong (2006) find an aggregate price duration for the aggregate

For each state, we then match the industry composition with the corresponding price durations in order to have a measure for the aggregate nominal price rigidities at the state level. 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.

Given the aggregate price duration for each state, we define the average price duration over all states and use it as a threshold price duration in order to classify states as either sticky or flexible[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). We then distinguish between state pairs where both states are defined as sticky, state pairs with both states classified as flexible, and asymmetric state pairs composed of one flexible and one sticky state. As shown in Table 6, there is a strong relation between the documented differences in dynamics across the three groups, and both the level of nominal price rigidities of both states and the relative price rigidity across the states of a given pair. For all four measures, between 60 and 75 per cent of repelling states belong to a pair in which both states are classified as sticky. The remaining 25 to 40 per cent are either state pairs in which both states are flexible or state pairs exhibiting asymmetries in price duration. For magnet states, we find that, according to the measure defining the most important industries, between 61 and 85 per cent of states belong to pairs where both states are defined as flexible. Finally, 69 to 83 per cent of all hybrid states belong to pairs composed of two states characterized by different price durations.

The respective state pairs with the biggest fraction in aggregate labour flows, analyzed in Section 2.3, are classified accordingly, for all four measures used to define the most important industries. The state pair Florida and New York is classified as sticky, Ohio and Texas are a flexible state pair, and our example state pair for asymmetries in price rigidities consists of California, which is classified as sticky, and Texas, which is flexible according to the data. Moreover, as noted in Section 2.4, all farm states are classified as magnet states. This observation is consistent with our computations finding that the median price duration for the industry Agriculture, Forestry, Fishing and Hunting is 2.34 months, which lies at the lower bound of all 19 industries under consideration. We therefore conclude that the observed heterogeneity in the dynamics of employment and net labour flows after a technology shock are consistent with the observed differences in the aggregate state-level price duration.

The insights we gain from the SVAR exercise lead to two conclusions. First, labour 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 labour mobility. Second, the conditional dynamic behaviour of net labour flows and employment differs across U.S. states in a way that can be explained with differences in nominal price rigidities. In the following section, we build a two-region model with endogenous labour mobility. We calibrate the model econ-

manufacturing industry of 3.4 months, which is very close to the 3.57 months resulting from our computations.

[18] 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 GSP of a given state.

omy consistently with the observed differences in the degree of nominal rigidities, and thereby replicate the three patterns of conditional responses in employment and labour flows across states.

3 A Two-Region Model with Labour Mobility

In this section we build a theoretical model consistent with the empirical evidence provided in Section 2. The framework is a variant of the dynamic two-country New Keynesian Model in Clarida, Galí and Gertler (2002), augmented with endogenous labour mobility. The model consists of two symmetric regions or states, Home and Foreign, that belong to a monetary union. The representative household in each of the two regions consists of a continuum $[0, 1]$ of family members. Each member supplies labour in either the domestic or the foreign labour market, with the respective fractions of family members to be decided at the household level. Working in the domestic or the foreign labour markets is assumed to entail different utility costs. Together with labour supply decisions, consumption and savings are defined at the household level. Wages and returns from savings are pulled together and redistributed equally among members so that they all enjoy an identical level of consumption[19].

Domestic production takes place in two stages: First, there is a continuum of intermediate firms, each producing a differentiated good that is sold to final goods producers. Intermediate firms employ native and migrant workers as sole production factors. Final goods producers then assemble domestically produced and imported intermediate goods into a non-traded final good, which they sell to households. Intermediate goods producers are monopolistic competitors who each produce a differentiated product and set nominal prices in a staggered fashion, as in in Calvo (1983). Final goods producers are perfectly competitive[20].

3.1 Households

In each region $i \in [H, F]$ there is a household consisting of a unit mass of infinitely lived family members, who obtain utility from consuming the final consumption good and disutility from supplying hours of labour in either of the two labour markets. Households choose aggregate consumption, savings and relative labour supply in both labour markets in order to maximize the expected lifetime utility:

$$U_o^i = E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{(C_t^i)^{1-\sigma}}{1-\sigma} - \frac{\left(N_t^i\right)^{1+\varphi}}{1+\varphi} \right] \tag{3.1}$$

[19]See Andolfatto (1996) and Merz (1995) for general references, and Binyamini and Razin (2008) for an example of an application of the big household assumption in a framework with labour mobility.

[20]Assuming that the two sectors display nominal price rigidities does not affect our results. In particular, the dynamic behaviour of net labour flows and employment is not affected qualitatively when prices in the final goods sector are assumed to be sticky.

where C_t^i, N_t^i denote consumption and hours worked, respectively[21], E_0 stands for the rational expectations operator using information up to time $t = 0$, and $\beta \in [0, 1)$ is the discount factor. The consumption good, produced by a perfectly competitive final goods producer, is a composite of domestic and foreign goods:

$$C_t^i = \left[(1 - \alpha_2)^{\frac{1}{\nu_2}} (C_{H,t}^i)^{\frac{\nu_2 - 1}{\nu_2}} + (\alpha_2)^{\frac{1}{\nu_2}} (C_{F,t}^i)^{\frac{\nu_2 - 1}{\nu_2}} \right]^{\frac{\nu_2}{\nu_2 - 1}}$$

$P_t^i = \left[(1 - \alpha_2)(P_{H,t}^i)^{1-\nu_2} + \alpha_2 (P_{F,t}^i)^{1-\nu_2} \right]^{\frac{1}{1-\nu_2}}$ denotes the corresponding consumer price index (CPI), expressed in units of the single currency, and $C_{H,t}^i$ and $C_{F,t}^i$ are given by the constant elasticity of substitution function:

$$C_{s,t}^i = \left[\int_0^1 C_{s,t}^i (k)^{\frac{\varepsilon - 1}{\varepsilon}} \, dk \right]^{\frac{\varepsilon}{\varepsilon - 1}}$$

where $s \in [H, F]$, and $k \in [0, 1]$ denotes the variety of intermediate goods. $\varepsilon > 1$ 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 ν_2, and $(1 - \alpha_2)$ measures the home bias in absorption of intermediate goods.

We allow for labour mobility in the sense that some household members offer their labour services to domestic firms, while others are sent to work in the foreign labour market. Aggregate labour supply, as part of the household's utility function, is assumed to be a CES-aggregator of family members' labour supply in the domestic and foreign labour markets, defined as N_t^{ii} and N_t^{ij}, respectively:

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

where $j \neq i$, $j \in [H, F]$, $\nu_1 < 0$ is a measure of the elasticity of substitution between working as a native in the domestic labour market and working as a migrant in the foreign labour market, and α_1 captures differences in the disutility attached to working in the domestic vs. the foreign labour market.

The representative household in region i maximizes equation (3.1), subject to a sequence of budget constraints:

$$P_t^i C_t^i + E_t \left\{ Q_{t,t+1} D_{t+1}^i \right\} \leq D_t^i + W_t^{ii} N_t^{ii} + W_t^{ij} N_t^{ij} + T_t^i$$

for $t = 0, 1, 2, ...$, where $W_t^{ii} N_t^{ii}$ is the nominal labour income of family members working in the domestic labour market, $W_t^{ij} N_t^{ij}$ is the nominal labour income of family

[21]We assume risk and consumption to be pooled among all members of a given household such that consumption is equal across all members (native and migrant workers) of that household. Assuming absence of home bias in the final goods sector and complete international markets implies that consumption is equal across households in both regions, and therefore also equal between native and migrant workers in a given region i.

members working in the foreign labour market and T_t^i contains lump-sum profits accruing from ownership of intermediate goods firms.

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. $E_t\left\{Q_{t,t+1}\right\}R_t^{-1} = 1$, 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.

The first-order necessary conditions for consumption allocation and intertemporal optimization are standard:

$$C_{H,t}^i = (1-\alpha_2)\left(\frac{P_{H,t}^i}{P_t^i}\right)^{-\nu_2} C_t^i \tag{3.2}$$

$$C_{F,t}^i = \alpha_2\left(\frac{P_{F,t}^i}{P_t^i}\right)^{-\nu_2} C_t^i \tag{3.3}$$

$$1 = \beta R_t E_t\left\{\left(\frac{C_t^i}{C_{t+1}^i}\right)^{\sigma}\left(\frac{P_t^i}{P_{t+1}^i}\right)\right\} \tag{3.4}$$

The remaining optimality conditions for the household's problem are the domestic and foreign labour supply conditions, respectively:

$$\frac{W_t^{ii}}{P_t^i} = \left(C_t^i\right)^{\sigma}\left(N_t^i\right)^{\varphi}\left(\frac{N_t^{ii}}{N_t^i}\right)^{-\frac{1}{\nu_1}}(1-\alpha_1)^{\frac{1}{\nu_1}} \tag{3.5}$$

$$\frac{W_t^{ij}}{P_t^i} = \left(C_t^i\right)^{\sigma}\left(N_t^i\right)^{\varphi}\left(\frac{N_t^{ij}}{N_t^i}\right)^{-\frac{1}{\nu_1}}(\alpha_1)^{\frac{1}{\nu_1}} \tag{3.6}$$

Compared with a standard labour supply condition, allowing for labour mobility implies that, for a given aggregate labour supply, households optimally choose the composition of the latter, i.e., how many members to send to work in the domestic and the foreign labour markets. It is useful to write a household's labour supply conditions (3.5) and (3.6) as log-linear deviations from the symmetric steady state:

$$w_t^{ii} - w_t^{ij} = -\frac{1}{\nu_1}\left(n_t^{ii} - n_t^{ij}\right)$$

where lowercase letters denote log deviations from the steady-state value of the respective variable, i.e., $z_t = log(Z_t) - log(Z)$. Labour mobility in our setup affects the intertemporal, but not the intratemporal choices of consumers. Moreover, labour supply in the domestic and foreign labour markets depends on the relative wage and the value of ν_1. Higher values of the elasticity of substitution between working in the domestic vs. the foreign labour market, ν_1, imply that labour supply for both types of workers is more sensitive to changes in relative wages across the two regions.

Combining the Euler conditions of both regions, together with the definition of the relative price of final goods, $Q_t^i \equiv \frac{P_t^j}{P_t^i}$, it follows (after iterating) that

$$C_t^i = \vartheta C_t^j \left(Q_t^i\right)^{\frac{1}{\sigma}}$$

for all t, where ϑ is a constant depending 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 $\vartheta = 1$.

3.2 Firms

We assume that there is a continuum of monopolistically competitive firms, each producing a different variety of the traded intermediate good, indexed by k on the unit interval $[0, 1]$. Each firm has access to the same constant return-to-scale production technology linking labour input and the level of region-specific technology to output:

$$Y_t^i(k) = A_t^i L_t^i(k) \tag{3.7}$$

where region-specific productivity denoted by A_t^i follows an AR(1) process:

$$a_t^i = \rho_a a_{t-1}^i + \varepsilon_t^a$$

with $a_t^i = \log(A_t^i)$, $\rho_a \in [0, 1]$ and ε_t^a being white noise[22].

We allow for labour mobility in the production sector as in Ottaviano and Peri (2012). Firms hire both native and migrant workers that are aggregated with a CES-function to total effective labour input for production of variety k:

$$L_t^i(k) = \left[(1-\alpha_3)^{\frac{1}{\nu_3}} \left(N_t^{ii}(k) \right)^{\frac{\nu_3 - 1}{\nu_3}} + (\alpha_3)^{\frac{1}{\nu_3}} \left(N_t^{ji}(k) \right)^{\frac{\nu_3 - 1}{\nu_3}} \right]^{\frac{\nu_3}{\nu_3 - 1}}$$

where α_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.

The first-order conditions for cost minimization that determine intermediate firms' demand for both native and migrant workers are

$$N_t^{ii}(k) = \frac{Y_t^i(k)}{A_t^i} \left\{ (\alpha_3)^{\frac{1}{\nu_3}} \left(\frac{1-\alpha_3}{\alpha_3} \right)^{\frac{1-\nu_3}{\nu_3}} \left(\frac{W_t^{ji}}{W_t^{ii}} \right)^{1-\nu_3} + (1-\alpha_3)^{\frac{1}{\nu_3}} \right\}^{\frac{\nu_3}{1-\nu_3}}$$

$$N_t^{ji}(k) = \frac{Y_t^i(k)}{A_t^i} \left\{ (1-\alpha_3)^{\frac{1}{\nu_3}} \left(\frac{\alpha_3}{1-\alpha_3} \right)^{\frac{1-\nu_3}{\nu_3}} \left(\frac{W_t^{ii}}{W^{ji}} \right)^{1-\nu_3} + (\alpha_3)^{\frac{1}{\nu_3}} \right\}^{\frac{\nu_3}{1-\nu_3}}$$

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

$$w_t^{ii} - w_t^{ji} = -\frac{1}{\nu_3} \left[n_t^{ii}(k) - n_t^{ji}(k) \right]$$

[22]By definition the production technology (3.7) satisfies the identification restrictions of the structural shocks in Section 2, i.e., only changes in A_t^i can have long-run effects on labour productivity in region i. Allowing for cross-state correlation of productivity shocks does not affect the results qualitatively.

The more substitutable the two types of workers are for intermediate producers, the more sensitive labour demand to changes in relative wages.

The real marginal cost of production expressed in terms of the prices of intermediate goods is common across firms:

$$RMC_t^i(k) = (1-\tau^i)\left(\frac{P_t^i}{P_{H,t}^i(k)}\right)\left[\frac{W_t^{ii}}{P_t^i A_t^i}\left(\frac{N_t^{ii}(k)}{(1-\alpha_3)L_t^i(k)}\right)^{\frac{1}{\nu_3}} + \frac{W_t^{ji}}{P_t^i A_t^i}\left(\frac{N_t^{ji}(k)}{\alpha_3 L_t^i(k)}\right)^{\frac{1}{\nu_3}}\right]$$

where $\frac{P_{H,t}^i}{P_t^i}$ denotes the relative price of intermediate to final consumption goods in region i. In log-linear terms,

$$\begin{aligned} rmc_t^i(k) =& \eta_1\left[w_t^{ii} - p_t^i - a_t^i + \frac{1}{\nu_3}\left(n_t^{ii}(k) - l_t^i(k)\right) - (p_{H,t}^i - p_t^i)\right] + \\ & \eta_2\left[w_t^{ji} - p_t^i - a_t^i + \frac{1}{\nu_3}\left(n_t^{ji}(k) - l_t^i(k)\right) - (p_{H,t}^i - p_t^i)\right] \end{aligned} \tag{3.8}$$

where η_1 and η_2 depend on steady-state values and on an employment subsidy neutralizing all distortions present in the intermediate sector, except the one related to nominal rigidities[23].

We suppose that firms set prices in a staggered fashion, as in Calvo (1983). Hence, a measure $(1-\theta^i)$ 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 with a fixed labour force, inflation of domestic prices can be expressed as a function of marginal costs:

$$\pi_{H,t}^i = \beta E_t\left\{\pi_{H,t+1}^i\right\} + \lambda^i rmc_t^i \tag{3.9}$$

where $\lambda^i \equiv \frac{(1-\beta\theta^i)(1-\theta^i)}{\theta^i}$, and $\pi_{H,t} \equiv p_{H,t}^i - p_{H,t-1}^i$.

In the presence of labour mobility, the standard relation linking inflation to firms' real marginal cost of production still holds, with the latter dependent on the wages of both native and migrant workers in the labour market of region i, weighted by the relative share in overall labour input for production of the respective workers. Hence, labour mobility affects domestic inflation through its effect on the marginal cost of production.

Let $\tilde{y}_t^i$ denote the domestic output gap, defined as the deviation of (log) output y_t^i, from its natural level $\bar{y}_t^i$, where the latter is the equilibrium level of output in the absence of nominal rigidities. Combining (3.8) and (3.9) gives rise to the New Keynesian Phillips curve

$$\begin{aligned} \pi_{H,t}^i = \beta E_t\left\{\pi_{H,t+1}^i\right\} + \lambda^i \Bigg\{ & \left(\frac{\nu_3 - 1}{\nu_3}\right)\tilde{y}_t^i + \\ & \eta\left[\left(\varphi + \frac{1}{\nu_1}\right)\left(\tilde{n}_t^i + \tilde{n}_t^j\right) + \gamma\left(\tilde{n}_t^{ii} + \tilde{n}_t^{ji}\right)\right]\Bigg\} \end{aligned}$$

[23]It can be shown that this employment subsidy for the intermediate sector depends on the markup of intermediate goods producers, as in a standard setup with a fixed labour force.

where η depends on steady-state values, $\gamma \equiv \left(\frac{\nu_3-\nu_1}{\nu_1\nu_3}\right)$, $\tilde{n}_t^i$ is the labour supply gap in region i and $\tilde{n}_t^{ii}$ the labour input gap of labour supplied by household members from region i employed in production in region i. The Phillips curve of intermediate goods producers in region i depends on gaps related to both labour inputs used in production of intermediate goods, i.e., on gaps linked to labour provided by both native and migrant workers ($\tilde{n}_t^{ii}$ and $\tilde{n}_t^{ji}$, respectively). Total labour used in production of the two types of workers, in turn, depends on the aggregate labour supply of households in both regions i and j ($\tilde{n}_t^i$ and $\tilde{n}_t^j$, respectively). Hence, relaxing the assumption of a fixed labour 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 labour force.

3.3 Market Clearing

The clearing of the market for intermediate good variety k, produced in region i requires

$$Y_t^i(k) = C_{H,t}^i(k) + C_{F,t}^j(k) \tag{3.10}$$

with $C_{H,t}^i(k)$ denoting domestic absorption, and $C_{F,t}^j(k)$ determining exports from region i to region j. Combining (3.10) with the respective demand functions (3.2) and (3.3), together with the law of one price for traded intermediate goods, yields total demand that a given intermediate producer k in region i faces:

$$Y_t^i(k) = \left(\frac{P_{H,t}^i(k)}{P_{H,t}^i}\right)^{-\varepsilon}\left(\frac{P_{H,t}^i}{P_t^i}\right)^{-\nu_2} C_t^i\left\{(1-\alpha_2)+\alpha_2(Q_t^i)^{\nu_2-\frac{1}{\sigma}}\right\}$$

for all $k \in [0,1]$ and all t. Using the previous condition in the definition of region i's aggregate output in the intermediate goods sector, $Y_t^i \equiv \left[\int_0^1 Y_t^i(k)^{\frac{\varepsilon-1}{\varepsilon}}dk\right]^{\frac{\varepsilon}{\varepsilon-1}}$, yields the aggregate intermediate goods market clearing condition for region i:

$$Y_t^i = \left(\frac{P_{H,t}^i}{P_t^i}\right)^{-\nu_2} C_t^i\left\{(1-\alpha_2)+\alpha_2(Q_t^i)^{\nu_2-\frac{1}{\sigma}}\right\} \tag{3.11}$$

Let aggregate labour input be

$$L_t^i = \int_0^1 L_t^i(k)dk$$

Integrating equation (3.7) over all firms k yields

$$Y_t^i = (\Delta_t^i)^{-1}A_t^i L_t^i$$

where Δ_t^i denotes the relative price dispersion, which reads as

$$\Delta_t^i = \int_0^1 \left(\frac{P_{H,t}^i(k)}{P_{H,t}^i}\right)^{-\varepsilon} dk$$

It is well known that $log\left(\Delta_t\right)$ is a second-order term and can thus be neglected when the model is approximated to the first order around the non-stochastic steady state.

Finally, we can combine (3.11) with the household's log-linear Euler equation to derive a standard IS-curve. For the particular case when $\sigma = \nu_2 = 1$,

$$y_t^i = E_t\{y_{t+1}^i\} - \left(r_t - E_t\{\pi_{t+1}^i\}\right) \tag{3.12}$$

Labour mobility in the present setup does therefore not affect the standard form of the IS-curve.

3.4 Monetary Policy

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

$$R_t = \beta^{-1}\left[\chi\pi_{H,t}^{H} + (1-\chi)\,\pi_{H,t}^{F}\right]^{\phi}$$

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

3.5 A Region-Specific Labour Productivity Shock

In this section we analyze the dynamics in the theoretical economies after a region-specific labour productivity shock. We choose parameter values, as defined in Table 7, to mimic the structure of a representative U.S. state pair. The utility cost of working in the foreign labour market, α_1, is chosen in order to match the average steady-state share of migrant workers to total labour input, $\frac{N^{ji}}{L^i}$, which, according to our U.S. state-level data, is 10.7 per cent[24]. The value for the elasticity of substitution between domestic and foreign labour supply, ν_1, is chosen in order to match the average volatility of net flows over all state pairs[25].

The value of the elasticity of substitution between domestically produced and imported goods, ν_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 the lower bound for regional trade, mainly because of the lower trade restrictions for regional trade compared with international trade. Bilgic et al. (2002) provide an overview of the literature on regional trade elasticities and report values between 1.5 and 3.5 for the United States.

[24] Over all 48 states under consideration, this share varies between 2 and 12 per cent. Our results are not sensitive to changes in α_1 within this range.

[25] The percentage standard deviation of net labour flows relative to GSP ranges from 1.62 to 7.70. The average standard deviation across all state pairs under consideration is 4.04. Our results are robust to the corresponding changes in ν_1 within this range.

Morgan, Mutti and Partridge (1989) use U.S. data to estimate an inter-regional trade elasticity of 3. We set $\nu_2 = 3$ and provide extensive sensitivity analysis.

Given our focus on different states in the United States, we choose a calibration for which workers from a given state, say Texas, are equally productive as workers from another state, say California; i.e., we assume native and migrant workers to be equally productive and perfectly substitutable. But our results hold for more general cases, where $\alpha_3 \neq 0.5$ and for $\nu_3 \in [0, 10, 000]$.

The degree of price stickiness and its effect on the dynamics is discussed in detail in what follows. All remaining parameter values are consistent with the values used in the literature. We focus on a symmetric steady state where the share of native and migrant workers in total labour input is equal across regions. Considering a non-symmetric steady state does not alter the results[26].

3.5.1 Symmetric Degrees of Nominal Rigidities

Figure 4 (a) shows the dynamics after a positive productivity shock in the Home economy for a degree of price stickiness implying an average price duration of one year in both regions ($\theta^H = \theta^F = 0.75$). In the region hit by the shock, production increases as a direct consequence of the rise in productivity. The presence of nominal rigidities prevents most of the producers in the Home region to perfectly adjust prices downward, thus they fall back on labour demand as their only alternative margin of adjustment. Consequentially, labour input in Home falls immediately after the shock. The Home producers that are able to adjust prices downward stimulate demand in both regions. Facing a higher demand, Foreign producers would like to adjust prices upward, but only some are able to do so. The remaining firms in Foreign fall back on labour as an alternative margin of adjustment. Consequentially, labour input in Foreign increases immediately after the shock. Observing the fall in labour demand in Home and the increase in labour demand in Foreign, households in both economies optimally send more members to work in the Foreign region. Therefore, workers flow out of the economy where the shock occurs, since it offers less employment.

The sign of the impact responses of employment and net labour flows in the region experiencing the shock crucially depend on the degree of nominal price rigidities. More precisely, the degree of price stickiness determines the net sign of two opposing effects. First, when prices are flexible and therefore falling immediately after the shock, we observe a demand substitution across the two regions, i.e., households in both regions demand relatively more of the relatively cheaper Home goods. This effect is referred to as the expenditure-switching effect. As a direct consequence of the increasing demand for Home goods, firms have an incentive to hire more workers. The

[26] In particular, we consider differences in labour income taxes across the two regions, which gives rise to a non-symmetric steady state with different shares of native and migrant workers across regions. Assuming labour income taxes to be relatively higher in region i leads to a smaller amount of labour used in production of intermediate goods in that region, and thus a strictly smaller steady-state output of final goods. Nevertheless, an asymmetric labour income tax does not have a qualitative impact on the dynamics in response to a technology shock and therefore does not account for the observed heterogeneity in the dynamics documented in Section 2.

expenditure-switching effect therefore induces an upward pressure on employment in Home. Second, as we have discussed above, the impossibility of adjusting prices immediately after the shock induces producers in Home to reduce employment. For a moderate to high degree of nominal rigidities, the downward pressure on employment resulting from price stickiness is more pronounced than the upward pressure caused by the expenditure-switching effect. Therefore, when considering the case of low degrees of nominal rigidities in both regions, we observe the opposite dynamics in terms of employment and net labour flows. Figure 4 (b) displays the dynamics in response to a positive productivity shock in Home for $\theta^H = \theta^F = 0.3$, corresponding to an average price duration of roughly four months. Clearly, in this case, the expenditure-switching effect is stronger, thus employment in Home increases in response to the shock. The relative fall in prices in Home is more pronounced compared with the previous case, thus the increase in demand for and production of goods is bigger. The subsequent increase in employment more than offsets the reduction of the workforce caused by an incomplete adjustment in prices. In Foreign, the decrease in demand resulting from households' expenditure switch toward Home goods induces a fall in production and employment. Households in both economies observe an increase in labour demand in Home and a fall in labour demand in Foreign, and optimally send more members to work in Home. Consequentially, workers flow into the economy where the shock occurs, since it offers more employment.

The dynamics in net labour flows and employment in the economy hit by the technology shock are very robust. Figures 5 (a) and (b) show the impact impulse response functions for net labour flows and employment over a range of reasonable values for all three elasticities of substitution, ν_1, ν_2 and ν_3, for both high and low degrees of nominal rigidities, respectively. First, our results are robust to changes in the elasticity of substitution between domestic and foreign labour supply within the range corresponding to the implied observed volatilities of net flows over all state pairs, i.e., $\nu_1 \in [-20, -1]$.

Second, the value for the elasticity of substitution between domestic and imported goods, ν_2, is positively related to the size of the expenditure-switching effect. For high degrees of nominal price rigidities, the size of the expenditure-switching effect on labour input in Home is always smaller than the effect linked to the presence of nominal rigidities, independently of the value of ν_2. For low degrees of nominal price rigidities and trade elasticities within the range reported in the relevant literature ($\nu_2 \in [1.5, 3.5]$), the opposite case is always true, such that both labour input and net labour flows increase in the region where the shock occurs. Only for very small trade elasticities ($\nu_2 \in [1.0, 1.5]$) is the expenditure-switching effect too small to generate an increase in production and labour input.

Finally, the strong assumptions of perfect substitutability between the two types of workers we have made for our model economy can be relaxed without affecting the dynamics qualitatively. As it becomes clear from Figures 5 (a) and (b), other than on the degree of price rigidities, the qualitative impact response of net flows does not depend on the assumption of perfect substitutability between the two types of workers[27].

[27] Assuming native and migrant workers to be perfect substitutes in production yields equality in their respective wages, i.e., $W_t^{ii} = W_t^{ji}$, which gives rise to two corner solutions: $W_t^{ii} > W_t^{ji}$ with $N_t^{ii} = 0$ and $L_t^i = N_t^{ji}$, and $W_t^{ii} < W_t^{ji}$ with $N_t^{ji} = 0$ and $L_t^i = N_t^{ii}$, respectively. It is easy to show that assuming

Hence, relaxing this assumption still yields a fall in both net flows and employment for high degrees of nominal rigidities, and an increase for low average price durations. Our proposed mechanism therefore also works for two additional cases of interest: the two types of workers being complements ($\nu_3 = 0$) and a Cobb-Douglas aggregation ($\nu_3 = 1$).

Combining the empirical evidence with the theoretical predictions of the model presented suggests that the dynamic behaviour of labour flows in response to a region-specific productivity shock depends primarily on the adjustment of employment in the two regions, which in turn is explained by the degree of nominal rigidities. In particular, according to our economic model, labour flows for repelling state pairs are primarily between regions that display high degrees of nominal rigidities, whereas labour flows between magnet states take place primarily between industries characterized by low price durations. These theoretical predictions are consistent with the empirical evidence presented in Section 2.

3.5.2 Asymmetric Degrees of Nominal Rigidities

In the previous section, one possible extreme view is presented, namely that the degree of price rigidity is the same in both regions. In the alternative setup presented in this section, we analyze the implications of labour flowing between sectors with asymmetric price durations. Figure 4 (c) shows the dynamic effects of a positive technology shock in Home, assuming $\theta^H = 0.75$ and $\theta^F = 0.25$. Goods produced in the region where the shock occurs become relatively cheaper, such that respective demand for Home goods increases in both regions. Production in Home thus rises, but given the inability of most producers to immediately lower prices, we observe an aggregate reduction in employment. The size of the expenditure-switching effect on labour input in Home is therefore smaller than the size of the effect linked to the presence of nominal rigidities. The opposite is true for the labour market in Foreign: Given the relatively short average price duration of four months, the size of the negative effect on employment caused by sticky prices is rather small. At the same time, foreign producers can adjust their prices upward relatively quickly, thus the size of the expenditure-switching effect is relatively big. Consequentially, foreign employment falls in response to a labour productivity shock in the Home economy.

In general, when the two regions are characterized by unequal degrees of nominal rigidities, the inverse symmetry in the net effect on employment is broken. The magnitude of this net effect, as a result of the expenditure-switching effect and the effect linked to the presence of nominal rigidities, therefore differs across the two economies. Whenever the degree of price rigidity is higher in the economy hit by the shock, i.e., $\theta^H > \theta^F$, the fall in foreign employment is strictly bigger than the reduction in labour input in Home. Observing the relative worsening of foreign labour market conditions induces households in both regions to reshuffle workers toward the Home economy. Consequentially, workers flow into the economy where the shock occurs, despite the initial fall in employment, given that the latter suffers a relatively less pronounced

imperfect substitutability of labour supply in the domestic vs. the foreign labour market in the households' problem is sufficient for these two corner solutions to be excluded.

reduction in employment.

To sum up, as in the setup with symmetric nominal rigidities, labour flows to the economy with relatively better labour 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 labour 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.

3.6 Spillover of Region-Specific Shocks

We have previously highlighted the fact that allowing for labour mobility gives rise to an additional transmission channel between the two regions in our model economy. Specifically, the Phillips curve of a given region depends on gaps related to labour market variables in both regions. One additional and interesting way to verify the predictions of our theoretical model is to study the spillover effects of a region-specific labour productivity shock. We consider an alternative SVAR, which allows for the estimation of the spillover effects of the technology shock in a given state j on employment and the GSP in the partner state i. In particular, we augment the benchmark four-variable SVAR in Section 2 with employment in the state that does not experience the shock. The vector of observables for a given pair of states i and j is defined accordingly:[28]

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

where all variables are defined as in Section 2, and the corresponding bilateral SVAR, written as an $MA(\infty)$, is stated as

$$Y_t = C(L)\varepsilon_t$$

with $\varepsilon_t = \left[\varepsilon_t^1, \varepsilon_t^2, \varepsilon_t^3, \varepsilon_t^4, \varepsilon_t^5\right]'$. As for our benchmark SVAR, we fall back on long-run restrictions to identify ε_t^2 for each state pair under consideration. We thus impose that the structural shocks ε_t^3, ε_t^4, ε_t^5 do not have permanent effects on labour productivity, employment and net flows.

According to our model economy, the three groups (repelling, magnet and hybrid states) differ in terms of their implied spillover effect on the labour market of their partner state i. Whenever prices adjust slowly, the expenditure switching effect is rather small, thus production and employment in the partner state expand immediately after the shock. This increase in employment (and consequentially in production) in the partner state i after the region-specific productivity shock in j is referred to as positive spillover. If the predicted dynamics of our theoretical model are correct, we should observe a positive spillover for states that have been classified as repelling. Effectively, for 71 per cent of all state pairs of repelling states, we estimate a positive spillover effect to the partner state's employment and production. In contrast, when

[28] The results of the augmented SVAR are robust to changing the order of employment and net labour flows in either state.

prices adjust rapidly, the spillover effect on region i's economy is negative, owing to an important demand substitution of goods produced in i with goods produced in j. Both production of intermediate goods and employment in region i therefore fall. We should observe these dynamics for both magnet and hybrid states. According to the augmented SVAR, the spillover effect is negative for 72 per cent of all state pairs of magnet states, and for 85 per cent of state pairs of hybrid states. We can therefore conclude that our theoretical model replicates the estimated spillover effects in the data reasonably well.

4 Conclusions

The first part of this paper provides empirical evidence of the dynamic behaviour of labour flows across U.S. states in response to state-specific labour productivity shocks. References to the cyclicality of internal migration have appeared before in the literature, but conditional moments of migration rates, which are important for a thorough understanding of labour mobility as an alternative adjustment mechanism, have not been analyzed. We use data on state-to-state migration in the United States for the 1976–2008 period to identify labour productivity shocks for 226 state pairs representing 80 per cent of aggregate labour flows in the same period. We find no uniform pattern describing the dynamic behaviour of economic variables in response to the technology shock. The crucial difference in the conditional behaviour across state pairs lies in the dynamic responses of both employment and net labour flows. This paper therefore contributes to the literature by investigating whether the finding that technology shocks reduce employment in the short run is robust at a more disaggregated level [29].

In the second part of this paper, we describe a two-region model with endogenous labour mobility consistent with the established empirical evidence. We use this model to show that differences in the degree of nominal price rigidities across the two regions provide an explanation consistent with the observed heterogeneity in the dynamic behaviour of labour flows. We discuss the differences in the dynamics of the model economy with high (low) degrees of nominal rigidities, compared with 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 labour-augmenting productivity shock are less (more) attractive to workers. Namely, labour market conditions become relatively worse (better) in the region hit by the shock, such that labour flows out of (in to) the region where the shock occurs. For states with asymmetric degrees of nominal rigidities labour flows into the state where labour market conditions rebound relatively more quickly.

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

[29]Chang and Hong (2006), Marchetti and Nucci (2005), and Franco and Philippon (2007) are a representative though not exhaustive sample.

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A Tables and Figures

Table 1: **Correlation Estimates: SVAR model**

	unconditional	conditional
Productivity		
Employment	0.0821	-0.4132
Net Flows	0.0258	-0.4115
GSP		
Employment	0.6256	-0.8766
Net Flows	0.2713	-0.2345

Unconditional correlations are computed as a simple average over all 48 states. State-specific correlations are significant at the 5 per cent level for all states under consideration. Conditional correlations are computed as a weighted average over all 452 specifications, where the weight is given by the respective share in aggregate labour flows of a given state pair (but using the simple average gives almost identical results). For 418 out of 452 specifications under consideration, all conditional correlations are significant at the 5 per cent level.

Table 2: **Percentage standard deviations across groups**

	Repelling States	Magnet States	Hybrid States	All States
σ_Y	1.84	2.19	1.70	1.99
$\sigma_{\frac{N}{Y}}$	0.63	0.56	0.62	0.60
$\sigma_{\frac{A}{Y}}$	0.79	0.77	0.81	0.79
$\sigma_{\frac{NET}{Y}}$	4.57	3.92	4.31	4.04

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

Table 3: **Unconditional correlations across groups**

	Repelling States	Magnet States	Hybrid States
Productivity			
Employment	0.0019	0.1389	-0.0235
Net Flows	0.0422	0.0483	0.0230
GSP			
Employment	0.6126	0.6497	0.5843
Net Flows	0.2119	0.2737	0.2491

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 4: **Four Measures for the Most Important Industries in a Given State**

Measure	**Definition**	**Source**
1	Average employment intensity of a given industry k and state i, relative to the average employment intensity of the same industry over all states: $\sum_{t=1}^{n}\left[\frac{\left(\frac{N_{i,k,t}}{Y_{i,k,t}}\right)}{\left(\sum_{i=1}^{48}\frac{N_{i,k,t}}{Y_{i,k,t}}\right)/48}\right]/n$	Data on annual employment per industry and state are obtained from the Bureau of Labor Statistics (BLS) and are available from 2001–2007. The series includes reported monthly employment data representing the number of covered workers who worked during, or received pay for, the pay period that included the 12th day of the month. The annual average employment is an average of the monthly employment levels.
2	Average number of establishments in a given industry k and state i, relative to the average number of establishments in the same industry over all states: $\sum_{t=1}^{n}\left[\frac{\left(\frac{EST_{i,k,t}}{Y_{i,k,t}}\right)}{\left(\sum_{i=1}^{48}\frac{EST_{i,k,t}}{Y_{i,k,t}}\right)/48}\right]/n$	Data on the annual number of establishments per industry and state are obtained from the BLS and are available from 2001–2007. The series includes the number of establishments whose activities were reported to the unemployment insurance system. The annual average number of establishments is an average of the corresponding quarterly number of establishment levels.
3	Gross operating surpluses per industry k and state i, relative to gross operating surpluses of the same industry over all states: $\sum_{t=1}^{n}\left[\frac{OS_{i,k,t}}{\left(\sum_{i=1}^{48}OS_{i,k,t}\right)/48}\right]/n$	Data for gross operating surpluses per industry and state are obtained from the Bureau of Economic Analysis (BEA) and are available 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.
4	Compensation of employees per industry k and state i, relative to the compensation paid to employees in the same industry over all states: $\sum_{t=1}^{n}\left[\frac{W_{i,k,t}}{\left(\sum_{i=1}^{48}W_{i,k,t}\right)/48}\right]/n$	Data on compensation of employees per industry and state are obtained from the BEA and are available from 1997–2008. The series includes the sum of employee wages and salaries as well as supplements to wages and salaries.

Table 5: **Median Price Duration (in Months) per Industry**

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

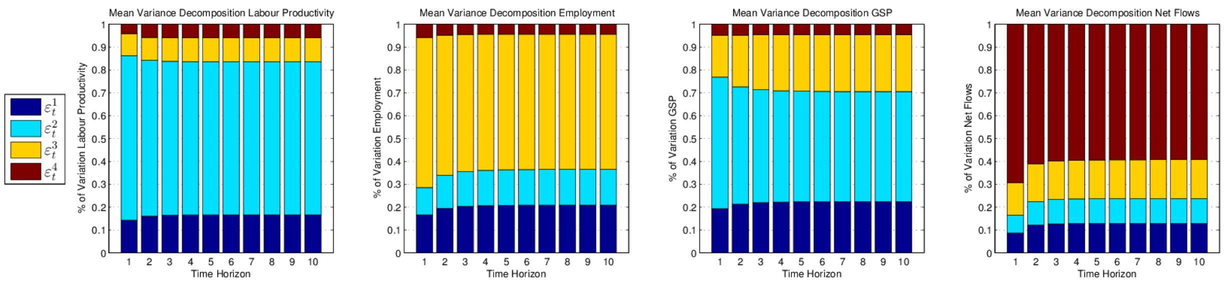
Table 6: **Price Duration Across State Pairs**

	Repelling States		Magnet States		Hybrid States	
Measure	Both Sticky	Other	Both Flexible	Other	Asymmetric	Other
1	60.47	39.53	71.43	28.57	63.38	36.62
2	75.56	24.44	85.71	14.29	73.24	26.76
3	63.04	36.96	75.68	24.32	69.01	30.99
4	71.43	28.57	61.54	38.46	84.51	15.49

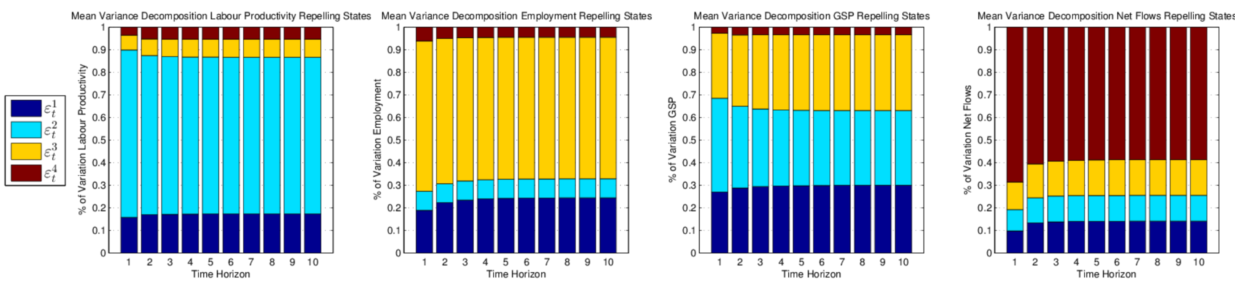
Table 7: **Parameter Values**

Parameter	**Mnemonic**	**Value**
Utility Cost of Working Abroad	α_1	0.107
Elasticity of Substitution Labour Supply (N_t^{ii} vs. N_t^{ij})	ν_1	-15
Home-Bias	α_2	0.5
Elasticity of Substitution Domestic vs. Foreign Goods	ν_2	3
Relative Productivity, Native vs. Foreign Workers	α_3	0.5
Elasticity of Substitution Labour Demand (N_t^{ii} vs. N_t^{ji})	ν_3	10,000
Discount Factor	β	0.99
Risk Aversion	σ	1
Labour Supply Elasticity	$\frac{1}{\varphi}$	$\frac{1}{3}$
Elasticity of Substitution Among Varieties	ε	6
Relative Weight Monetary Authority	χ	0.5
Inflation Reaction Coefficient	ϕ	1.5
Persistence Technology Shock	ρ_a	1
Degree of Nominal Rigidities	$\theta^H = \theta^F$	$\in$ [0,0.75]

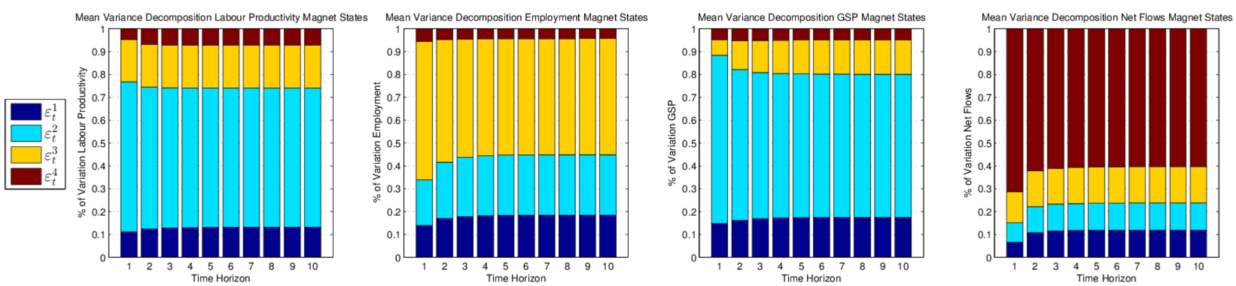
Figure 1: Variance Decomposition



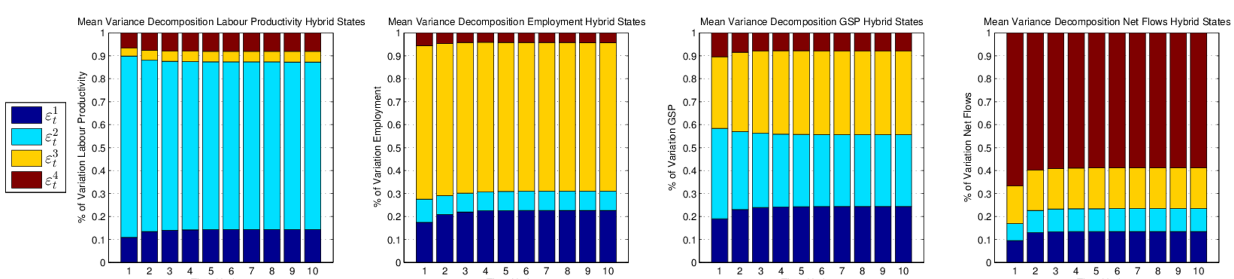
(a) Mean Variance Decomposition over all 452 state pairs



(b) Mean Variance Decomposition over all Repelling States

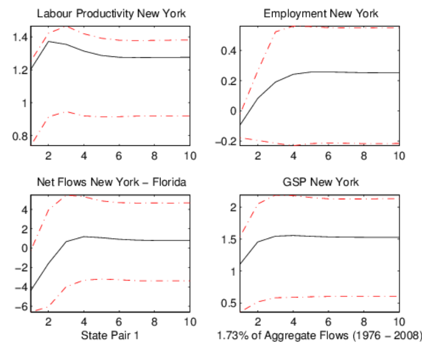


(c) Mean Variance Decomposition over all Magnet States



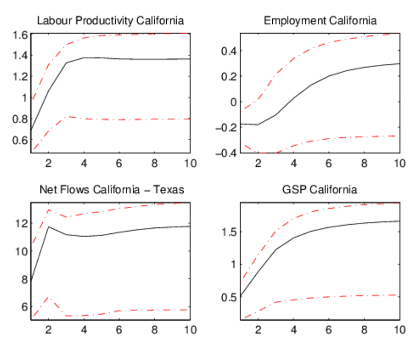
(d) Mean Variance Decomposition over all Hybrid States

Figure 2: Estimated impulse response functions to one standard error increase in labour productivity (relative to aggregate U.S. labour productivity) along with 95% bootstrapped confidence intervals, for a representative state pair from each group



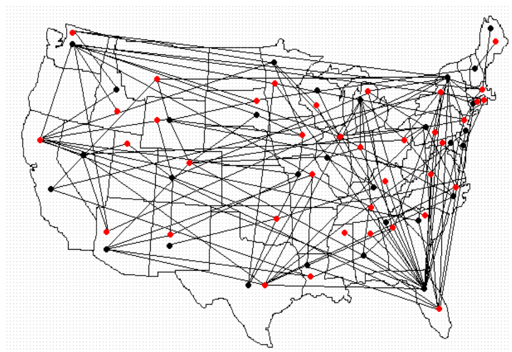
(a) Repelling States

(b) Magnet States

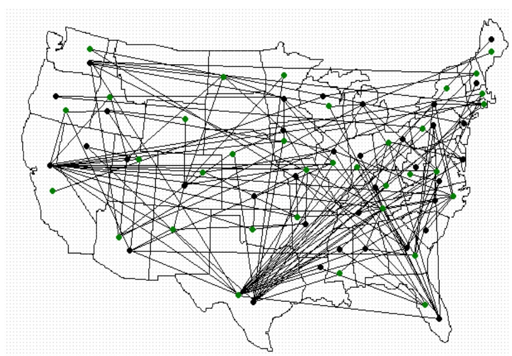


(c) Hybrid States

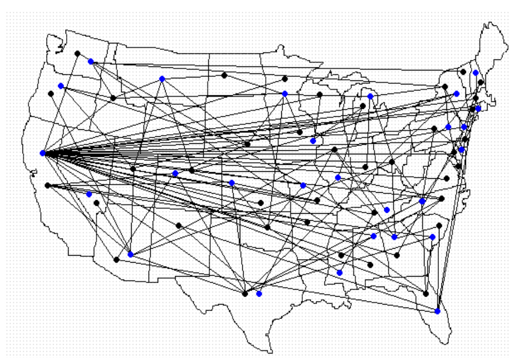
Figure 3: Graphical representation of all state pairs belonging to the three groups. Coloured dots (red, green or blue) represent the state where the productivity shock is identified, and black dots denote the respective partner state for a given pair.



(a) Repelling States



(b) Magnet States

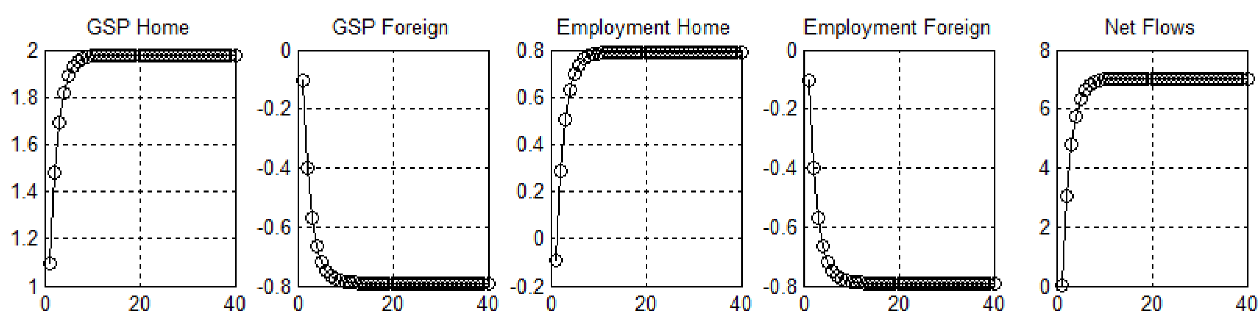


(c) Hybrid States

Figure 4: Theoretical impulse response functions to a permanent, positive productivity shock in the Home economy

(a) Repelling States: High price duration in both regions ($\theta^i = \theta^j = 0.75$)

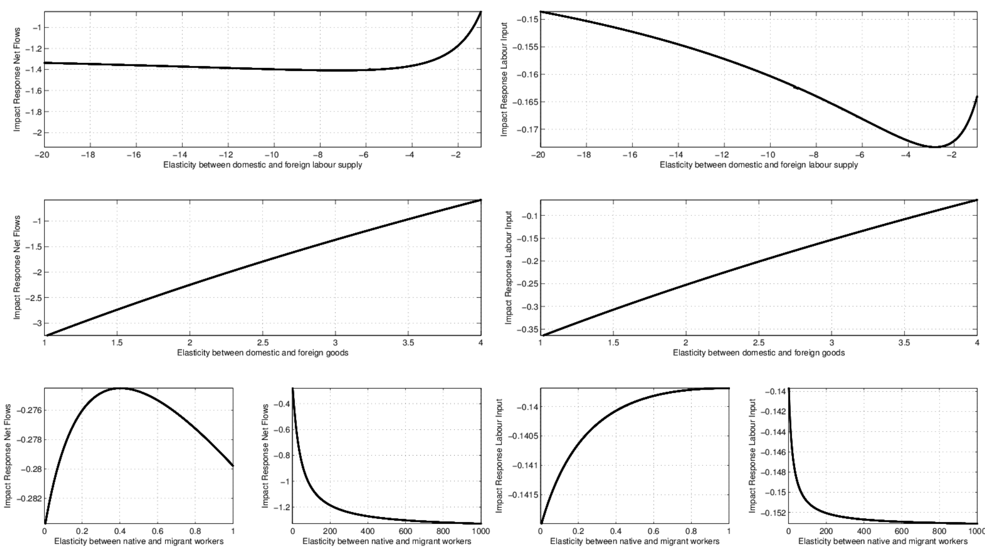
(b) Magnet States: Low price duration in both regions ($\theta^i = \theta^j = 0.3$)



(c) Hybrid States: Asymmetric price duration across the two regions ($\theta^i = 0.75$; $\theta^j = 0.25$)

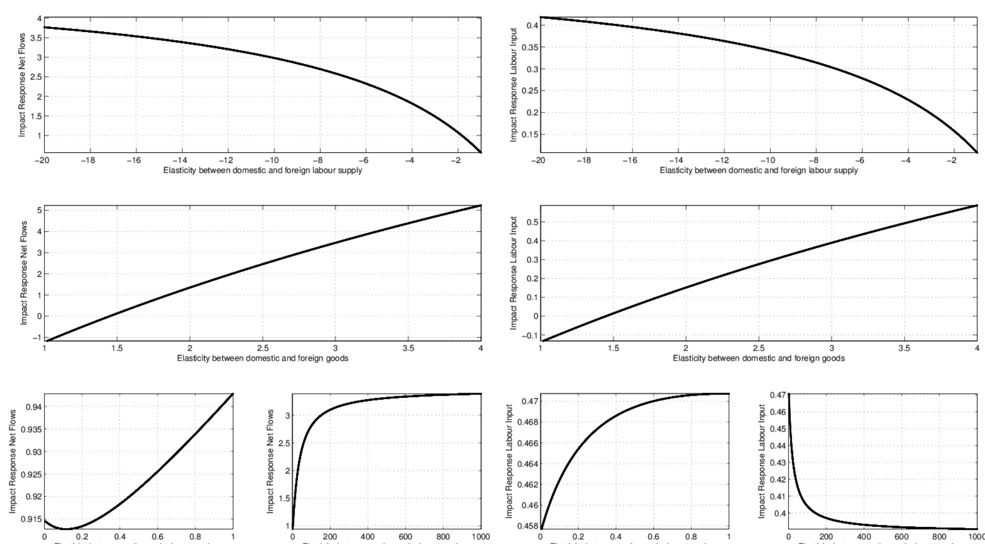
Figure 5: Sensitivity of impact responses: net labour flows and employment

Assuming high price duration ($\theta^i = \theta^j = 0.75$)



(a) Elasticity of substitution between domestic and foreign labour supply, ν_1; domestic and foreign intermediate goods, ν_2; and native and migrant workers in intermediate production, ν_3

Assuming low price duration ($\theta^i = \theta^j = 0.3$)



(b) Elasticity of substitution between domestic and foreign labour supply, ν_1; domestic and foreign intermediate goods, ν_2; and native and migrant workers in intermediate production, ν_3