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Alexander Chudik, Janet Koech and Mark A. Wynne

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Alexander Chudik[†], Janet Koech[‡] and Mark A. Wynne[§]

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Abstract

The growth of globalization in recent decades has increased the importance of external factors as drivers of the business cycle in many countries. Globalization affects countries not just at the macro level but at the level of states and metro areas as well. This paper isolates the relative importance of global, national and region-specific shocks as drivers of the business cycle in individual U.S. states and metro areas. We document significant heterogeneity in the sensitivity of states and metro areas to global shocks, and show that direct trade linkages are not the only channel through which the global business cycle impacts regional economies.

Keywords: Global and regional business cycles, U.S. state and metro employment fluctuations, Global VAR (GVAR) approach

JEL Classification: E24, E32, F62, F66

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1 Introduction

This paper is motivated by three observations. First, the United States economy has become a lot more globalized in recent years. One simple metric of the extent of that globalization is the ratio of the value of imports and exports of goods and services relative to total nominal GDP. Between 1985 and 2008 that ratio increased from 16.6 percent to 29.9 percent. It fell to 24.6 percent in 2009 as global trade collapsed during the Global Financial Crisis, but subsequently rebounded to more than 30 percent in 2011-2014.

Second, globalization occurs not just at the level of the aggregate U.S. economy, but in individual states and metropolitan areas. Some states and metro areas are more integrated into the global economy than others, and some states and metro areas have become more or less integrated into the global economy over time. Exports of goods amounted to 20.6 percent of Louisiana's nominal Gross State Product (GSP) in 2016, and 14.5 percent of Texas' GSP that same year. At the other extreme, exports of goods accounted for only 1.1 percent of the GSP of the District of Columbia, and 1.5 percent of the GSP of Hawaii. The biggest change in the importance of exports relative to GSP between 1996 and 2016 was for Vermont, where exports declined from 24.5 percent of GSP in 1996 to just 9.6 percent in 2016. One consequence of the greater globalization of the U.S. economy, and of the differential rates of globalization across individual states and metros, is that the global business cycle potentially plays a larger role in state and metro employment cycles than in the past.

Third, there is considerable heterogeneity in the fluctuations in economic activity across U.S. states and metros. While there is considerable co-movement of employment across U.S. states and metro areas, it is not unusual for some states to be growing while others are contracting; the same is true at the level of individual metros as well.

The question we are interested in is: to what extent are the heterogeneities in the business cycle across U.S. states and metro areas due to their different susceptibility to aggregate (global and national) shocks? We document significant differences across states and metro areas in the share of employment variation that is attributable to a global and national shocks. We then ask: what characteristics of states and metro areas can account for these differences? For example, is it the case that states or metro areas that are more dependent on international trade are more susceptible to external shocks? Or are other characteristics of states and metro areas more important? We

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will show that the channels through which global shocks impact economic activity at the state and metro area levels are more subtle than we might think.

In the remainder of this paper we review the related literature in Section 2, outline the methodology in Section 3, summarize the main findings in Section 4, and conclude in Section 5.

2   Related literature

There is a large literature documenting the effects of aggregate or macro (for want of a better word) shocks on disaggregate or micro entities. In international economics, we are used to thinking about the drivers of business cycles in small open economies, where the aggregate macro driver is frequently some measure of global shocks or the global business cycle. In regional economics, we are used to thinking about how national or sectoral shocks drive business cycles in regional economies, which may be regional aggregates of individual states, cities or metro areas.

One of the earliest studies examining the drivers of cyclical fluctuations in individual U.S. states was Norrbin and Schlagenhauf (1988) who decomposed fluctuations in employment at the industrial sector and regional levels into components attributable to aggregate (national), region-specific, industry-specific and idiosyncratic shocks. They focused on employment data for U.S. census regions (aggregations of U.S. states) at a quarterly frequency for the period 1954-84. They also allowed for international influences on employment fluctuations as measured by a trade-weighted average of industrial production in ten of the U.S.' largest trading partners (Germany, Japan, France, U.K., Canada, Italy, Netherlands, Belgium, Sweden and Switzerland). Norrbin and Schlagenhauf (1988) found that the national factor accounts for an average of 23.4 percent of employment fluctuations across census regions, ranging from a high of 53.7 percent in the East North Central region to a low of 7.0 percent in the West South Central region. The trade-weighted average of industrial production in foreign economies accounted for an average of 3.0 percent of employment fluctuations across census regions, ranging from a high of 6.1 percent in the East North Central region to a low of 0.5 percent in the West South Central region.

Altonji and Ham (1990) do a similar exercise for employment fluctuations in seven Canadian provinces using annual data for the period 1963-82. They use U.S. GNP to quantify the importance of external influences. Perhaps not surprisingly, they find that the largest single factor accounting

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for variation in employment growth across Canadian provinces are shocks to U.S. GNP, accounting for an average of 47 percent (ranging from a high of 61.4 percent in Ontario to a low of 37.9 percent in Alberta). The national (Canadian) shock only accounts for an average of 22.3 percent. By contrast, Prasad and Thomas (1998), using annual data for the period 1975-98 find that industry-specific shocks account for the largest fraction of the variation in employment growth across Canadian provinces, although they still find a significant role for external shocks, again proxied by shocks to U.S. GDP growth. More recently Campolieti et al. (2014) find that external and national factors play a much smaller role than the earlier research for Canadian provinces, with industry and provincial factors playing a more important role.

Kuttner and Sbordone (1997) use a similar methodology to Norrbin and Schlagenhauf (1988) and Altonji and Ham (1990) to examine the drivers of quarterly employment fluctuations in New York state over the period 1969-93. They decompose employment fluctuations into components driven by aggregate (national), industry and regional factors, but do not allow for international influences.

Clark (1998) also looked at the sources of quarterly employment fluctuations in U.S. census regions over the period 1947-90, but using a structural VAR methodology rather than the factor methodology of Norrbin and Schlagenhauf (1988). External drivers of employment fluctuations were captured using the relative price of oil (the U.S. PPI for crude petroleum deflated by the U.S. PPI for finished goods), and a (nominal) trade weighted index of seven of the U.S.' biggest trade partners (Belgium, Canada, Italy, U.K., Netherlands, Sweden and Switzerland).

Clark and Shin (2000) examine the sources of business fluctuations across a large number of countries (the U.S. plus ten European countries) and find that common (global) shocks are less important as drivers of cycles than within-country shocks.

Del Negro (2002) assesses the contributions of national, regional, state-level and idiosyncratic shocks to fluctuations in both output and consumption in U.S. states over the periods 1969-95 and 1978-95. He finds that national, regional and state-specific shocks are of about equal importance when it comes to explaining output fluctuations. However, for consumption fluctuations, state-specific shocks seem to play a more important role than national or regional shocks.

Studies of the drivers of employment fluctuations at the level of U.S. metro areas include Chang and Coulson (2001), Carlino et al. (2001) and Wall (2013). Chang and Coulson (2001) find that

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local metro shocks account for more than half of the variation in employment growth in the four cities they look at (Baltimore, Washington D.C., New York and Philadelphia) in the short run, dominating other shocks (national and sectoral). Carlino et al. (2001) also find that local (within-MSA) industry shocks explain more of the variation in employment growth than aggregate shocks in the five metro areas they look at (Chicago, Los Angeles, Oklahoma City, San Francisco and Tucson).

In the international economics literature, Norrbin and Schlagenhauf (1996) examine the importance of a common global shock as a driver of business cycles in a group of nine industrial countries, along with a nation-specific and industry-specific factor over the period 1956-92. They find that for most countries, the nation-specific factor accounts for a large amount of the forecast error variance for industrial output growth at a five-year horizon, and is the most important factor driving fluctuations. For small open economies such as Belgium and the Netherlands, the global factor is more important than the nation-specific factor. Somewhat surprisingly, they also find that the global factor is about as important as the national factor for large economies such as the U.S. and Germany.

Raddatz (2007) finds that only 11 percent of the long run variance on per capita GDP in a sample of 40 low income countries is due to external shocks, with within-country factors playing a greater role. Boschi and Girardi (2011) find that domestic and regional factors play a greater role in the fluctuations of output in the six Latin American countries that they look at. Guerron-Quintana (2013) uses an estimated DSGE model to account for fluctuations in output in seven small developed countries, and finds that country-specific factors account for the bulk of the variability, with shocks to a common international factor explaining on average 10 percent.

More recently, Karadimitropoulou and León-Ledesma (2013) use a similar framework as Norrbin and Schlagenhauf (1996) to decompose value added growth into a global, nation-specific, sector specific and idiosyncratic components using data for the G7 countries over the period 1974-2004. While they look at a smaller number of countries, they include a larger number of business sectors, and estimate their model using Bayesian techniques. They also find that fluctuations are dwarfed by nation-specific factors. In contrast, Crucini et al. (2011) find that 46.7% of the output fluctuations in G7 economies can be accounted for by global shocks, on average.

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3 Methodology

In this paper we rely on the Global Vector AutoRegression (GVAR) modelling framework originally proposed by Pesaran et al. (2004), and later extended by a number of contributions (see Chudik and Pesaran (2016) for an overview of the approach, and a survey of the GVAR literature.) Our GVAR model developed below differs from the mainstream GVAR models literature in that it accommodates two cross-sectional dimensions - a global (country) dimension, and a regional (state or metro area) dimension. The remainder of this section describes the data that we use (Subsection 3.1), outlines the GVAR model (Subsection 3.2), and then describes the approach for explaining state-level and metro-level heterogeneity (Subsection 3.3).

3.1 Data

Let output growth in country i and period t, computed as the first difference of logarithm of real output, be denoted as y_{it}, for $i = 1, 2, ..., N$ and $t = 1, 2, ..., T$, where N denotes the number of countries and T the number of available time periods. Our sample consists of $N = 22$ advanced and emerging economies and the time dimension covers the period from the third quarter of 1980 to the fourth quarter of 2016. For convenience, and without any loss of generality, we index the U.S. as country N.

In addition to the individual country output growth rate for the U.S. (y_{Nt}), we also collected U.S. national and geographically disaggregated (state or metro area) employment growth data (computed as the first difference of logarithm of employment), denoted below as h_t and h_{jt}, respectively, for $j = 1, 2, ..., n$, where $n = 51$ U.S. states (including the District of Colombia) or, in the case of metro-level disaggregation, $n = 415$ metro areas.[1] The index i is used throughout for individual countries and the index j denotes the individual U.S. states or metro areas. Further information about the data is provided in Appendix A.1.

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[1] Our metro-level disaggregation consists of all metro areas and a small number of cities and town areas available from Bureau of Labor Statistics. This includes 381 Metropolitan Statistical Areas (MSAs) (374 in the United States and 7 in Puerto Rico), 9 Metropolitan Divisions within their respective MSAs, and 25 New England City and Town Areas (NECTAs) as defined by the Office of Management and Budget (OMB).

3.2 GVAR model of output and employment

3.2.1 Specification and estimation of individual models

As is common in the GVAR approach, we start with the specification of country-specific models that are augmented by cross-section averages to account for global spillovers,

$$y_{it} = c_{yi} + \sum_{\ell=1}^{p} \theta_{i,\ell} y_{i,t-\ell} + a_{i,0} y_t^* + \sum_{\ell=1}^{p} a_{i,\ell} y_{t-\ell}^* + e_{it}, \tag{1}$$

for all countries except the U.S., indexed by $i = 1, 2..., N - 1$. For the U.S. economy, indexed as country N, the following cross-section-augmented VAR model is specified for the national U.S. variables collected in the vector $\mathbf{z}_{Nt} = (y_{Nt}, h_t)'$,

$$\mathbf{z}_{Nt} = \mathbf{c}_{zi} + \sum_{\ell=1}^{p} \mathbf{\Theta}_{N,\ell} \mathbf{z}_{N,t-\ell} + \mathbf{a}_{N,0} y_t^* + \sum_{\ell=1}^{p} \mathbf{a}_{N,\ell} y_{t-\ell}^* + \mathbf{e}_{Nt}, \tag{2}$$

where $y_t^* = (N-1)^{-1} \sum_{i=1}^{N-1} y_{it}$ is the global growth factor proxy, computed as a simple cross-section average of all foreign (from the perspective of U.S.) economies.[2] For future reference, let $\mathbf{z}_t = (y_{1t}, y_{2t}, ..., y_{Nt}, h_t)'$, and let $\mathbf{w}' = [1/(N-1), 1/(N-1), ..., 1/(N-1), 0, 0]'$ be the $1 \times (N+1)$ row weights vector for $y_t^* = \mathbf{w}' \mathbf{z}_t$.

The U.S. state or metro employment models condition on the national as well as global aggregates, and are given by

$$h_{jt} = c_{hj} + \sum_{\ell=1}^{p} \psi_{j,\ell} h_{j,t-\ell} + \boldsymbol{\lambda}_{j0}' \mathbf{z}_{Nt} + \sum_{\ell=1}^{p} \boldsymbol{\lambda}_{j\ell}' \mathbf{z}_{N,t-\ell} + \alpha_{j0} y_t^* + \sum_{\ell=1}^{p} \alpha_{j,\ell} y_{t-\ell}^* + \varepsilon_{jt}, \tag{3}$$

for $j = 1, 2, ..., n$. We shall refer to (3) as the satellite regional model below.

The specification of the individual models in (1)-(3) resembles the standard specifications in the GVAR literature, where domestic variables are modelled as a function of their lags and contemporaneous and lagged values of cross-section (or global) averages. In the case of U.S. regional employment equations, national variables are added alongside the global averages, to capture national spillovers. A formal justification of these specifications is provided by Dees, Mauro, Pesaran,

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[2]Whether U.S. is included in the global cross-section average y_t^* or not makes little empirical difference. The simple cross-section average is almost identical to the first principal component of $\{y_{1t}, y_{2t}, ..., y_{Nt}\}$.

and Smith (2007) in the context of a global unobserved common factor model, and by Chudik and Pesaran (2011, hereafter CP) in the more general context of a factor-augmented high-dimensional VAR setup. Such specifications are justified asymptotically in a large n, N context.[3]

In addition to the conditional models in (1)-(3), we specify the following marginal model for the global aggregate y_t^*,

$$y_t^* = c_y + \sum_{\ell=1}^{p} \rho_\ell y_{t-\ell}^* + v_t, \tag{4}$$

and we refer to v_t as the global growth shock. It is important to highlight that (4) is not redundant even though the system (1)-(3) consists of $k = n + N + 1$ equations for k variables. This issue is discussed in detail in Section 4.1 of Chudik et al. (2016), who show that the system (1)-(3) alone is undetermined when the number of countries is large, and a strong unobserved common factor is present. In particular, augmentation of (1)-(3) by (4) will be necessary when a strong unobserved common factor (the global business cycle) is present and N is large, whereas the augmentation is innocuous when cross-sectional dependence is not sufficiently strong.[4]

The individual models in (1)-(4) can be consistently estimated separately by Least Squares (LS). Conditions for consistency and asymptotic normality of the LS estimator for the individual country models (1)-(2) are established by CP, as $N, T \to \infty$ such that $N/T \to \kappa_1$ for some $0 < \kappa_1 < \infty$. Similarly, the asymptotic normality of the LS estimator of the individual state employment models in (3) can be established, using the same arguments, as $n, N, T \to \infty$ such that $N/T \to \kappa_1$ and $n/T \to \kappa_2$ for some $0 < \kappa_1, \kappa_2 < \infty$. The survey by Chudik and Pesaran (2016) provides further discussions of the GVAR approach, including the specification of individual equations, estimation and inference, and the uses of GVAR models in the literature.

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[3] A structural (rather than econometric) macroeconomic justification for such (small open economy) specifications is provided by Chudik and Straub (2017) as an approximation of an equilibrium of a large multi-country DSGE model.

[4] See also Cesa-Bianchi et al. (2018) for a related discussion on the identification of global shocks in the GVAR framework.

3.2.2 GVAR solution

Stacking (1)-(2) and substituting (4) for y_t^*, we obtain the following GVAR representation of $\mathbf{z}_t$ featuring a global (common) and country-specific (idiosyncratic) error structure,

$$\mathbf{z}_t = \mathbf{c}_z + \sum_{\ell=1}^{p} \mathbf{G}_{z,\ell}\mathbf{z}_{t-\ell} + \mathbf{a}_0 v_t + \mathbf{e}_t, \tag{5}$$

where $\mathbf{a}_\ell = \left(a_{1,\ell}, a_{2,\ell}, ..., a_{N-1,\ell}, \mathbf{a}'_{N,\ell}\right)'$, for $\ell = 0, 1, ..., p$, $\mathbf{e}_t = (e_{1t}, e_{2t}, ..., e_{N-1,t}, \mathbf{e}'_{Nt})'$, and

$$\mathbf{G}_{z,\ell} = \mathbf{\Theta}_\ell + (\rho_\ell \mathbf{a}_0 + \mathbf{a}_\ell)\, \mathbf{w}',$$

in which $\mathbf{\Theta}_\ell$ is a block-diagonal matrix given by

$$\underset{(N+1)\times(N+1)}{\mathbf{\Theta}_\ell} = \begin{pmatrix} \theta_{1,\ell} & 0 & 0 & \cdots & \mathbf{0}_{1\times 2} \\ 0 & \theta_{2,\ell} & 0 & & \mathbf{0}_{1\times 2} \\ \vdots & & \ddots & & \mathbf{0}_{1\times 2} \\ 0 & 0 & & \theta_{N-1,\ell} & \mathbf{0}_{1\times 2} \\ \mathbf{0}_{2\times 1} & \mathbf{0}_{2\times 1} & & \mathbf{0}_{2\times 1} & \mathbf{\Theta}_{N,\ell} \end{pmatrix}.$$

Similarly, stacking (3) and substituting (4) for y_t^* and (2) for $\mathbf{z}_{Nt}$ yields the following satellite GVAR representation of the $n \times 1$ vector of U.S. regional employment growth rates, collected in the vector $\mathbf{h}_t = (h_{1t}, h_{2t}, ..., h_{nt})'$, featuring an error structure composed of global, national, and regional innovations,

$$\mathbf{h}_t = \mathbf{c}_h + \sum_{\ell=1}^{p} \mathbf{\Psi}_\ell \mathbf{h}_{t-\ell} + \sum_{\ell=1}^{p} \mathbf{G}_{hz,\ell}\mathbf{z}_{t-\ell} + \boldsymbol{\delta} v_t + \mathbf{\Lambda}_0 \mathbf{e}_{Nt} + \boldsymbol{\varepsilon}_t, \tag{6}$$

where $\boldsymbol{\varepsilon}_t = (\varepsilon_{1t}, \varepsilon_{2t}, ..., \varepsilon_{nt})'$ is the $n\times 1$ vector of regional shocks, $\mathbf{\Lambda}_\ell = (\boldsymbol{\lambda}_{1,\ell}, \boldsymbol{\lambda}_{2,\ell}, ..., \boldsymbol{\lambda}_{n,\ell})'$, $\boldsymbol{\delta} = \boldsymbol{\alpha}_0 + \mathbf{\Lambda}_0 \mathbf{a}_{N,0}$, $\boldsymbol{\alpha}_\ell = (\alpha_{1,\ell}, \alpha_{2,\ell}, ..., \alpha_{n,\ell})'$, $\mathbf{\Psi}_\ell$, for $\ell = 1, .., p$, are $n \times n$ diagonal matrices with elements $\{\psi_{j,\ell}\}_{j=1}^{n}$ on the diagonal, and individual coefficient matrices $\mathbf{G}_{hz,\ell}$ are given by

$$\mathbf{G}_{hz,\ell} = \mathbf{\Lambda}_0 \left[\mathbf{\Theta}_{N,\ell}\mathbf{S}_N + (\rho_\ell \mathbf{a}_{N,0} + \mathbf{a}_{N,\ell})\mathbf{W}\right] + \mathbf{\Lambda}_\ell \mathbf{S}_N + (\rho_\ell \boldsymbol{\alpha}_0 + \boldsymbol{\alpha}_\ell)\mathbf{W},$$

in which $\mathbf{S}_N$ is $2 \times (N+1)$ selection matrix that selects $\mathbf{z}_{Nt}$ from $\mathbf{z}_t$, namely $\mathbf{z}_{Nt} = \mathbf{S}_N \mathbf{z}_t$.

The GVAR model of all of the variables collected in the vector $\boldsymbol{\xi}_t = (\mathbf{z}_t', \mathbf{h}_t')'$, is given by stacking (5) and (6), and it features global, national as well as regional shocks. We use this model in a standard way to obtain a variance decomposition of regional employment fluctuations into contributions from global (g), national (n), and regional (r) shocks. Hence, we decompose the total (tot) variance $V_j^{tot} = Var(h_{jt})$ into its three components, $V_j^{tot} = V_j^g + V_j^n + V_j^r$. Details on the variance-decomposition using (5)-(6) are relegated to Appendix A.2.

In addition, we compute the expected impact of a one standard error (s.e.) surprise decrease in the growth rate of global and national output on regional employment growth, which is given by the concept of the generalized impulse response function (GIRF) advanced by Koop, Pesaran, and Potter (1996) and Pesaran and Shin (1998). Details on GIRFs are relegated to Appendix A.3.

3.3 Explaining regional heterogeneities

To shed light on what determines the importance of the global and national business cycles for employment fluctuations in individual states or metros, we relate our findings on variance decompositions to a set of observed regional characteristics. To this end, let $\zeta_j = V_j^g + V_j^n$, for $j = 1, 2, ..., n$, be the share of the total variance in employment growth in region j explained by the global and national shocks. We are interested in understanding if the differences across regions as measured by our estimates of ζ_j can be explained by a set of region-specific explanatory variables collected in the $s \times 1$ vector $\mathbf{x}_j$. To this end, we suppose,

$$\zeta_j = \boldsymbol{\beta}' \mathbf{x}_j + u_j, \tag{7}$$

where $\mathbf{x}_j$ is a $s \times 1$ vector of regressors (summarizing different characteristics of states or metro areas), which includes an intercept, $\boldsymbol{\beta}$ is a $s \times 1$ vector of unknown parameters, and u_j is an error term assumed to be uncorrelated with the regressors and uncorrelated over j, and distributed with mean zero and variance σ_{uj}^2.[5] The dependent variable ζ_j is not directly measured. Instead, we have an estimate $\hat{\zeta}_j$ obtained from the GVAR model using a sample (n, N, T). Let $\hat{\epsilon}_j$ denote the

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[5]It is assumed that σ_{uj}^2 is bounded below and above in n.

estimation error so that $\hat{\zeta}_j = \zeta_j + \hat{\epsilon}_j$. Hence, (7) can be written as

$$\hat{\zeta}_j = \boldsymbol{\beta}'\mathbf{x}_j + u_j^*, \; u_j^* = u_j + \hat{\epsilon}_j, \text{ for } j = 1, 2, ..., n,$$

or, more compactly after stacking over j,

$$\hat{\boldsymbol{\zeta}} = \mathbf{X}\boldsymbol{\beta} + \tilde{\mathbf{u}}, \tag{8}$$

where $\hat{\boldsymbol{\zeta}} = \left(\hat{\zeta}_1, \hat{\zeta}_2, ..., \hat{\zeta}_n\right)'$ is the $n \times 1$ vector of observations on the dependent variable, $\mathbf{X} = (\mathbf{x}_1, \mathbf{x}_2, ..., \mathbf{x}_n)'$ is $n \times s$ matrix of observations on the regressors, and $\tilde{\mathbf{u}} = (\tilde{u}_1, \tilde{u}_2, ..., \tilde{u}_n)'$.

Consider the LS estimator of $\boldsymbol{\beta}$ obtained by regressing $\hat{\zeta}_j$ on $\mathbf{x}_j$,

$$\hat{\boldsymbol{\beta}} = \left(\mathbf{X}'\mathbf{X}\right)^{-1} \mathbf{X}'\hat{\boldsymbol{\zeta}}. \tag{9}$$

Substituting (8) in (9), and noting that $\tilde{\mathbf{u}} = \mathbf{u} + \hat{\boldsymbol{\epsilon}}$, we obtain

$$\hat{\boldsymbol{\beta}} - \boldsymbol{\beta}_0 = \left(\mathbf{X}'\mathbf{X}\right)^{-1} \mathbf{X}'\mathbf{u} + \left(\mathbf{X}'\mathbf{X}\right)^{-1} \mathbf{X}'\hat{\boldsymbol{\epsilon}}, \tag{10}$$

where we use $\boldsymbol{\beta}_0$ to denote the true value of $\boldsymbol{\beta}$. A sufficient condition for consistency of $\hat{\boldsymbol{\beta}}$ is the usual requirement on u_j and $\mathbf{x}_j$,[6] and, in addition, $n^{-1}\mathbf{X}'\hat{\boldsymbol{\epsilon}} \rightarrow_p 0$. Using the same arguments as in Theorem 1 of Chudik and Pesaran (2011), and assuming $n, N, T \rightarrow \infty$ such that $N/T \rightarrow \kappa_1$ and $n/T \rightarrow \kappa_2$, then all of the GVAR coefficients as well as the individual elements of the standard covariance matrix estimator are $\sqrt{T}$-consistent, and therefore $\hat{\zeta}_j$ is also $\sqrt{T}$-consistent, namely $\hat{\epsilon}_j = O_p\left(T^{-1/2}\right)$. Hence, (assuming $\mathbf{x}_j = O_p(1)$)

$$n^{-1}\mathbf{X}'\hat{\boldsymbol{\epsilon}} = n^{-1}\sum_{j=1}^{n}\mathbf{x}_j\hat{\epsilon}_j = n^{-1}\sum_{j=1}^{n}O_p\left(T^{-1/2}\right) = O_p\left(T^{-1/2}\right),$$

and therefore $n^{-1}\mathbf{X}'\hat{\boldsymbol{\epsilon}} \rightarrow_p \mathbf{0}$ and $\hat{\boldsymbol{\beta}}$ is consistent. We rely on bootstrapping described in Appendix A.4 to conduct inference, allowing for heteroskedasticity of errors.

We compiled 48 state-level indicators and (due to much more limited availability) 16 metro-level

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[6]Namely, $n^{-1}\mathbf{X}'\mathbf{X} \rightarrow_p \mathbf{Q}_{xx}$, $\mathbf{Q}_{xx}$ is invertible, and $n^{-1}\mathbf{X}'\mathbf{u} \rightarrow_p 0$, as $n \rightarrow \infty$.

regional indicators to see what characteristics of a state or metro might account for (be correlated with) its sensitivity to global and national shocks. The state level indicators are described in Table A2. Obvious candidates include exposure to international trade as measured by the share of imports and exports in Gross State Product, the diversity of international trade links (either by product or destination), the size of the state as measured by various indicators, the composition and diversity of the states' economic structure, and measures of educational attainment (the idea being that states with more human capital might respond differently to external shocks than states with less human capital). In keeping with the agnostic spirit of our empirical exercise, we also included other variables that are less obviously directly related to a state's sensitivity to global or national shocks, such as indicators of the physical environment (heating and cooling degree days), the burden of local government debt and the homeownership rate, to highlight just a few.

Data availability at the metro area is much more limited. But again we were able to obtain measures of the share of exports in metro area output, measures of the economic size of the metro areas, measures of business dynamism, and measures of educational attainment. The full set of metro indicators that we consider is listed in Table A3.

Assuming that the number of regressors (s) is fixed does not seem to be an issue when considering metro areas, where the number of regions is quite large (342 after discarding some due to limited coverage of individual MSA indicators), and the number of explanatory indicators is limited. However, this is no longer the case in the case of states, where we have 48 indicators and only 51 states. To deal with the large number of state-level indicators in comparison to the available sample size, we employ the One Covariate at a Time Multiple Testing (OCMT) selection method proposed by Chudik, Kapetanios, and Pesaran (2018) to weed out 'noise' indicators. Noise indicators are defined here as the indicators that are not part of $\mathbf{x}_j$ and are uncorrelated with the indicators in $\mathbf{x}_j$, which are also called as the 'signal' indicators. An advantage of OCMT as opposed to penalized regressions, such as Lasso, is that it seems to be very effective at selecting a pseudo-true model, which is defined to contain all signals, and no noise indicators, while possibly retaining also some of the pseudo-signals, defined as the indicators not in $\mathbf{x}_j$, but correlated with signals. Hence, OCMT provides a consistent selection approach (as n, k are both large) of a parsimonious model that encompasses the true model, and does not feature noise indicators.

4 Role of the global and national business cycle in explaining the regional employment fluctuations in the U.S.

As noted in the introduction, there is significant heterogeneity across U.S. states and metro areas in terms of where they are in the business cycle at any given point in time. It is not uncommon for some states to be growing rapidly while others are contracting. It is rare for all states to be expanding at the same time. The same is true at the level of metro areas. Figure 1 and Figure A1 in the Appendix illustrate the extent of this heterogeneity over the past thirty to forty years. Figure 1a shows that only once in the nearly forty years of data shown in the chart did employment decline in all fifty U.S. states at the same time, and that was during the recent Global Financial Crisis. At the level of metro areas (Figure 1b), we have never witnessed an episode in which employment declined in all metro areas at the same time.

However, a visual inspection of data plotted in panels A and B of Figure A1 shows that there is also significant co-movement of employment across states and metro areas, suggesting that aggregate (global or national) shocks play an important role as drivers of these fluctuations.

Table 1 reports the results of two commonly-used tests of cross-section dependence in the state and metro area data. The first is the cross section dependence (CD) test of Pesaran (2004, 2015) which is based on the average of all of the pair-wise correlations between units i and j: $\hat{\bar{\rho}} = 2N^{-1}(N-1)^{-1} \sum_{i=1}^{N} \sum_{j=i+1}^{N} \hat{\rho}_{ij}$ where $\hat{\rho}_{ij}$ is the correlation coefficient of cross-section unit i and j. The test statistic CD is computed as $CD = TN(N-1)\hat{\bar{\rho}}/2$ and it is asymptotically normally distributed with unit variance, under the null of no or very limited cross-sectional dependence (see Pesaran (2015)). For our state level data we compute a value of the test statistic of $CD = 220.56$. For the metro area data we compute a value of $CD = 830.99$. Both values well exceed any reasonable critical values, allowing us to decisively reject the implicit null of no or sufficiently weak cross-section dependence. The second test statistic we report is the estimate of the exponent of cross-sectional dependence proposed by Bailey et al. (2016), or $\hat{\alpha}$. Values of this statistic that are close to 1 indicate a strong degree of cross-sectional dependence in the data.[7] Again we cannot reject the null of a high degree of cross-section dependence in our data, at both the state and metro area levels. The strong cross-section dependence that we find here could be due to either national

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[7]The definition of weak and strong cross-sectional dependence is provided in Chudik et al. (2011).

or global factors, and it is to the investigation of these factors that we now turn.

4.1 State-level findings

Figure 2a shows the share of employment fluctuations in each of the fifty U.S. states and the District of Columbia that is accounted for by global, national and residual (state-specific) shocks, with the states ordered from left to right in terms of the importance of the aggregate (global and national) shocks. On average, global shocks account for 24.5 percent of the variation in employment growth across states, while national shocks account for 30.8 percent. However, there is considerable variation across states in terms of the importance of global and national shocks. Perhaps not surprisingly, global and national shocks play the smallest role in accounting for employment fluctuations in the District of Columbia. Note that global and national shocks also play a relatively small role in accounting for employment fluctuations in Louisiana, North Dakota, Alaska and West Virginia. One thing all of these states have in common is that energy (either coal or oil) accounts for an important share of economic activity in these states. To the right of the chart are states such as North Carolina, Ohio and Wisconsin, where global and national shocks together account for about four fifths of employment fluctuations.

Figure 3a shows the cumulative effect on employment growth across states after one year of a 0.5 percent negative shock to global output, with states ranked from left to right in terms of the size of the impact. The average effect across states is -0.64 percent, but again there is considerable heterogeneity. In almost all cases employment declines, and by a statistically significant amount. The exception is Alaska, where we estimate a modest increase in employment growth, but the effect is not statistically significant. Note that a 0.5 percent negative shock to global output growth has the biggest effect on employment growth in Nevada, where we estimate that employment growth declines by 1.1 percent after one year.

The cumulative one-year effect on employment growth across states of a negative national output shock of 1 percent is shown in Figure 4a. The average effect is -0.69 percent, with the biggest effect on employment growth in Nevada and the smallest effect on employment growth in Washington DC. For Wyoming, the impact is not statistically different from zero.

4.2 MSA-level findings

Figure 2b shows the results of a similar variance decomposition for the 415 metro areas for which we have employment data. Due to the large number of metros it is not possible to include labels, but the chart illustrates again that there is significant heterogeneity across metro areas in terms of the role played by global and national shocks as drivers of employment cycles. On average the global shock accounts for 17.9 percent of employment fluctuations across metro areas, while national shocks account for 16.0 percent. Global and national shocks play the smallest role in employment fluctuations in the New Orleans-Metairie LA metro area (where they account for just 0.05 percent and 2.60 percent of employment fluctuations respectively), and play the largest role in employment fluctuations in the Dallas-Fort Worth-Arlington TX metro area, where they account for 44.11 percent and 41.24 percent of employment fluctuations respectively.

We also calculated the effect on metro area employment growth after one year of a -0.5 percent shock to global output growth, and the results are shown in Figure 3b. On average, employment growth declines by about -0.62 percent after one year (very similar in magnitude to the average across states), but as with the state level calculations, there is considerable heterogeneity across metros. Note that for several metro areas the effect is indistinguishable from zero. The biggest effect is on employment growth in Elkhart-Goshen IN, where employment growth declines by 2.27 percentage points. The next biggest effects are on employment growth in Midland TX and Odessa TX, where employment growth declines by 1.76 and 1.62 percentage points respectively. The smallest effects are on employment growth in Bismarck ND (0.04 percentage point decline) and College Station-Bryan TX (also a 0.04 percentage point decline).

And Figure 4b repeats the exercise for a -1 percent shock to national output growth. On average, employment growth declines by 0.61 percentage points after one year in response to a national output growth shock of -1 percent, but we find that in several metro areas the effect on employment growth is positive after one year, although this effect is not statistically significant. The biggest declines in employment growth in response to a national output shock after one year are in Elkhart-Goshen IN (-2.19 percentage points), Las Vegas-Henderson-Paradise NV (-1.81 percentage points) and Naples-Immokalee-Marco Island FL (-1.71 percentage points). We estimate that employment growth increases after one year in response to a negative national output shock in Midland TX

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(0.80 percentage points), Odessa TX (0.52 percentage points) and Hammond LA (0.39 percentage points). The positive response of employment in Midland and Odessa to a negative national output shock probably reflects the importance of the oil industry to employment in those metros, with employment in both cities co-moving positively with oil prices while aggregate U.S. output co-moves negatively with oil prices.

4.3 Reconciling the regional differences

How can we account for these heterogeneities in the importance of global shocks across states and metro areas? Do they simply reflect differences in the openness of individual states and metro areas, as measured by the share of exports in state or metro area economic activity? It is common practice to get back-of-the-envelope estimates of the impact of external shocks on a nation or region by simply multiplying the size of the shock by the share of exports in the region's economic activity. But perhaps other characteristics of a state or metro area matter as well? Perhaps the way in which external shocks are propagated to state and metro area employment growth rates over time depends not just on direct trade linkages, but also indirect trade linkages and other characteristics of a state or metro area's economy. For example, states or metro areas with more flexible or diversified economies may respond very differently to external shocks than states with less flexible or less diversified economies, even if exports are equally important to both.

We put together data on various characteristics of states and metro areas to try to tease out which characteristics of states and metro areas were associated with global shocks playing a large role in employment fluctuations. As we noted above, there are more indicators available for states than for metro areas. The indicators we looked at are listed in Tables A2 (for states) and A3 (for metro areas). We looked for measures of size (GSP relative to U.S. GDP), level of economic development (per capita income), industrial structure (relative importance of various sectors in state or metro GSP), demographic structure (population growth, migration), business dynamism (building permits, bankruptcies, economic freedom), intranational and international linkages (interstate flow of goods, exports and imports relative to GSP), burden of government (taxes, debt) and physical environment (heating and cooling degree days, motor vehicle miles per capita).

Table 2 reports the results of our attempt to uncover the drivers of the heterogeneities in the sensitivity to global and national shocks that we document at the state level. As noted above, given

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the abundance of indicators at the state level we used the OCMT method of Chudik, Kapetanios, and Pesaran (2018) to narrow down the list of potential explanatory variables. The top panel of the table reports the net effect coefficient estimates $\widehat{\theta}$ and the R^2 from the first stage regressions where we simply regress ζ_j on each indicator individually.[8] The indicators are ranked in Table 2 by the size of the R^2. We find that the share of manufacturing in GSP and the share of mining in GSP can each in insolation account for a bit less than one third of the variation across states in the sensitivity to global and national shocks. Note however, that the coefficient estimates differ in sign: states with a larger manufacturing sector tend to experience employment declines when the global and national economies decline, while states with a larger mining sector (which includes oil) tend to experience employment expansions when the global and national economies decline. Note also that the highest ranked trade-related indicators are the Herfindahl index for exports by product ($R^2 = 0.163$), followed by the share of interstate exports in GSP ($R^2 = 0.118$) and the Herfindahl index for exports by destination ($R^2 = 0.060$). Note that the R^2 for the share of exports in GSP is only 0.036, comparable to that for indicators such as the number of motor vehicle registrations or the share of the population aged 18-24 without a high school diploma.

The OCMT method selects five out of the 48 variables that we start with at the state level as potentially explaining the differences in the response to global and national shocks, namely the relative size of the state (as measured by GSP relative to U.S. GDP), the importance of manufacturing (as measured by manufacturing's share of GSP), the importance of mining (as measured by the mining sector's share of GSP), the size of government (as measured by the share of government purchases in GSP) and a measure of economic dynamism or churn (as measured by the number of nonbusiness bankruptcies). Collectively, these five variables can account for just under two-thirds of the variation across states in the sensitivity of state-level employment to national and global shocks. Note that none of our trade indicators (either international or intranational) are included among the final set of explanatory variables selected by the OCMT procedure.

Table 3 shows the results for the metro areas. Since we have fewer indicators relative to the number of metro areas, we simply report the results of a cross-section regression including all of the potential explanatory variables. However, the top panel of the table shows the results from

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[8] See Pesaran and Smith (2014) for the concept of net effect coefficients, and Chudik, Kapetanios, and Pesaran (2018) for a discussion of the role of net effect coefficients in the selection of a pseudo-true model.

a first stage regression similar to that reported in Table 2 where again we rank indicators by the size of the R^2. We find that a measure of the relative size of a metro area (its GDP as a share of U.S. GDP) has the most explanatory power of any of the metro area indicators when considered in isolation for explaining the heterogeneity in sensitivity to global and national shocks across metros, followed by two indicators of the level of economic development (metro area per capita GDP and fraction of the population aged 18-24 with college education.). Exports as a share of metro area GDP explain less than 1 percent of the heterogeneity across metro areas in the sensitivity to global and national shocks.

5   Conclusion

This paper contributes to the existing literature on the drivers of cyclical fluctuations in economic activity at the level of individual U.S. states and metro areas using a GVAR approach extended to accommodate the global and regional cross-section dimensions. We isolate the effects of global and national shocks at the state and metro level and document differences across states and metro areas. We find that global shocks account for an average of 24.5 percent of the variation in employment growth across states and 17.9 percent of the variation in employment growth across metro areas. We also find that there is significant heterogeneity in how important global shocks are for state and metro business cycles, ranging from a low of almost no effect in Washington DC or Louisiana to accounting for more than two-thirds of employment fluctuations in North Carolina or Ohio. We see even more diversity at the level of metro areas.

We go beyond the existing literature on drivers of local business cycles to try to isolate the characteristics of state and metro area economies that may account for these differences. Somewhat surprisingly, the share of exports in state GSP does not seem to play an important role in accounting for these heterogeneities across states, although measures of state size do. The same is true for metro areas as well. This suggests that the common practice of using a measure of exports relative to GDP to assess the vulnerability of a state or metro area to global or national shocks is potentially misleading, and that the channels through which global and national shocks impact regional economies are more subtle than just direct trade linkages.

Table 1: Summary measures of cross-sectional dependence of U.S. regional employment growth rates.

Geographic unit	$\widehat{\bar{\rho}}$	CD	$\hat{\alpha}$	Conf. interval
States	0.51	220.56	0.996	[0.922, 1.071]
Metropolitan Areas	0.27	830.99	1.000	[0.923, 1.077]

Notes: $\widehat{\bar{\rho}}$ is the average pair-wise correlation, given by $\hat{\bar{\rho}} = 2N^{-1}(N-1)^{-1}\sum_{i=1}^{N}\sum_{j=i+1}^{N}\hat{\rho}_{ij}$ where $\hat{\rho}_{ij}$ is the correlation coefficient of cross-section unit i and j. CD is the cross-sectional dependence (CD) test statistics of Pesaran (2004, 2015). $CD = TN(N-1)\hat{\bar{\rho}}/2$ and it is asymptotically normally distributed with unit variance, under the null of no or very limited cross-sectional dependence, see Pesaran (2015). $\hat{\alpha}$ is the estimate of the exponent of cross-sectional dependence proposed by Bailey et al. (2016). Confidence intervals in square brackets are the 95% intervals.

Table 2: Explaining heterogeneity across U.S. states in the importance of global and national business cycles

Net effect coefficient estimates				
(Regressors ordered based on R^2)	$\hat{\theta}$	Conf. int.	R^2	n
Manufacturing share of GSP	1.836	[1.124, 2.545]	0.312	51
Mining share of GSP	-1.897	[-2.463, -1.333]	0.299	51
Govt. share of GSP	-2.134	[-2.759, -1.527]	0.231	51
GSP share of US GDP	3.470	[1.853, 5.082]	0.183	51
NonBusiness bankruptcies	0.160	[0.091, 0.230]	0.170	51
Herfindahl index (product)	-0.067	[-0.097, -0.037]	0.163	50
WRR trade share of GSP	3.304	[1.592, 5.019]	0.145	51
Real GSP per capita	0.000	[-0.001, 0.000]	0.142	51
Building permits	7.931	[3.354, 12.331]	0.121	51
Interstate exports share of GSP	0.308	[0.112, 0.512]	0.118	51
TPU share of GSP	-3.748	[-6.881, -0.600]	0.105	51
Net migration	1.155	[0.430, 1.901]	0.104	51
Employment of foreign MNCs	0.486	[0.171, 0.800]	0.098	51
Population density	-0.004	[-0.005, -0.003]	0.095	51
Agriculture share of GSP	-2.656	[-4.613, -0.700]	0.062	51
Herfindahl index (destination)	-0.063	[-0.135, 0.009]	0.060	50
Homeownership rate	0.767	[-0.072, 1.600]	0.060	51
Average temperature	0.520	[-0.084, 1.142]	0.056	48
Imports share of GSP	0.402	[-0.129, 0.925]	0.056	51
Services share of GSP	2.669	[0.353, 4.981]	0.055	51
State tax rates	3.405	[-0.554, 7.440]	0.050	51
FIRE share of GSP	0.762	[-0.184, 1.718]	0.046	51
Median home values	-0.059	[-0.135, 0.022]	0.045	51
Heating degree days	-0.002	[-0.004, 0.001]	0.044	51
Average precipitation	3.161	[-1.131, 7.253]	0.044	48
Population growth	5.446	[0.358, 10.286]	0.043	51
Education (25+) no highsch	2.377	[0.283, 4.400]	0.042	51
Economic freedom index	5.833	[-0.964, 12.659]	0.041	50
Interstate imports share of GSP	0.218	[-0.066, 0.500]	0.039	51
MVehicle registrations	-0.029	[-0.080, 0.022]	0.036	51
Education (18-24) no highsch	1.233	[-0.435, 2.868]	0.036	51
Exports share of GSP	1.028	[-0.606, 2.657]	0.036	51
Per capita personal income	-0.564	[-1.523, 0.370]	0.024	51
Education(25+) college	-0.406	[-1.359, 0.555]	0.015	51
Taxes per capita	2.210	[-3.799, 7.948]	0.010	51
Credit card debt per capita	-4.312	[-15.982, 7.018]	0.010	51
Poverty rates	-0.526	[-1.908, 0.865]	0.009	51
Employment tied to exports	0.867	[-2.043, 3.848]	0.008	50
Government debt share of GSP	0.491	[-0.988, 1.953]	0.008	51
Education(18-24) college	-0.501	[-2.190, 1.195]	0.008	51
Rate of natural increase	-0.464	[-2.277, 1.369]	0.004	51
Business bankruptcies	-0.212	[-1.291, 0.851]	0.002	51
Auto debt per capita	-1.673	[-12.610, 9.486]	0.002	51
Prisoners per capita	-0.387	[-4.307, 3.530]	0.001	50
Mortgage debt per capita	0.052	[-0.509, 0.614]	0.001	51
MVehicle miles traveled per capita	0.215	[-3.378, 3.895]	0.000	51
Cooling degree days	0.000	[-0.006, 0.006]	0.000	51
Construction share of GSP	-0.167	[-6.389, 6.083]	0.000	51
CS regression for variables selected by OCMT				
	$\hat{\beta}$	Conf. int.		
GSP share of US GDP	2.587	[1.658, 3.534]		
Manufacturing share of GSP	0.802	[0.139, 1.469]		
Mining share of GSP	-1.265	[-1.931, -0.597]		
Govt. share of GSP	-0.794	[-1.483, -0.116]		
NonBusiness bankruptcies	0.095	[0.051, 0.141]		
adjusted R^2	0.613			
n	51			

Notes: The dependent variable is the variance share (in %) of employment fluctuations explained by global and national shocks. Confidence intervals in square brackets are the 90% intervals. A constant is included in all regressions (not reported). Definitions of individual regressors and their regional availability is provided in Appendix Table A2. The OCMT selection procedure is applied to all state-level indicators using critical value function with $p = 10\%$, $\delta = 1$ and $\delta^* = 2$.

Table 3: Explaining heterogeneity across U.S. metros in the importance of global and national business cycles

Net effect coefficient estimates				
(Regressors ordered based on R^2)	$\hat{\theta}$	Conf. int.	R^2	n
GDP share of US GDP	12.030	[6.691, 17.363]	0.215	365
Real GSP per capita	0.617	[0.473, 0.761]	0.147	364
Education (18-24) college	1.954	[1.524, 2.390]	0.135	383
Education (25+) college	0.608	[0.414, 0.798]	0.080	383
Poverty rates	-0.759	[-0.923, -0.585]	0.072	372
Per capita personal income	0.697	[0.344, 1.039]	0.055	365
Net migration	0.477	[0.226, 0.729]	0.042	365
Median home values	0.033	[0.019, 0.049]	0.029	361
Building permits	-1.340	[-2.005, -0.674]	0.017	364
Population growth	1.802	[0.245, 3.357]	0.013	374
NonBusiness bankruptcies	-0.025	[-0.049, -0.002]	0.007	365
Education (18-24) no highsch	0.200	[-0.051, 0.451]	0.004	383
Education (25+) no highsch	-0.292	[-0.633, 0.052]	0.003	383
Real GDP growth	0.827	[-0.442, 2.149]	0.003	365
Exports share of GDP	0.057	[-0.104, 0.218]	0.001	342
Business bankruptcies	-0.279	[-1.322, 0.769]	0.000	364
Full CS regression				
	$\hat{\beta}$	Conf. int.		
Exports share of GDP	0.134	[-0.017, 0.281]		
Real GDP growth	-2.124	[-3.731, -0.494]		
GDP share of US GDP	7.244	[2.939, 11.519]		
Real GSP per capita	0.477	[0.206, 0.738]		
Population growth	-0.845	[-2.781, 1.079]		
Net migration	0.754	[0.442, 1.064]		
Business bankruptcies	1.367	[0.254, 2.483]		
NonBusiness bankruptcies	0.028	[-0.002, 0.058]		
Building permits	-0.852	[-1.692, -0.021]		
Education (18-24) no highsch	0.470	[0.075, 0.860]		
Education (18-24) college	1.590	[0.699, 2.470]		
Education (25+) no highsch	0.505	[-0.134, 1.150]		
Education (25+) college	0.022	[-0.331, 0.386]		
Per capita personal income	-0.405	[-0.788, -0.007]		
Median home values	-0.024	[-0.043, -0.004]		
Poverty rates	-0.798	[-1.279, -0.322]		
adjusted R^2	0.340			
n	335			

Notes: The dependent variable is the variance share (in %) of employment fluctuations explained by global and national shocks. Confidence intervals in square brackets are the 90% intervals. A constant is included in all regressions (not reported). Definitions of individual regressors and their regional availability is provided in Appendix Table A3.

Figure 1: Yearly employment growth range across U.S. states (A) and U.S. metropolitan areas (B)
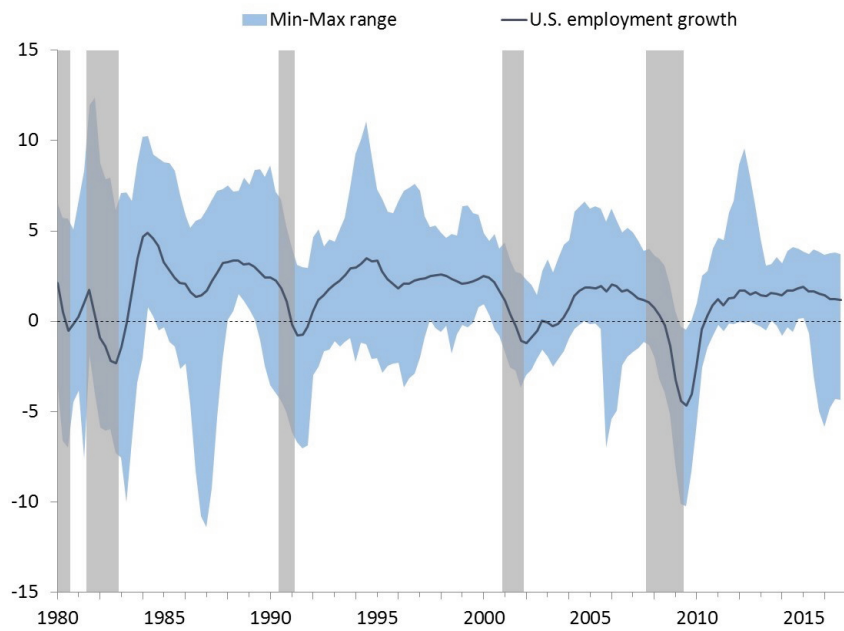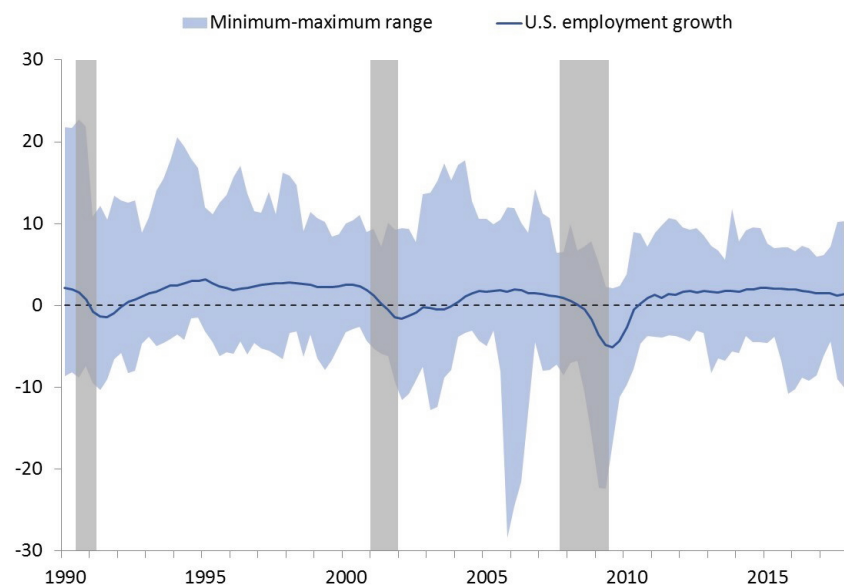
A. U.S. states

B. U.S. metropolitan areas

Notes: Employment fluctuations are computed as year-over-year growth of quarterly nonfarm payroll employment. Shaded bars indicate U.S. recessions.

Figure 2: Share of U.S. states' employment variation explained by global, national and residual shocks
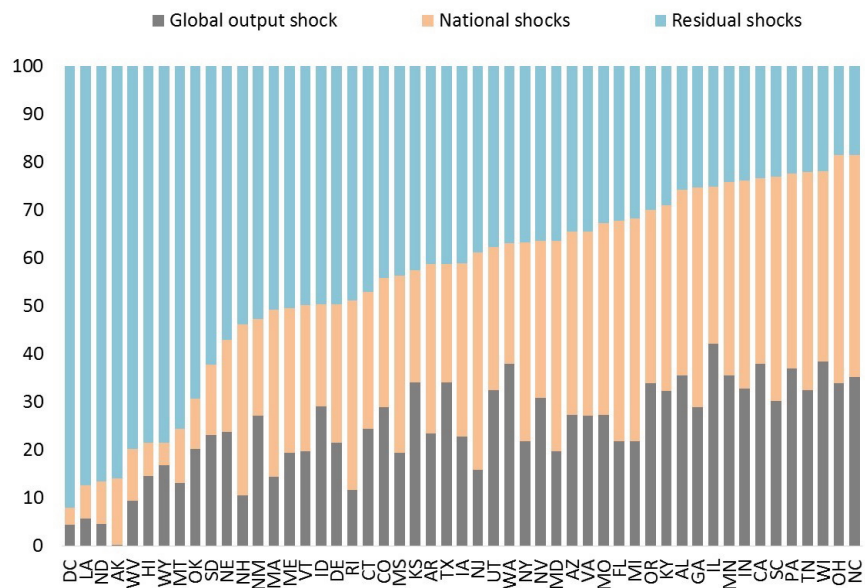
A. U.S. states
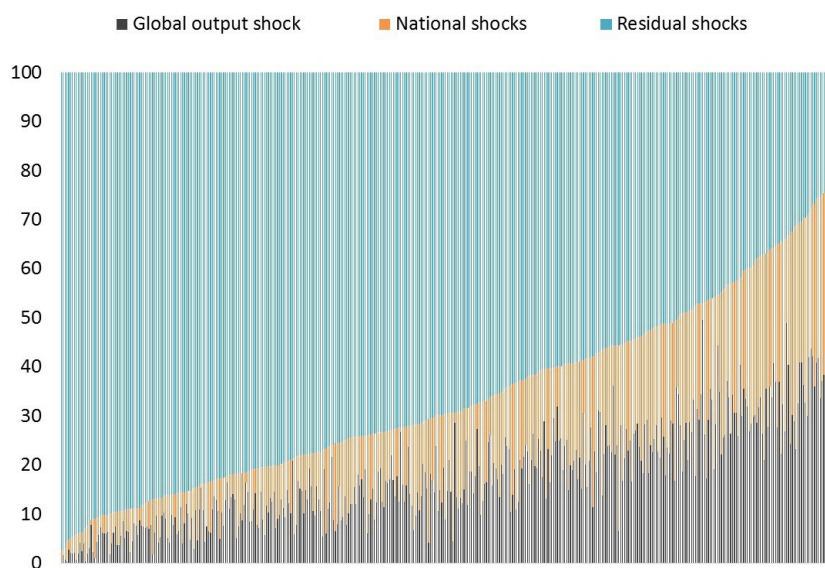
B. U.S. metropolitan areas

Notes: This figure shows the decomposition of the total variance of regional employment fluctuations to contributions from global (black bars), national (orange bars), and regional/residual (blue bars) shocks, based on the GVAR model outlined in Section 3.2. The average share of the variation in employment growth at the state level that is accounted for by the different shocks is 24.5 percent for the global shock, 30.8 percent for the national shock and 44.7 percent for the residual shock. At the MSA level, the average contributions are 17.9 percent for the global shock, 16.0 percent for the national shock and 66.1 percent for the residual shock.

Figure 3: Effect of a 0.5% negative shock to foreign output on U.S. states and metro areas employment levels one year after the shock (deviations from baseline)
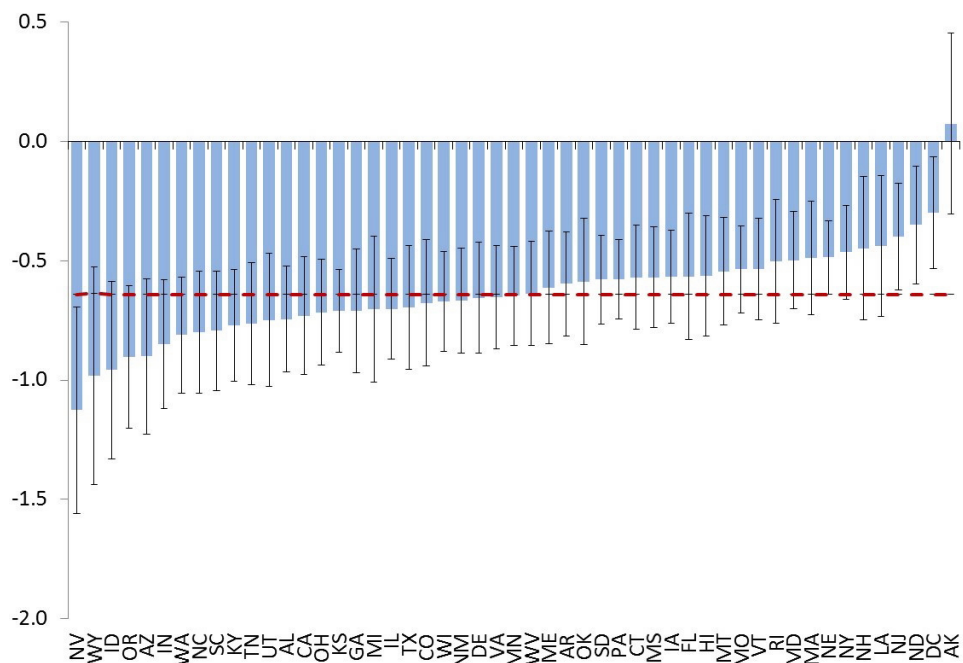
A. U.S. states

B. U.S. metropolitan areas
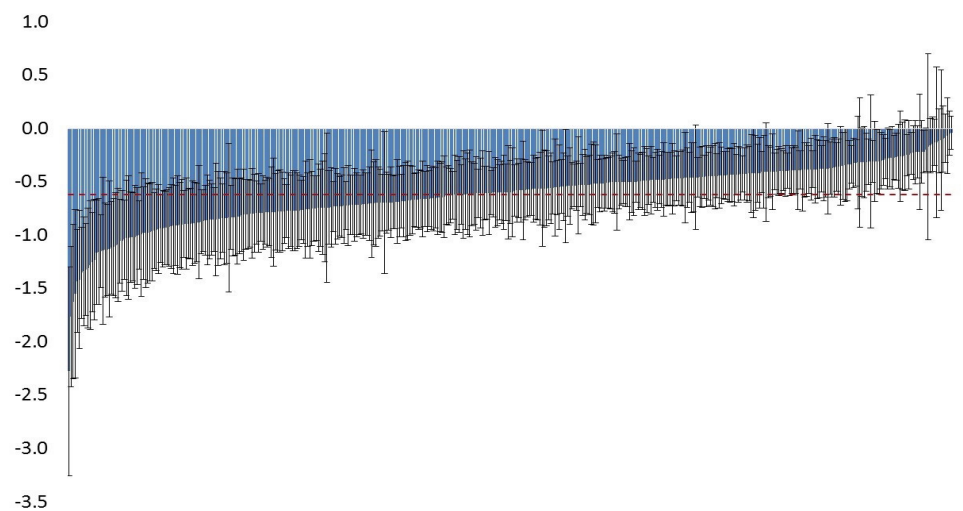
Notes: Figures show the cumulative effects on employment growth in U.S. states and metro areas of a negative shock to global output growth. A one year cumulative impact on national employment growth is -0.65 percent for states and -0.66 percent for MSAs. The 0.5 percentage point magnitude of the shock is relatively large given that the sample standard deviation (a statistical measure of a standard size of a shock) is 0.36 percentage points in states GVAR model and 0.37 percentage points in MSA GVAR model. The red dashed line shows the average cumulative impact on state employment (-0.64 percent) and MSA employment (-0.62 percent).

Figure 4: Effect of a 1% negative shock to U.S. output on U.S. states and metro areas
employment levels one year after the shock (deviations from baseline)
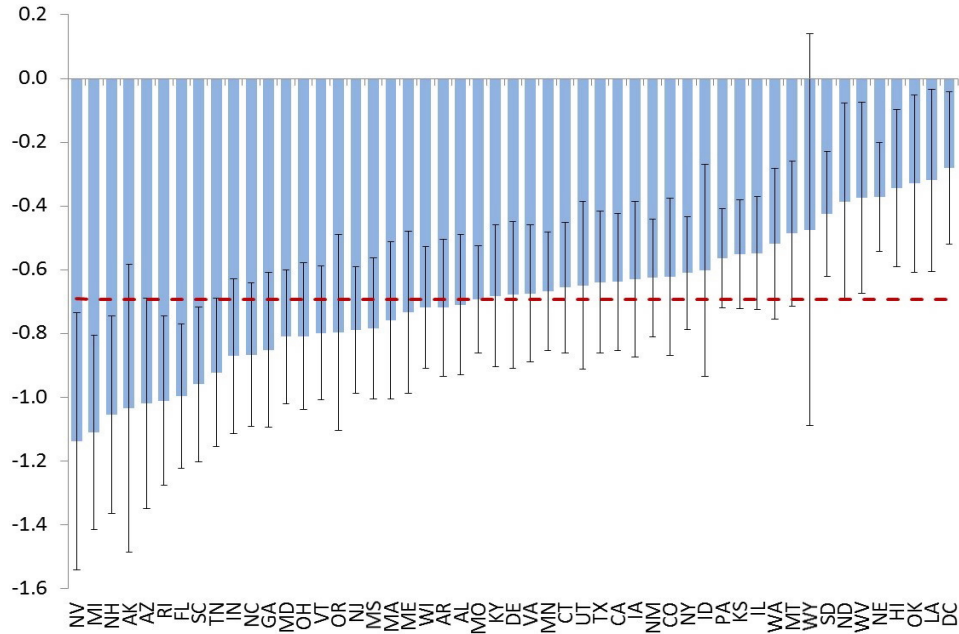
A. U.S. states

B. U.S. metropolitan areas
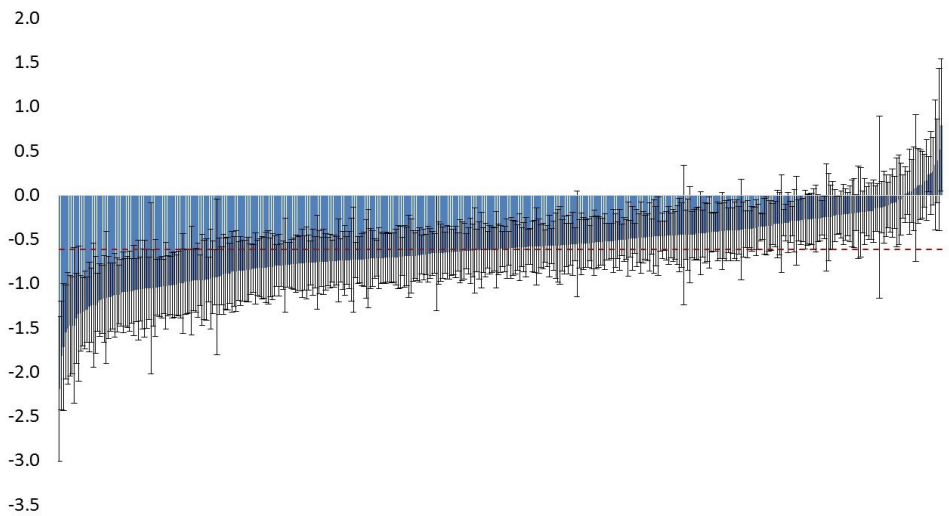
Notes: Figures show the one year cumulative impact on employment growth in U.S. states and MSAs of a 1
percentage point negative shock to U.S. output growth. The effect on national employment growth is -0.70 percent
for states and -0.68 percent for MSAs. The 1 percentage point magnitude of the shock is relatively large given that
the sample standard deviation (a statistical measure of a standard size of a shock) is 0.58 percentage points in
states GVAR model and 0.48 percentage points in MSA GVAR model. The red dashed line shows the average
cumulative impact on state employment (-0.69 percentage points) and MSA employment (-0.61 percentage points).

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A Appendix

This appendix is organized as follows. Section A.1 describes the data, Section A.2 provides details on variance decompositions, Section A.3 provides details on generalized impulse-response analysis, Section A.4 describes the bootstrapping procedures, and Section A.5 presents additional figures and tables.

A.1 Data

Table A1: Description of GVAR variables

Variable	Geographic coverage	Time coverage	Sources
	Employment*		
U.S. employment	U.S.	1980Q2:2016Q4	BLS/Haver Analytics
Employment by state	50 U.S. states plus DC	1980Q2:2016Q4	BLS/Haver Analytics
Employment by MSA	415 U.S. MSAs	1990Q2:2016Q4	BLS/Haver Analytics
	Output**		
U.S. output	U.S.	1980Q2:2016Q4	BEA/Haver Analytics
Foreign output	Argentina, Australia, Austria, Belgium,	1980Q2:2016Q4	DGEI database by
	Canada, China, Colombia, France, Germany,		Grossman et al. (2014)***
	Italy, Japan, Korea, Mexico, Netherlands,		
	Peru, Portugal, South Africa, Spain,		
	Sweden, Switzerland, U.K.		

Notes: (*) Employment is measured as first difference of logarithms of quarterly total nonfarm payroll employment data. (**) Output is measured as first difference of logarithms of quarterly real GDP data. (***) The underlying source of this dataset are national statistical offices as reported in Table 7 of Grossman et al. (2013). BLS stands for Bureau of Labor Statistics, and BEA stands for Bureau of Economic Analysis.

Table A2: Description of State-level indicators

Indicator	Measurement	Time period	Data Sources*
Exports share of GSP	Percent share of exports in state gross state product (GSP)	1996-2016	CB;BEA/HA
Imports share of GSP	Percent share of imports in state GSP	2008-2016	CB;BEA/HA
Employment tied to exports	Jobs tied to state exports as a percent share of wage and salary employment	2000-2015	ITA
GSP share of US GDP	Percent share of state GSP in total U.S. GDP	1980-2016	BEA/HA
Manufacturing share of GSP	Percent share of manufacturing GSP in total state GSP	1997-2016	BEA/HA
Mining share of GSP	Percent share of mining GSP in total state GSP	1997-2016	BEA/HA
Construction share of GSP	Percent share of construction GSP in total state GSP	1997-2016	BEA/HA
Agriculture share of GSP	Percent share of agriculture GSP in total state GSP	1997-2016	BEA/HA
Government share of GSP	Percent share of government GSP in total state GSP	1997-2016	BEA/HA
FIRE share of GSP	Percent share of fire, insurance and real estate sector GSP in total state GSP	1997-2016	BEA/HA
W&R trade share of GSP	Percent share of wholesale and retail trade GSP in total state GSP	1997-2016	BEA/HA
Services share of GSP	Percent share of services GSP in total state GSP	1997-2016	BEA/HA
TPU share of GSP	Percent share of transportation and utilities sector's GSP in total state GSP	1997-2016	BEA/HA
Herfindahl index (destination)	Index measuring diversification of state exports by export destinations	1997-2014	KW
Herfindahl index (product)	Index measuring diversification of state exports by export product	1997-2014	KW
Education (18-24) no highsch	Percent of population 18-24 with less than high school education in total pop aged 18-24	2005-2016	CB/HA
Education (18-24) college	Percent of population 18-24 with bachelor's degree or higher in total pop aged 18-24	2005-2016	CB/HA
Education (25+) no highsch	Percent of population 25+ with less than high school education in total pop aged 25+	2005-2016	CB/HA
Education (25+) college	Percent of population 25+ with bachelor's degree or higher in total pop aged 25+	2006-2016	CB/HA
Population growth	Averages of annual total population growth rates	1980-2017	CB/HA
Real GSP per capita	Real GSP as a share of state population (in thousands)	1980-2017	BEA/HA
Net migration**	Net domestic migration plus net international migration as a share of state population	1991-2017	BEA/HA
Building permits**	Number of permits for new privately owned building as a share state construction output	1980-2017	BEA/HA
Employment of foreign MNCs**	Employment of majority owned U.S. affiliates of foreign multinationals as a share of emp	2007-2017	BEA/HA
Business bankruptcies**	Business bankruptcy filings in the state as a share of state GSP	1980-2017	BEA/HA
NonBusiness bankruptcies**	Nonbusiness bankruptcy filings in the state as a share of state GSP	1980-2017	BEA/HA
Government debt share of GSP	Outstanding state government debt as a percent share of state GSP	1993-2015	CB;BEA/HA
Average temperature	Average temperature in a state relative to the U.S. national average (state temp-U.S. temp)	1980-2015	NCDC/HA
Average precipitation	Average precipitation in a state relative to the U.S. national average (state temp-U.S. temp)	1980-2015	NCDC/HA
Heating degree days	Heating Degree Days index measures heating energy requirements (state HDD-U.S.HDD)	1997-2017	NCDC/HA
Cooling degree days	Cooling Degree Days index measures cooling energy requirements (state CDD-U.S.CDD)	1999-2017	NCDC/HA
Auto debt per capita	Outstanding auto debt balance per capita in the state	1999-2017	FRBNY/HA
Credit card debt per capita	Outstanding credit card debt balance per capita in the state	1999-2017	FRBNY/HA
Mortgage debt per capita	Outstanding mortgage debt balance per capita in the state	1999-2017	FRBNY/HA
Homeownership rate	Owner-occupied housing units as share of total occupied housing unit	1984-2017	CB/HA
Median home values	Zillow estimates of median home values measured by the Zillow Home Value Index	1997-2017	Zillow/HA
Motor vehicle registrations	Number of motor vehicle registrations as a share of state population	1980-2017	FHA/HA
Motor vehicle miles per capita	Number of annual motor vehicle miles traveled as a share of state population	1989-2017	FHA/HA
Rate of natural increase	Rate of natural increase is computed as births minus deaths as a share of state population	2001-2017	CB/HA
Poverty rates	Number of people below poverty level as a percent share of total state population	1980-2016	CB/HA
Population density	Number of people per square mile	1980-2017	CB/HA
Prisoners per capita	Prisoners under state and federal correctional authorities as a share of state population	1982-2016	BJS/HA
Per capita personal income	Real personal income in chained 2009 dollars as a share of state population	1980-2017	BEA/HA
State tax rates	State and local taxes collected as a percent share of total state income taxes	1980-2012	TF
Taxes per capita	State and local taxes collected as a share of state population	1980-2012	TF
Economic freedom index	Index measures degree of economic freedom in govt., legal system, trade, and regulation	1981-2015	FI
Interstate imports share of GSP	Flow of goods into a state from all other U.S. states as a share of state GSP	2012	CFS
Interstate exports share of GSP	Flow of goods out of a state to all other U.S. states as a share of state GSP	2012	CFS

Notes: All shares are expressed in percent. Geographic coverage for all variables is for each of the 50 U.S. states plus Washington D.C., (*) CB = Census Bureau, BEA = Bureau of Economic Analysis , HA = Haver Analytics, KW=Koech and Wynne (2017), ITA = International Trade Administration. NCDC = National Climatic Data Center; FRBNY = Federal Reserve Bank of New York; BJS = Bureau of Justice Statistics; CFS = Commodity Flow Survey; FHA = Federal Highway Administration; TF = Tax Foundation; FI = Fraser Institute (**) These variables are scaled by $1,000,000$ to adjust for their small values.

Variable	Measurement	Time coverage	Data Sources*
Exports share of GDP	Percent share of exports in MSA gross domestic product (GDP)	1996-2016	CB;BEA/HA
Real GDP growth	Annual average growth rate of real GDP in each MSA	2008-2016	CB;BEA/HA
GSP share of US GDP	Percent share of MSA GDP in total U.S. GDP	1980-2016	BEA/HA
Education (18-24) no highsch	Percent of population 18-24 with less than high school education in total pop aged 18-24	2005-2016	CB/HA
Education (18-24) college	Percent of population 18-24 with bachelor's degree or higher in total pop aged 18-24	2005-2016	CB/HA
Education (25+) no highsch	Percent of population 25+ with less than high school education in total pop aged 25+	2005-2016	CB/HA
Education (25+) college	Percent of population 25+ with bachelor's degree or higher in total pop aged 25+	2006-2016	CB/HA
Population growth	Averages of annual total population growth rates	1980-2017	CB/HA
Real GSP per capita	Real GDP as a share of MSA population (in thousands)	1980-2017	BEA/HA
Net migration**	Net domestic migration plus net international migration as a share of MSA population	1991-2017	BEA/HA
Building permits**	Number of permits for new privately owned building as a share MSA GDP	1980-2017	BEA/HA
Business bankruptcies**	Business bankruptcy filings in the MSA as a share of MSA GSP	1980-2017	BEA/HA
NonBusiness bankruptcies**	Nonbusiness bankruptcy filings in the MSA as a share of MSA GSP	1980-2017	BEA/HA
Median home values	Zillow estimates of median home values in a region measured by the Zillow Home Value Index	1997-2017	Zillow/HA
Poverty rates	Number of people below poverty level as a percent share of total MSA population	1980-2016	CB/HA
Per capita personal income	Real personal income in chained 2009 dollars as a share of MSA population	1980-2017	BEA/HA

Notes: (*) CB = Census Bureau, BEA = Bureau of Economic Analysis , HA = Haver Analytics, AOC= Administrative Office of the U.S. Courts. (**) These variables are scaled by 1,000,000 to adjust for their small values.

A.2 Variance Decompositions

Stacking (5) and (6), yields the following GVAR representation of the vector of all variables $\boldsymbol{\xi}_t = (\mathbf{z}_t', \mathbf{h}_t')'$,

$$\boldsymbol{\xi}_t = \mathbf{c}_\xi + \sum_{\ell=1}^{p} \mathbf{G}_{\boldsymbol{\xi},\ell} \boldsymbol{\xi}_{t-\ell} + \boldsymbol{\gamma} v_t + \mathbf{B}\boldsymbol{\eta}_t, \tag{A.1}$$

where $\mathbf{c}_\xi = (\mathbf{c}_z', \mathbf{c}_h')'$, $\boldsymbol{\gamma} = \left(\mathbf{a}_0', \boldsymbol{\delta}'\right)'$, $\boldsymbol{\eta}_t = (\mathbf{e}_t', \boldsymbol{\varepsilon}_t')'$,

$$\mathbf{G}_{\boldsymbol{\xi},\ell} = \left(\begin{array}{cc} \mathbf{G}_{z,\ell} & \mathbf{0} \\ \mathbf{G}_{hz,\ell} & \boldsymbol{\Psi}_\ell \end{array} \right), \text{ for } \ell = 1, 2, ..., p, \text{ and } \mathbf{B} = \left(\begin{array}{cc} \mathbf{I} & \mathbf{0} \\ \boldsymbol{\Lambda}_0 \mathbf{S}_N & \mathbf{I} \end{array} \right).$$

It is useful to define $\mathbf{G}_{\boldsymbol{\xi}}(L) = \mathbf{I} - \sum_{\ell=1}^{p} \mathbf{G}_{\boldsymbol{\xi},\ell} L^\ell$, and its inverse, $\mathbf{Q}_{\boldsymbol{\xi}}(L) = \mathbf{G}_{\boldsymbol{\xi}}^{-1}(L) = \sum_{\ell=0}^{\infty} \mathbf{Q}_{\boldsymbol{\xi},\ell} L^\ell$.[9] In addition, let $\mathbf{S}_h$ be the selection matrix that selects sub-vector $\mathbf{h}_t$ of $\boldsymbol{\xi}_t = (\mathbf{z}_t', \mathbf{h}_t')'$, namely

---

[9] We note that $\mathbf{Q}_{\boldsymbol{\xi},0} = \mathbf{I}$.

$\mathbf{h}_t = \mathbf{S}_h \boldsymbol{\xi}_t$. Then the total variance of regional employment variables is given by

$$V_h^{tot} = \mathbf{S}_h \sum_{\ell=0}^{\infty} \mathbf{Q}_{\xi,\ell} \boldsymbol{\Sigma}_\xi^{tot} \mathbf{Q}_{\xi,\ell} \mathbf{S}_h', \text{ where } \boldsymbol{\Sigma}_\xi^{tot} = \boldsymbol{\gamma}\boldsymbol{\gamma}'\sigma_v^2 + \mathbf{B}\boldsymbol{\Sigma}_\eta \mathbf{B}',$$

in which $\sigma_v^2 = Var(v_t)$ and $\boldsymbol{\Sigma}_\eta = Var(\boldsymbol{\eta}_t)$. In the estimation of $\boldsymbol{\Sigma}_\eta$, we impose $cov(\mathbf{e}_{Nt}, \boldsymbol{\varepsilon}_t) = \mathbf{0}$ which follows from he specifications of our models, but the remaining elements of $\boldsymbol{\Sigma}_\eta$ are unrestricted. The variance of regional employment variables explained by the global shock v_t alone is

$$V_h^{glob} = \mathbf{S}_h \sum_{\ell=0}^{\infty} \mathbf{Q}_{\xi,\ell} \boldsymbol{\Sigma}_\xi^{glob} \mathbf{Q}_{\xi,\ell} \mathbf{S}_h', \text{ where } \boldsymbol{\Sigma}_\xi^{glob} = \boldsymbol{\gamma}\boldsymbol{\gamma}'\sigma_v^2.$$

Similarly, the variance of $\mathbf{h}_t$ explained by the U.S. national shocks is given by

$$V_h^{glob} = \mathbf{S}_h \sum_{\ell=0}^{\infty} \mathbf{Q}_{\xi,\ell} \boldsymbol{\Sigma}_\xi^{nat} \mathbf{Q}_{\xi,\ell} \mathbf{S}_h', \text{ where } \boldsymbol{\Sigma}_\xi^{nat} = \mathbf{B}\mathbf{S_N}E(\mathbf{e}_{Nt}\mathbf{e}_{Nt}')\mathbf{S_N'}\mathbf{B}'.$$

A.3 Generalized Impulse Response Functions

Generalized IRFs are obtained from the GVAR representation (A.1) in a standard fashion. In particular, the vector of GIRFs for a one s.e. increase in v_t on U.S. regional employment variables is given by

$$\begin{aligned}
GIRF_v(\ell) &= E(\mathbf{h}_{t+\ell}|v_t = 1, \mathcal{I}_{t-1}) - E(\mathbf{h}_{t+\ell}|\mathcal{I}_{t-1}) \\
&= \mathbf{S}_h \mathbf{Q}_{\xi,\ell} \boldsymbol{\gamma}\sigma_v,
\end{aligned}$$

where $\mathbf{S}_h$, $\mathbf{Q}_{\xi,\ell}$ and $\boldsymbol{\gamma}$ are defined in Section A.2, and $\mathcal{I}_t$ is the information set consisting of all information up to time period t. Denote the two row vectors of $\mathbf{S}_N$ as $\mathbf{S}_N = \left(\mathbf{s}_{N,y}', \mathbf{s}_{N,h}'\right)$ so that $y_{Nt} = \mathbf{s}_{N,y}'\mathbf{z}_t$ and $h_{Nt} = \mathbf{s}_{N,h}'\mathbf{z}_t$. In addition, partition the U.S. national shocks $\mathbf{e}_{Nt}$ as $\mathbf{e}_{Nt} = (e_{Nyt}, e_{Nht})'$. Then, the GIRF of one s.e. increase in e_{Nyt} is given by

$$\begin{aligned}
GIRF_{e_{Ny}}(\ell) &= E(\mathbf{h}_{t+\ell}|e_{Nyt} = 1, \mathcal{I}_{t-1}) - E(\mathbf{h}_{t+\ell}|\mathcal{I}_{t-1}) \\
&= \frac{\mathbf{S}_h \mathbf{Q}_{\xi,\ell} \boldsymbol{\Sigma}_\xi^{nat}\mathbf{s}_{N,y}}{\sqrt{\mathbf{s}_{N,y}'\boldsymbol{\Sigma}_\xi^{nat}\mathbf{s}_{N,y}}}.
\end{aligned}$$

Similarly, the GIRF for a one s.e. increase in e_{Nht} is given by

$$
\begin{aligned}
GIRF_{e_{Nh}}\left(\ell\right) &= E\left(\mathbf{h}_{t+\ell}|\, e_{Nht}=1, \mathcal{I}_{t-1}\right) - E\left(\mathbf{h}_{t+\ell}|\mathcal{I}_{t-1}\right) \\
&= \frac{\mathbf{S}_h \mathbf{Q}_{\xi,\ell}\boldsymbol{\Sigma}_\xi^{nat}\mathbf{s}_{N,h}}{\sqrt{\mathbf{s}'_{N,y}\boldsymbol{\Sigma}_\xi^{nat}\mathbf{s}_{N,h}}}.
\end{aligned}
$$

A.4 Bootstrapping Procedures

The estimated GVAR model (A.1) is given by $\boldsymbol{\xi}_t = \hat{\mathbf{c}}_\xi + \sum_{\ell=1}^p \hat{\mathbf{G}}_{\boldsymbol{\xi},\ell}\mathbf{z}_{t-\ell} + \hat{\boldsymbol{\gamma}}\hat{v}_t + \hat{\mathbf{B}}\hat{\boldsymbol{\eta}}_t$, where we used hats to denote the sample LS estimates. Using these estimates, we generate R bootstrap samples denoted by $\boldsymbol{\xi}_t^{(r)}$, for $r = 1, 2, ..., R$, computed as

$$
\boldsymbol{\xi}_t^{(r)} = \hat{\mathbf{c}}_\xi + \sum_{\ell=1}^p \hat{\mathbf{G}}_{\boldsymbol{\xi},\ell}\boldsymbol{\xi}_{t-\ell}^{(r)} + \hat{\boldsymbol{\gamma}}v_t^{(r)} + \hat{\mathbf{B}}\hat{\boldsymbol{\eta}}_t^{(r)}, \text{ for } t = 1, 2, ..., T,
$$

with initial values set to the actual data vectors, $\boldsymbol{\xi}_{-\ell}^{(r)} = \boldsymbol{\xi}_{-\ell}$ for $\ell = 0, 1, ..., p-1$, and by resampling with replacement the columns of the matrix of residuals

$$
\hat{\Omega} = \left(\begin{array}{cccc} \hat{\boldsymbol{\eta}}_1 & \hat{\boldsymbol{\eta}}_2 & \cdots & \hat{\boldsymbol{\eta}}_T \end{array}\right) = \left(\begin{array}{cccc} \hat{\mathbf{e}}'_1 & \hat{\mathbf{e}}'_2 & \cdots & \hat{\mathbf{e}}'_T \\ \hat{\boldsymbol{\varepsilon}}_1 & \hat{\boldsymbol{\varepsilon}}_2 & \cdots & \hat{\boldsymbol{\varepsilon}}_T \end{array}\right)'.
$$

Generated bootstrap samples $\boldsymbol{\xi}_t^{(r)}$ are used to estimate the GVAR model, and the objects of interests (impulse-responses and variance decompositions). $(1-\alpha)\%$ confidence sets are given by the $\alpha/2$ and $1 - \alpha/2$ quantiles. The number of bootstrap replication is set to $R = 2000$.

The cross-section regression (8) is bootstrapped as follows. We generate R bootstrap samples $\tilde{u}_\ell^{(r)} = \varkappa_\ell^{(r)}\hat{u}_\ell$, for $\ell = 1, 2, ..., n$, where $\varkappa_\ell^{(r)}$ are i.i.d. and generated such that

$$
\varkappa_\ell = \left\{\begin{array}{ll} -1 & \text{with probability } 1/2 \\ 1 & \text{with probability } 1/2 \end{array}\right. .
$$

Then, we generate $\boldsymbol{\zeta}^{(r)} = \mathbf{X}\hat{\boldsymbol{\beta}} + \tilde{\mathbf{u}}^{(r)}$, and compute the corresponding estimate

$$
\hat{\boldsymbol{\beta}}^{(r)} = \left(\mathbf{X}'\mathbf{X}\right)^{-1}\mathbf{X}'\boldsymbol{\zeta}^{(r)}, \tag{A.2}
$$

and compute quantiles of $\left\{ \hat{\boldsymbol{\beta}}^{(r)}, r = 1, 2, ..., R \right\}$. As before, we set $R = 2000$.

A.5   Additional Figures and Tables

This section contains additional results that are intended for the working paper/online version of the paper but not necessarily for publication.

Panel A of Figure A1 shows employment growth for all fifty U.S. states plus the District of Columbia, while panel B shows employment growth for 255 of the metro areas in our sample. The figure shows that there is significant co-movement in employment at both the state and metro area level.

Panels A and B of Figure A2 provide confidence intervals for our estimates of the share of employment variation at the state and metro area level explained by global shocks. Note that the estimates for D.C., Louisiana, North Dakota and Alaska are not significantly different from zero.

Panels A and B of Figure A3 provide confidence intervals for our estimates of the share of employment variation at the state and metro area level explained by national shocks. Note that the estimates for D.C. and Wyoming are not significantly different from zero.

Panels A and B of Figure A4 provide confidence intervals for our estimates of the share of employment variation at the state and metro area level explained by residual (state- or metro-specific) shocks.

Table A4 repeats the exercise in Table 2, except that we look at the factors that help explain heterogeneity across states in the four-quarter cumulative impact of a global shock on state employment. Note that net migration explains more than a third of the variation across states in the four-quarter response to a global output shock, and is also selected by the OCMT procedure, along with several other indicators that do not show up in Table 2. However, once again the international trade measures do not make the cut.

Table A5 repeats the exercise in Table 2, except that we look at the factors that help explain heterogeneity across states in the four-quarter cumulative impact of a U.S. national output shock on state employment. Employment of foreign multinationals has the highest R^2 in the first stage regression, but it is not that different from the R^2 for population growth. The OCMT procedure picks just these two variables to explain cross-state variation in the four-quarter response of

employment to a U.S. national output shock.

Table A6 repeats the exercise in Table 2, except that we look at the factors that help explain heterogeneity across states in the four-quarter cumulative impact of a U.S. national employment shock on state employment. Net migration rates and population growth both show up as important, as do the size of government relative to GSP, the share of agriculture in GSP and building permits.

Table A7 repeats the exercise in Table 3, except that we look at the factors that help explain heterogeneity across metro areas in the four-quarter cumulative impact of a global output shock on metro area employment. Note that our two measures of international linkages at the metro area level (exports as a share of GDP and net migration) both show up as statistically significant.

Table A8 repeats the exercise in Table 3, except that we look at the factors that help explain heterogeneity across metro areas in the four-quarter cumulative impact of a U.S. national output shock on metro area employment. Exports as a share of metro area GDP no longer show up as statistically significant, but net migration does, along with several other variables.

Table A9 repeats the exercise in Table 3, except that we look at the factors that help explain heterogeneity across metro areas in the four-quarter cumulative impact of a U.S. national employment shock on metro area employment. Exports and migration are again both significant.

Figure A1: Yearly employment growth range across the U.S. states (A) and U.S. metropolitan areas (B)
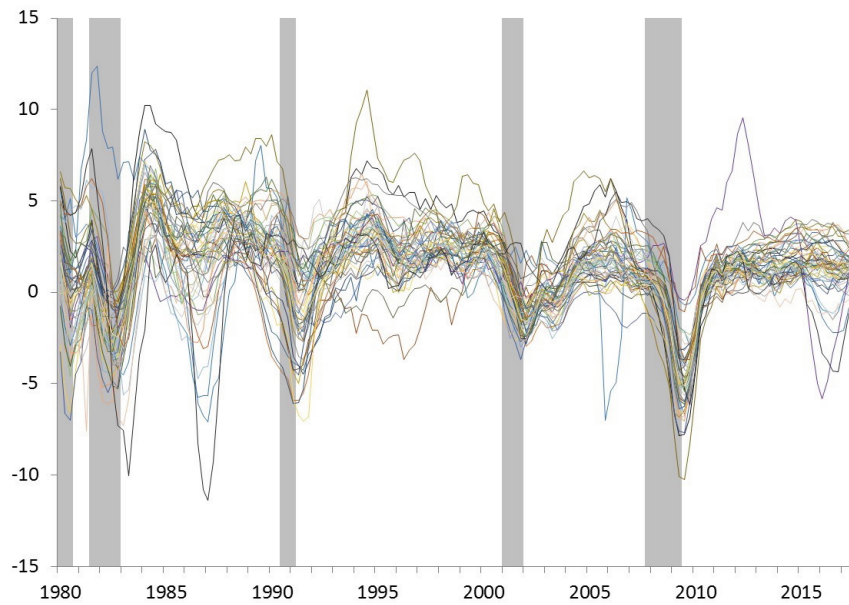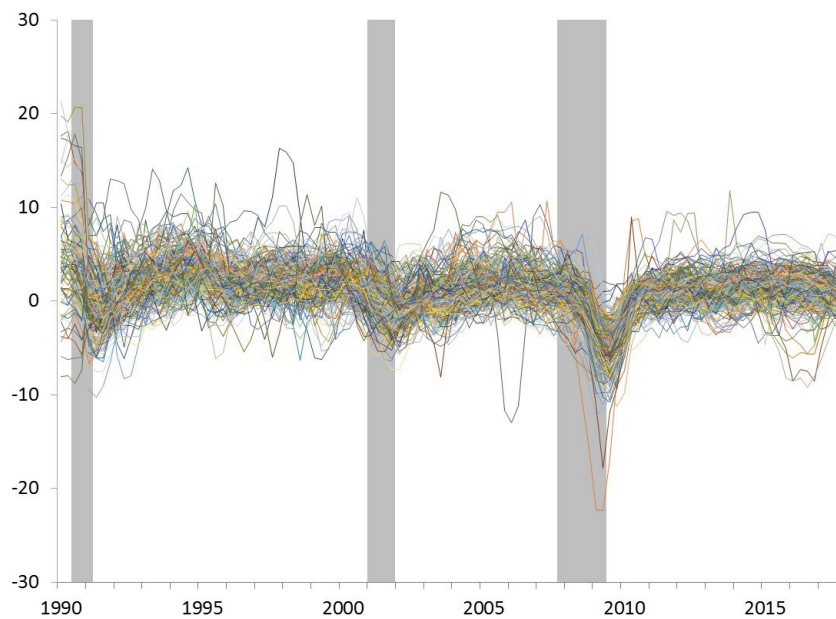
A. U.S. states

B. U.S. metropolitan areas

Notes: Employment fluctuations are computed as year-over-year growth of quarterly nonfarm payroll employment. Data for all 50 U.S. states plus DC are plotted in the top graph and for a sample of first 255 metro areas (in alphabetical order) in the bottom chart (A sample of 255 MSAs is used because of our graphics editor limitations)

Figure A2: Share of U.S. states' employment variation explained by global shocks

A. U.S. states
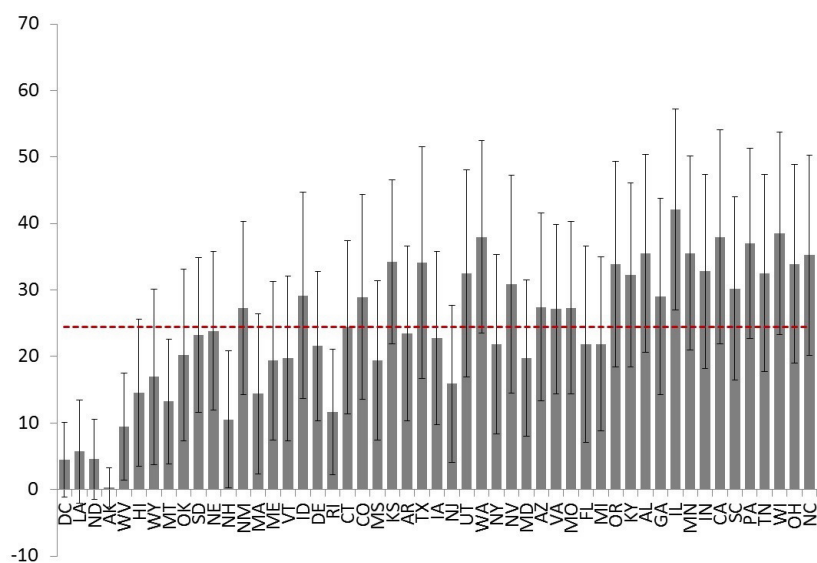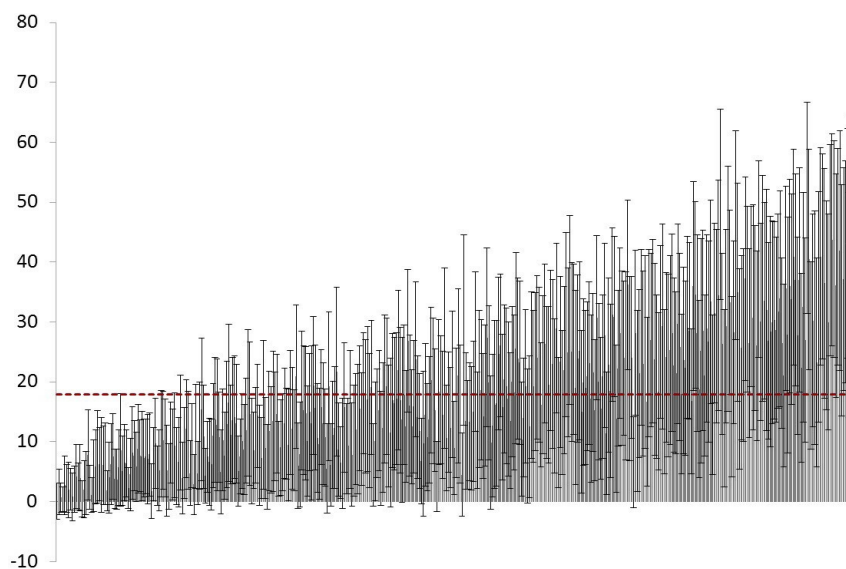
B. U.S. metropolitan areas

Notes: This figure shows the decomposition of the total variance of regional employment fluctuations to contributions from global shocks and 10%-90% confidence bounds, based on the GVAR model outlined in Section 3.2.

Figure A3: Share of U.S. states' employment variation explained by national shocks

A. U.S. states
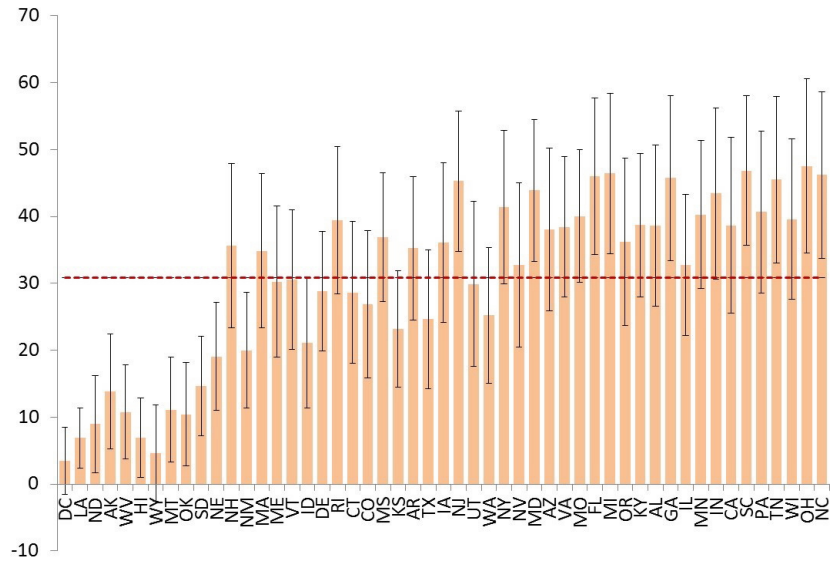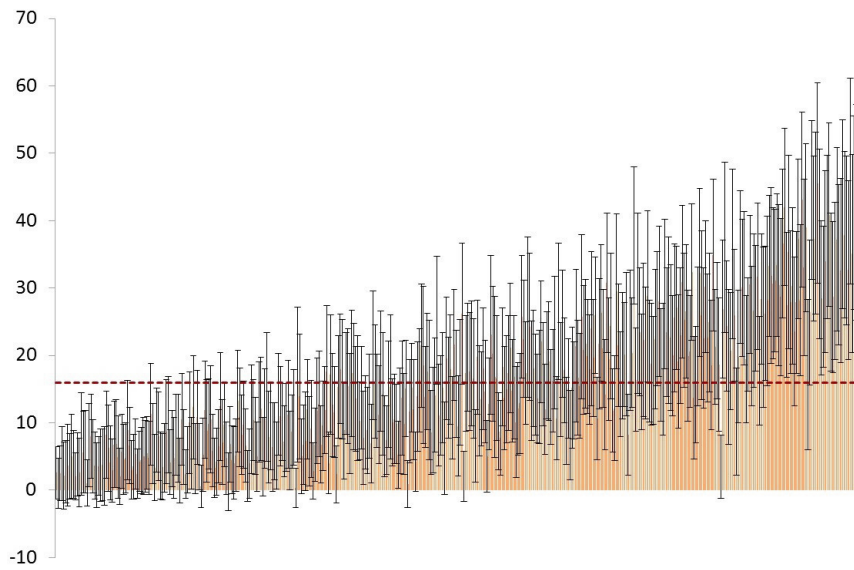
B. U.S. metropolitan areas

Notes: This figure shows the decomposition of the total variance of regional employment fluctuations to contributions from national shocks and 10%-90% confidence bounds, based on the GVAR model outlined in Section 3.2.

Figure A4: Share of U.S. states' employment variation explained by residual shocks

A. U.S. states

B. U.S. metropolitan areas

Notes: This figure shows the decomposition of the total variance of regional employment fluctuations to contributions from residual shocks and 10%-90% confidence bounds, based on the GVAR model outlined in Section 3.2.

Table A4: Explaining state heterogeneity in the four-quarter cumulative impacts of global output shock on state employment

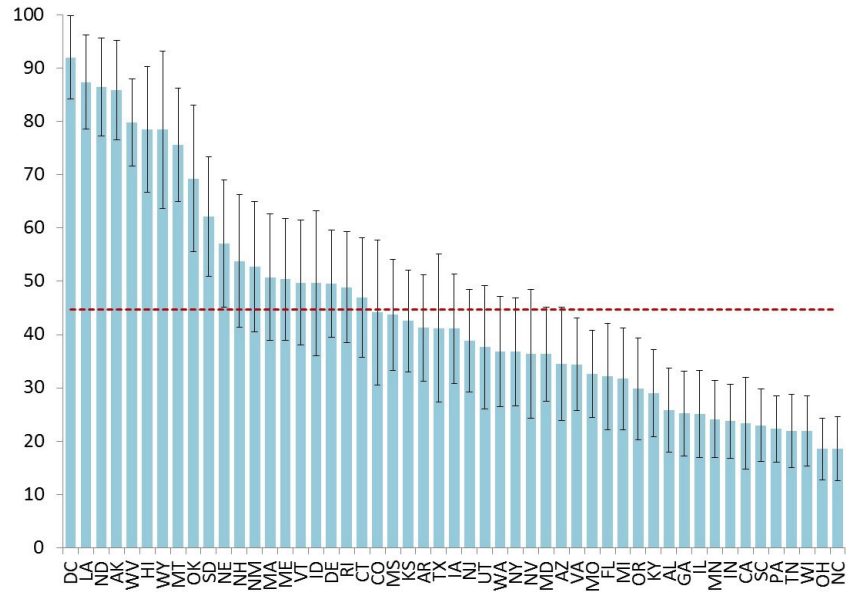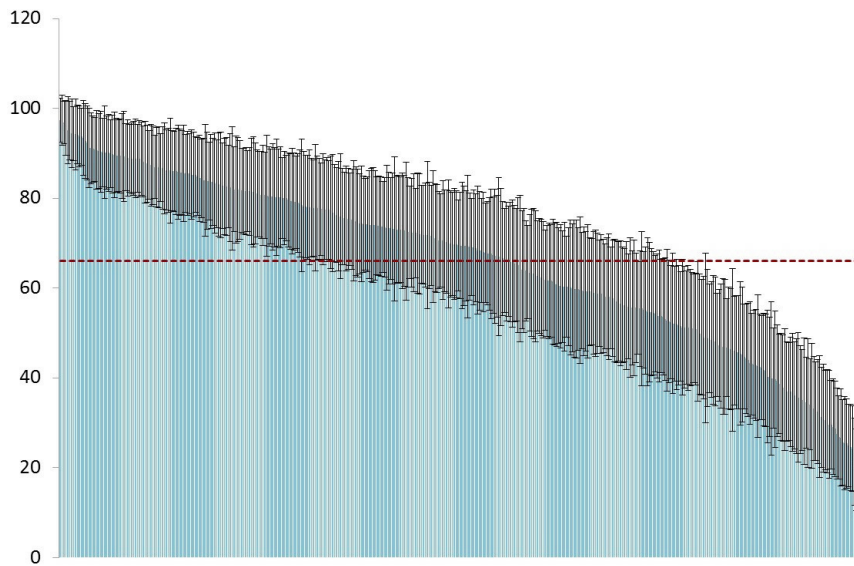| Net effect coefficient estimates				
(Regressors ordered based on R^2)	$\hat{\theta}$	Conf. int.	R^2	n
Net migration	0.162	[0.116, 0.208]	0.390	51
Building permits	0.869	[0.513, 1.222]	0.274	51
NonBusiness bankruptcies	0.014	[0.008, 0.021]	0.253	51
Construction share of GSP	0.626	[0.333, 0.908]	0.177	51
Population growth	0.790	[0.373, 1.214]	0.171	51
Per capita personal income	-0.109	[-0.161, -0.057]	0.168	51
Education (18-24) college	-0.163	[-0.247, -0.079]	0.158	51
Real GSP per capita	0.000	[0.000, 0.000]	0.153	51
Business bankruptcies	0.139	[0.062, 0.216]	0.152	51
MVehicle miles traveled per capita	0.300	[0.119, 0.487]	0.141	51
Education (25+) college	-0.086	[-0.123, -0.050]	0.129	51
Average precipitation	-0.360	[-0.638, -0.073]	0.124	48
Manufacturing share of GSP	0.083	[0.014, 0.151]	0.121	51
Education (18-24) no highsch	0.160	[0.053, 0.266]	0.116	51
Credit card debt per capita	-1.006	[-1.910, -0.081]	0.101	51
Govt. share of GSP	-0.096	[-0.152, -0.040]	0.089	51
Population density	0.000	[0.000, 0.000]	0.086	51
W&R trade share of GSP	0.183	[0.007, 0.359]	0.085	51
Heating degree days	0.000	[0.000, 0.000]	0.084	51
Interstate imports share of GSP	0.021	[0.000, 0.041]	0.066	51
Homeownership rate	0.056	[0.007, 0.102]	0.059	51
Median home values	-0.005	[-0.009, 0.000]	0.056	51
Taxes per capita	-0.372	[-0.734, -0.011]	0.053	51
Government debt share of GSP	-0.087	[-0.215, 0.044]	0.047	51
Interstate exports share of GSP	0.014	[-0.003, 0.031]	0.045	51
TPU share of GSP	-0.158	[-0.517, 0.201]	0.035	51
Economic freedom index	0.391	[-0.234, 1.039]	0.033	50
Mining share of GSP	-0.041	[-0.169, 0.086]	0.027	51
Herfindahl index (product)	0.002	[-0.002, 0.005]	0.024	50
Employment tied to exports	-0.106	[-0.375, 0.165]	0.023	50
Education (25+) no highsch	0.119	[-0.060, 0.296]	0.020	51
Auto debt per capita	0.418	[-0.403, 1.211]	0.019	51
Exports share of GSP	0.048	[-0.042, 0.136]	0.015	51
Herfindahl index (destination)	-0.002	[-0.007, 0.002]	0.014	50
Cooling degree days	0.000	[0.000, 0.001]	0.013	51
MVehicle registrations	0.001	[-0.002, 0.004]	0.011	51
Services share of GSP	-0.079	[-0.276, 0.124]	0.009	51
Employment of foreign MNCs	-0.010	[-0.033, 0.011]	0.008	51
Imports share of GSP	0.011	[-0.019, 0.042]	0.008	51
Poverty rates	0.033	[-0.060, 0.126]	0.006	51
State tax rates	-0.077	[-0.530, 0.382]	0.005	51
Mortgage debt per capita	-0.008	[-0.040, 0.024]	0.003	51
Average temperature	0.007	[-0.027, 0.042]	0.002	48
Rate of natural increase	0.027	[-0.131, 0.185]	0.002	51
GSP share of US GDP	0.028	[-0.073, 0.125]	0.002	51
Agriculture share of GSP	-0.028	[-0.206, 0.149]	0.001	51
Prisoners per capita	-0.005	[-0.300, 0.300]	0.000	50
FIRE share of GSP	-0.001	[-0.062, 0.057]	0.000	51
CS regression for variables selected by OCMT				
	$\hat{\beta}$	Conf. int.		
Construction share of GSP	0.092	[-0.436, 0.626]		
Population growth	-0.801	[-2.003, 0.387]		
Net migration	0.218	[0.086, 0.348]		
Building permits	0.045	[-0.527, 0.627]		
NonBusiness bankruptcies	0.008	[0.003, 0.012]		
Per capita personal income	0.002	[-0.082, 0.088]		
adjusted R^2	0.448			
n	51			

Notes: The dependent variable is the four-quarter cumulative impact of the global output shock, scaled by 1000. Confidence intervals in square brackets are the 90% intervals. Constant is included in all regressions (not reported). Definitions of individual regressors and their regional availability is provided in Appendix. OCMT selection procedure is applied to all state-level indicators using critical value function with $p = 10\%$, $\delta = 1$ and $\delta^* = 2$.

Table A5: Explaining state heterogeneity in the four-quarter cumulative impacts of U.S. national output shock on state employment

Net effect coefficient estimates				
(Regressors ordered based on R^2)	$\hat{\theta}$	Conf. int.	R^2	n
Employment of foreign MNCs	0.043	[0.024, 0.062]	0.176	51
Population growth	0.720	[0.389, 1.045]	0.172	51
Net migration	0.094	[0.047, 0.141]	0.158	51
Agriculture share of GSP	-0.266	[-0.367, -0.163]	0.143	51
Government debt share of GSP	0.108	[0.031, 0.183]	0.088	51
Govt. share of GSP	-0.087	[-0.134, -0.039]	0.088	51
Education (18-24) no highsch	0.105	[-0.004, 0.216]	0.061	51
Auto debt per capita	0.664	[0.005, 1.350]	0.059	51
W&R trade share of GSP	0.132	[-0.010, 0.272]	0.053	51
Population density	0.000	[0.000, 0.000]	0.053	51
Building permits	0.326	[-0.021, 0.683]	0.047	51
Real GSP per capita	0.000	[0.000, 0.000]	0.045	51
Construction share of GSP	0.287	[-0.067, 0.648]	0.045	51
Poverty rates	-0.076	[-0.158, 0.006]	0.040	51
Credit card debt per capita	0.577	[-0.089, 1.242]	0.040	51
Manufacturing share of GSP	0.043	[-0.013, 0.099]	0.039	51
Imports share of GSP	0.022	[-0.011, 0.054]	0.039	51
NonBusiness bankruptcies	0.005	[0.000, 0.010]	0.037	51
Average precipitation	0.201	[-0.111, 0.509]	0.036	48
Mining share of GSP	-0.041	[-0.107, 0.025]	0.031	51
Education (18-24) college	-0.066	[-0.151, 0.018]	0.031	51
Business bankruptcies	-0.054	[-0.126, 0.021]	0.028	51
Prisoners per capita	0.150	[-0.107, 0.409]	0.026	50
Economic freedom index	0.312	[-0.196, 0.814]	0.025	50
Average temperature	0.024	[-0.015, 0.062]	0.025	48
State tax rates	-0.156	[-0.415, 0.099]	0.024	51
Homeownership rate	0.031	[-0.021, 0.086]	0.023	51
MVehicle registrations	-0.001	[-0.004, 0.001]	0.019	51
Exports share of GSP	0.048	[-0.056, 0.151]	0.018	51
TPU share of GSP	-0.096	[-0.352, 0.162]	0.016	51
FIRE share of GSP	0.029	[-0.019, 0.079]	0.015	51
Employment tied to exports	0.077	[-0.095, 0.249]	0.015	50
Education (25+) college	-0.024	[-0.080, 0.033]	0.012	51
Mortgage debt per capita	0.014	[-0.020, 0.048]	0.011	51
Herfindahl index (product)	-0.001	[-0.003, 0.001]	0.009	50
Services share of GSP	-0.070	[-0.215, 0.076]	0.009	51
MVehicle miles traveled per capita	-0.052	[-0.244, 0.135]	0.005	51
Interstate imports share of GSP	0.005	[-0.013, 0.023]	0.005	51
Rate of natural increase	-0.031	[-0.144, 0.082]	0.004	51
Median home values	-0.001	[-0.006, 0.004]	0.004	51
GSP share of US GDP	0.030	[-0.058, 0.119]	0.003	51
Taxes per capita	-0.080	[-0.399, 0.239]	0.003	51
Education (25+) no highsch	0.032	[-0.114, 0.179]	0.002	51
Cooling degree days	0.000	[0.000, 0.000]	0.002	51
Interstate exports share of GSP	0.002	[-0.013, 0.017]	0.001	51
Per capita personal income	-0.006	[-0.063, 0.049]	0.001	51
Heating degree days	0.000	[0.000, 0.000]	0.001	51
Herfindahl index (destination)	0.000	[-0.005, 0.005]	0.000	50
CS regression for variables selected by OCMT				
	$\hat{\beta}$	Conf. int.		
Population growth	0.808	[0.508, 1.109]		
Employment of foreign MNCs	0.048	[0.031, 0.065]		
adjusted R^2	0.350			
n	51			

Notes: The dependent variable is the four-quarter cumulative impact of the U.S. national output shock, scaled by 1000. Confidence intervals in square brackets are the 90% intervals. Constant is included in all regressions (not reported). Definitions of individual regressors and their regional availability is provided in Appendix. OCMT selection procedure is applied to all state-level indicators using critical value function with $p = 10\%$, $\delta = 1$ and $\delta^* = 2$.

Table A6: Explaining state heterogeneity in the four-quarter cumulative impacts of U.S. national employment shock on state employment

Net effect coefficient estimates				
(Regressors ordered based on R^2)	$\hat{\theta}$	Conf. int.	R^2	n
Net migration	0.171	[0.117, 0.224]	0.335	51
Population growth	1.117	[0.693, 1.515]	0.265	51
Government share of GSP	-0.176	[-0.220, -0.130]	0.232	51
Building permits	0.760	[0.386, 1.145]	0.163	51
NonBusiness bankruptcies	0.012	[0.006, 0.019]	0.146	51
Employment of foreign MNCs	0.048	[0.024, 0.072]	0.138	51
Agriculture share of GSP	-0.324	[-0.479, -0.168]	0.136	51
Manufacturing share of GSP	0.099	[0.030, 0.167]	0.133	51
Education (18-24) no highsch	0.190	[0.048, 0.330]	0.127	51
Real GSP per capita	0.000	[0.000, 0.000]	0.119	51
Population density	0.000	[0.000, 0.000]	0.115	51
W&R trade share of GSP	0.237	[0.083, 0.390]	0.111	51
Mining share of GSP	-0.091	[-0.139, -0.043]	0.102	51
Construction share of GSP	0.502	[-0.031, 1.045]	0.088	51
Imports share of GSP	0.041	[0.003, 0.080]	0.087	51
TPU share of GSP	-0.240	[-0.466, -0.007]	0.063	51
Education (18-24) college	-0.117	[-0.235, 0.001]	0.063	51
Economic freedom index	0.584	[0.097, 1.067]	0.062	50
Auto debt per capita	0.809	[-0.104, 1.690]	0.056	51
Average temperature	0.044	[0.000, 0.088]	0.054	48
FIRE share of GSP	0.064	[0.008, 0.121]	0.048	51
Exports share of GSP	0.098	[-0.025, 0.223]	0.048	51
Heating degree days	0.000	[0.000, 0.000]	0.047	51
Homeownership rate	0.054	[-0.026, 0.133]	0.043	51
Prisoners per capita	0.223	[-0.055, 0.508]	0.040	50
GSP share of US GDP	0.132	[0.020, 0.240]	0.039	51
Education (25+) college	-0.053	[-0.129, 0.022]	0.039	51
Government debt share of GSP	0.079	[-0.023, 0.182]	0.031	51
Education (25+) no highsch	0.155	[-0.017, 0.326]	0.027	51
Herfindahl index (product)	-0.002	[-0.004, 0.000]	0.025	50
Poverty rates	-0.074	[-0.177, 0.028]	0.025	51
Herfindahl index (destination)	-0.003	[-0.010, 0.004]	0.025	50
Motor vehicle registrations	-0.002	[-0.006, 0.002]	0.024	51
Per capita personal income	-0.045	[-0.121, 0.030]	0.022	51
Interstate exports share of GSP	0.011	[-0.008, 0.029]	0.022	51
Median home values	-0.003	[-0.009, 0.003]	0.017	51
Interstate imports share of GSP	0.012	[-0.010, 0.033]	0.017	51
Mortgage debt per capita	0.019	[-0.026, 0.066]	0.014	51
Average precipitation	0.105	[-0.306, 0.529]	0.007	48
Employment tied to exports	0.057	[-0.145, 0.257]	0.005	50
State tax rates	-0.075	[-0.390, 0.240]	0.004	51
Cooling degree days	0.000	[0.000, 0.001]	0.003	51
Taxes per capita	-0.091	[-0.512, 0.336]	0.002	51
Credit card debt per capita	0.166	[-0.604, 0.949]	0.002	51
Business bankruptcies	0.018	[-0.089, 0.128]	0.002	51
Rate of natural increase	0.015	[-0.101, 0.133]	0.001	51
MVehicle miles traveled per capita	0.017	[-0.233, 0.257]	0.000	51
Services share of GSP	0.007	[-0.194, 0.207]	0.000	51
CS regression for variables selected by OCMT				
	$\hat{\beta}$	Conf. int.		
Agriculture share of GSP	-0.418	[-0.523, -0.314]		
Government share of GSP	-0.164	[-0.211, -0.119]		
Population growth	0.190	[-0.467, 0.831]		
Net migration	0.047	[-0.068, 0.166]		
Building permits	0.613	[0.185, 1.056]		
adjusted R^2	0.616			
n	51			

Notes: The dependent variable is the four-quarter cumulative impact of the U.S. national employment shock, scaled by 1000. Confidence intervals in square brackets are the 90% intervals. Constant is included in all regressions (not reported). Definitions of individual regressors and their regional availability is provided in Appendix. OCMT selection procedure is applied to all state-level indicators using critical value function with $p = 10\%$, $\delta = 1$ and $\delta^* = 2$.

Table A7: Explaining MSA heterogeneity in the four-quarter cumulative impacts of global output shock on MSA employment

Net effect coefficient estimates				
(Regressors ordered based on R^2)	$\hat{\theta}$	Conf. int.	R^2	n
Education (18-24) no highsch	0.126	[0.083, 0.168]	0.103	383
Net migration	0.074	[0.038, 0.110]	0.068	365
Education (18-24) college	-0.147	[-0.195, -0.097]	0.053	383
Education (25+) college	-0.047	[-0.069, -0.025]	0.034	383
Population growth	0.326	[0.108, 0.545]	0.029	374
Exports share of GDP	0.026	[0.005, 0.046]	0.014	342
Business bankruptcies	0.177	[0.023, 0.334]	0.013	364
Poverty rates	-0.039	[-0.064, -0.014]	0.013	372
Real GDP growth	0.174	[-0.065, 0.415]	0.009	365
Education (25+) no highsch	0.051	[0.001, 0.101]	0.007	383
NonBusiness bankruptcies	0.003	[0.000, 0.007]	0.007	365
Median home values	0.001	[0.000, 0.003]	0.002	361
Per capita personal income	0.013	[-0.039, 0.065]	0.001	365
Real GSP per capita	-0.003	[-0.019, 0.013]	0.000	364
Building permits	0.014	[-0.090, 0.119]	0.000	364
GDP share of US GDP	0.013	[-0.127, 0.153]	0.000	365

CS regression featuring all indicators		
	$\hat{\beta}$	Conf. int.
Exports share of GDP	0.041	[0.020, 0.062]
Real GDP growth	-0.011	[-0.410, 0.373]
GDP share of US GDP	0.004	[-0.199, 0.207]
Real GSP per capita	0.052	[0.011, 0.092]
Population growth	-0.191	[-0.454, 0.070]
Net migration	0.106	[0.056, 0.153]
Business bankruptcies	0.136	[-0.043, 0.315]
NonBusiness bankruptcies	0.000	[-0.004, 0.004]
Building permits	-0.051	[-0.178, 0.082]
Education (18-24) no highsch	0.046	[-0.042, 0.133]
Education (18-24) college	-0.075	[-0.191, 0.043]
Education (25+) no highsch	-0.067	[-0.166, 0.034]
Education (25+) college	-0.051	[-0.103, 0.001]
Per capita personal income	-0.077	[-0.159, 0.007]
Median home values	0.002	[-0.001, 0.004]
Poverty rates	-0.041	[-0.104, 0.022]
adjusted R^2	0.158	
n	335	

Notes: The dependent variable is the four-quarter cumulative impact of the global output shock, scaled by 1000. Confidence intervals in square brackets are the 90% intervals. Constant is included in all regressions (not reported). Definitions of individual regressors and their regional availability is provided in Appendix.

Table A8: Explaining MSA heterogeneity in the four-quarter cumulative impacts of U.S. national output shock on MSA employment

Net effect coefficient estimates				
(Regressors ordered based on R^2)	$\hat{\theta}$	Conf. int.	R^2	n
Net migration	0.065	[0.044, 0.085]	0.075	365
NonBusiness bankruptcies	0.007	[0.004, 0.009]	0.048	365
Business bankruptcies	0.272	[0.151, 0.387]	0.045	364
Population growth	0.326	[0.171, 0.476]	0.041	374
Education (18-24) no highsch	0.054	[0.022, 0.087]	0.028	383
Median home values	0.003	[0.002, 0.004]	0.022	361
Per capita personal income	-0.038	[-0.083, 0.009]	0.016	365
GDP share of US GDP	0.274	[0.109, 0.439]	0.011	365
Real GDP growth	-0.160	[-0.343, 0.032]	0.010	365
Education (25+) no highsch	-0.047	[-0.094, 0.002]	0.009	383
Poverty rates	0.026	[-0.002, 0.052]	0.008	372
Exports share of GDP	-0.010	[-0.024, 0.004]	0.003	342
Education (25+) college	0.009	[-0.009, 0.028]	0.002	383
Building permits	0.025	[-0.104, 0.153]	0.001	364
Real GSP per capita	-0.003	[-0.016, 0.010]	0.000	364
Education (18-24) college	0.001	[-0.040, 0.040]	0.000	383
CS regression featuring all indicators				
	$\hat{\beta}$	Conf. int.		
Exports share of GDP	0.009	[-0.006, 0.023]		
Real GDP growth	-0.332	[-0.597, -0.072]		
GDP share of US GDP	0.246	[0.034, 0.454]		
Real GSP per capita	0.016	[-0.013, 0.045]		
Population growth	0.130	[-0.093, 0.357]		
Net migration	0.068	[0.030, 0.104]		
Business bankruptcies	0.100	[-0.016, 0.215]		
NonBusiness bankruptcies	0.005	[0.001, 0.008]		
Building permits	-0.016	[-0.177, 0.149]		
Education (18-24) no highsch	0.058	[-0.003, 0.118]		
Education (18-24) college	0.060	[-0.026, 0.149]		
Education (25+) no highsch	-0.091	[-0.173, -0.010]		
Education (25+) college	-0.009	[-0.045, 0.028]		
Per capita personal income	-0.062	[-0.131, 0.008]		
Median home values	0.003	[0.001, 0.005]		
Poverty rates	-0.025	[-0.078, 0.030]		
adjusted R^2	0.221			
n	335			

Notes: The dependent variable is the four-quarter cumulative impact of the U.S. national output shock, scaled by 1000. Confidence intervals in square brackets are the 90% intervals. Constant is included in all regressions (not reported). Definitions of individual regressors and their regional availability is provided in Appendix.

Table A9: Explaining MSA heterogeneity in the four-quarter cumulative impacts of U.S. national employment shock on MSA employment

Net effect coefficient estimates				
(Regressors ordered based on R^2)	$\hat{\theta}$	Conf. int.	R^2	n
Net migration	0.093	[0.070, 0.116]	0.118	365
Population growth	0.419	[0.237, 0.601]	0.052	374
Median home values	0.005	[0.003, 0.007]	0.048	361
GDP share of US GDP	0.633	[0.312, 0.957]	0.044	365
Education (18-24) no highsch	0.062	[0.028, 0.096]	0.028	383
Education (25+) college	0.041	[0.021, 0.060]	0.027	383
Business bankruptcies	0.227	[0.086, 0.366]	0.024	364
Real GSP per capita	0.027	[0.011, 0.042]	0.021	364
Education (18-24) college	0.076	[0.028, 0.120]	0.016	383
Poverty rates	-0.035	[-0.058, -0.012]	0.011	372
NonBusiness bankruptcies	0.003	[0.000, 0.006]	0.009	365
Education (25+) no highsch	-0.037	[-0.088, 0.013]	0.004	383
Per capita personal income	0.013	[-0.030, 0.055]	0.001	365
Real GDP growth	0.044	[-0.128, 0.216]	0.001	365
Exports share of GDP	0.004	[-0.019, 0.027]	0.000	342
Building permits	0.014	[-0.107, 0.134]	0.000	364
CS regression featuring all indicators				
	$\hat{\beta}$	Conf. int.		
Exports share of GDP	0.027	[0.008, 0.047]		
Real GDP growth	-0.271	[-0.528, -0.020]		
GDP share of US GDP	0.304	[0.041, 0.560]		
Real GSP per capita	0.047	[0.013, 0.081]		
Population growth	-0.066	[-0.280, 0.153]		
Net migration	0.116	[0.078, 0.155]		
Business bankruptcies	0.163	[0.029, 0.291]		
NonBusiness bankruptcies	0.005	[0.002, 0.009]		
Building permits	-0.053	[-0.170, 0.067]		
Education (18-24) no highsch	0.074	[0.015, 0.134]		
Education (18-24) college	0.101	[-0.006, 0.209]		
Education (25+) no highsch	-0.090	[-0.170, -0.010]		
Education (25+) college	-0.006	[-0.047, 0.037]		
Per capita personal income	-0.072	[-0.153, 0.009]		
Median home values	0.003	[0.001, 0.006]		
Poverty rates	0.000	[-0.063, 0.062]		
adjusted R^2	0.211			
n	335			

Notes: The dependent variable is the four-quarter cumulative impact of the U.S. national employment shock, scaled by 1000. Confidence intervals in square brackets are the 90% intervals. Constant is included in all regressions (not reported). Definitions of individual regressors and their regional availability is provided in Appendix.