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A State-Level Analysis of Okun's Law*

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Abstract

Okun's law is an empirical relationship that measures the correlation between the deviation of the unemployment rate from its natural rate and the deviation of output growth from its potential. This relationship is often referred to by policy makers and used by forecasters. In this paper, we estimate Okun's coefficients separately for each U.S. state using an unobserved components framework and find variation of the coefficients across states. We exploit this heterogeneity of Okun's coefficients to directly examine the potential factors that shape Okun's law, and find that indicators of more flexible labor markets (higher levels of education achievement in the population, lower rate of unionization, and a higher share of non-manufacturing employment) are important determinants of the differences in Okun's coefficient across states.

[JEL codes: C32, E32, R11]

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1 Introduction

Okun's law is an empirically observed relationship between the deviation of the unemployment rate from its natural rate and the deviation of output growth from its potential. In his original specification, Okun [1962] used data on the quarter-to-quarter growth rate of the real gross national product (GNP) and the quarter-to-quarter difference in the unemployment rate from 1947 to 1960. He estimated that for each 1 percent increase in real GNP growth, the unemployment rate would decrease 0.3 percentage points.

While subsequent studies have attempted to develop theories explaining the existence of Okun's law, the original manifestation was a purely statistical relationship. Attributing an underlying mechanism for Okun's law, however, is problematic since any number of theories could be consistent with the observed empirical relationship. One way to help identify the mechanism is to exploit cross-sectional differences in the magnitude of Okun's coefficient. For example, past research has verified the existence of an Okun's law for other countries. More recently, the relationship has been estimated for various regional groupings within a country. While most of the literature has found significant regional disparities in Okun's coefficient (e.g., in the Czech Republic and Slovakia [Durech et al., 2014], Canada [Adanu, 2005], and France [Binet and Facchini, 2013]), some countries were not found to have significant regional variation (e.g., Spain [Villaverde and Maza, 2009] and Greece [Apergis and Rezitis, 2003]). Moreover, the strength of the relationship has been found to vary across countries (see Paldam [1987], Kaufman [1988], Moosa [1997], Lee [2000], Freeman [2001], Cazes et al. [2013], Hutengs and Stadtmann [2013]). This variation is often attributed to differences in employment protection and minimum wage laws, the power of trade unions, and demographics.

Confounding these cross-country studies is the variation in the implementation of both monetary and national fiscal policy, which may change the timing or conditions under which shocks to either unemployment or output could affect each other. Concerns about the variation in national policy are mitigated for the U.S. states, which provide variation in labor markets, demographics, and industrial compositions while simultaneously residing in a single currency union. For the United States, Okun's law has been estimated at a state-level for selective states [Blackley, 1991] and larger regional groups [Freeman, 2000] with mixed results on regional differences.[1]

In this paper, we exploit state-level data to determine the effects of labor market structure on the strength of the Okun relationship. We first verify the existence of Okun's law at the state-level. We estimate Okun's law using an unobserved components (UC) framework, which has two main advantages over estimating the relationship in differences, as is common in the literature. First, the UC framework allows for the potential output and the natural rate of unemployment to be time varying. Second, UC allows us to estimate the Okun coefficient simultaneously with the potential output and the natural rate. This allows us to take into account the uncertainty of estimating the potential output and natural rate of unemployment, thereby allowing us to accurately estimate the coefficients and standard errors.

We confirm the existence of the Okun relationship at the state level and find substantial variation by state, with estimated coefficients ranging from -4.38 (North Dakota) to -1.25 (Colorado). These numbers compare with the national coefficient (-2.03) and are similar to other recent studies [Lee, 2000, Daly et al., 2014]. We also find some interesting variation in the dynamics of potential output and the natural rate across states.

We next examine the potential factors that explain the geographic variation across the estimated Okun relationships. We consider indicators of labor market flexibility and demographic characteristics, which have been indicated as possible determinants of variation in the macroeconomic literature. Our results illustrate that indicators of labor market flexibility have a significant effect on the strength of the Okun relationship. In particular, we find that union membership, education, and industry concentration are statistically significant. More union membership and more concentrated industries are associated with a larger (magnitude) Okun's coefficient. Alternatively, states with a larger share of their population having a college education are associated with a lower (magnitude) of Okun's coefficient and more labor market flexibility.

The balance of the paper is organized as follows: Section 2 describes the model that we use to estimate Okun's coefficient. We employ an unobserved components decomposition that allows us to estimate both the time-varying potential output and the time-varying natural rate of unemployment. Section 3 describes the methods and data we use for the estimation. Section 4 discusses the

[1] Regional-level data has also been used to exploit spatial relationships to estimate Okun's law at a national level [Kosfeld and Dreger, 2006, Kangasharju et al., 2012].

estimated Okun's coefficients at the national and state level. Section 5 describes the methodology used to estimate the determinants of the state-level relationship. Section 6 summarizes and offers some concluding remarks.

2 The Empirical Model

Okun's law measures the correlation between the deviation of the unemployment rate from its natural rate and the deviation of output growth from its potential. This correlation can be estimated from:

$$Y_t - Y_t^* = \alpha + \beta\,(u_t - u_t^*) + \omega_t, \tag{1}$$

where Y_t is period$-t$ log real output, Y_t^* is log potential output, u_t^* is the natural rate of unemployment, u_t is the unemployment rate, and ω_t is a zero-mean i.i.d. innovation.[2] The intercept term α represents the expected growth rate of output at a stable unemployment rate and the coefficient β represents how a one-percentage-point increase in the unemployment rate affects the output growth rate—the so-called Okun's coefficient. While potential output and the natural rate of unemployment are unobserved, if they are assumed to be constant, it is straightforward to estimate the relationship in differences:

$$\Delta Y_t = \alpha + \beta \Delta u_t + \omega_t^{\dagger}. \tag{2}$$

However, if potential output and the natural rate are time-varying, (2) will return biased estimates of Okun's coefficient.[3]

One method used to estimate (1) is to obtain Y_t^* and u_t^* through prefiltering techniques (e.g.,

[2]Okun [1962] originally estimated deviations in the unemployment rate as the dependent variable and deviations in output as the independent variable. As it is common to assume that other shocks affect output more than unemployment, we prefer to treat output deviations as the dependent variable. This alternative specification, however, does not imply that the inverse of our coefficient is comparable with the original Okun [1962] results [Plosser and Schwert, 1979].

[3]Nelson and Plosser [1982] found evidence that most U.S. time series data are not well identified by a deterministic, linear trend. Additionally, Perry et al. [1970] and Adams and Coe [1990] find that the natural rate of unemployment varies over time, which may be due to changes in demographics, the unemployment insurance, relative minimum wages, and other factors of labor market rigidities (such as unionization rates). We find that changing the specification (i.e., how we identify the permanent component) leads to different point estimates of Okun's coefficients, which is consistent with previous research [Lee, 2000, Prachowny, 1993].

the Hodrick and Prescott [1997] filter). The HP-filter and some band-pass filters, however, can introduce spurious cycles into the resulting data. The results are also sensitive to the sample period and have poor end-of-sample properties. A second method uses third-party (e.g., Congressional Budget Office) estimates of Y_t^* and u_t^*, which can be problematic if they already assume an Okun-type relationship—i.e., the third party data may assume the result. Moreover, the data may not be available at the relevant level of disaggregation, as in our case. For both methods, potential output and the natural rate are often treated as *known quantities*, meaning that the coefficients associated with the estimation of (1) may be more uncertain than reported.

In this paper, we estimate (1) for U.S. states using the unobserved components (UC) framework, which allows for time variation in both Y_t^* and u_t^* and provides the state-level trend and cycle for the unemployment rate and output.[4] Let Y_{nt} and u_{nt} represent state n's period$-t$ log level of output and the unemployment rate, respectively. Each series is assumed to be $I(1)$ and can be decomposed into a permanent component, Y_{nt}^* and u_{nt}^*, and a transitory component, c_{nt}^i, $i = \{y, u\}$ so that

$$\begin{bmatrix} Y_{nt} \\ u_{nt} \end{bmatrix} = \begin{bmatrix} Y_{nt}^* \\ u_{nt}^* \end{bmatrix} + \begin{bmatrix} c_{nt}^y \\ c_{nt}^u \end{bmatrix}. \tag{3}$$

where Y_{nt}^*, u_{nt}^*, c_{nt}^y, and c_{nt}^u are unobserved.[5]

To identify the latent components, we assume the permanent components follow unit root processes with constant drift, μ_n^i:

$$Y_{nt}^* = \mu_n^y + Y_{nt-1}^* + \eta_{nt}^y, \tag{4}$$

$$u_{nt}^* = \mu_n^u + u_{nt-1}^* + \eta_{nt}^u, \tag{5}$$

[4] Unlike the HP-filter, the UC can be generalized to allow for multiple series and correlation between the innovations to the components, but it still suffers from the poor end-of-sample properties [Orphanides and Norden, 2002].

[5] The I(1) assumption for both variables is consistent with Sinclair [2009]. Additionally, we fail to reject the null hypothesis that the data is stationary for 42 and 50 states at the 5% significance level for output and the unemployment rate, respectively. These results are available upon request from the corresponding author.

and the transitory components follow stationary autoregressive processes:

$$c^i_{nt} = \phi^i_n(L)\, c^i_{nt-1} + \varepsilon^i_{nt}, \tag{6}$$

where $\phi^i_n(L)$ is a polynomial in the lag operator of at least order 2, $v_{nt} = [\eta^y_{nt}, \eta^u_{nt}, \varepsilon^y_{nt}, \varepsilon^u_{nt}]'$, and $v_{nt} \sim N(0, \Omega_n)$.[6]

While the canonical unobserved components model (e.g., Harvey [1985] and Clark [1987]) assumes that Ω_n is diagonal, recent work (e.g., Morley et al. [2003] and Sinclair [2009]) has shown that this assumption can be relaxed, but that it relegates most of the dynamics to the permanent component. We impose zero restrictions on the off-diagonal elements of the covariance matrix except for $\sigma_{n\varepsilon^y\varepsilon^u}$, the correlation between the innovations of the two transitory components:

$$\Omega_n = \begin{bmatrix} \sigma^2_{n\eta^y} & 0 & 0 & 0 \\ 0 & \sigma^2_{n\eta^u} & 0 & 0 \\ 0 & 0 & \sigma^2_{n\varepsilon^y} & \sigma_{n\varepsilon^y\varepsilon^u} \\ 0 & 0 & \sigma_{n\varepsilon^y\varepsilon^u} & \sigma^2_{n\varepsilon^u} \end{bmatrix}. \tag{7}$$

Thus, correlation between state-level output and the unemployment rate arises only through the transitory innovations, which is consistent with Okun's original interpretation.[7]

The model (3) relates directly back to the original specification of Okun's law, (1), where the trend components are interpreted as a time-varying natural rate and a time-varying potential output. The cyclical components then reflect the deviations from potential and the natural rate discussed by Okun. To see this, rewrite each state's cyclical components as a VAR:

$$\begin{bmatrix} c^y_{nt} \\ c^u_{nt} \end{bmatrix} = \phi_n(L) \begin{bmatrix} c^y_{nt} \\ c^u_{nt} \end{bmatrix} + \begin{bmatrix} \varepsilon^y_{nt} \\ \varepsilon^u_{nt} \end{bmatrix} \tag{8}$$

and define $A_n \Sigma_n A'_n = E_t\left[e^p_{nt} e^{p\prime}_{nt}\right]$ as the upper right submatrix of Ω_n, where $e^p_{nt} = [\varepsilon^y_{nt}, \varepsilon^u_{nt}]'$, Σ_n is diagonal, and A^{-1}_n is upper triangular with unit diagonal.[8] We can rewrite (8) in a "structural"

[6]Harvey [1985], Clark [1987], and Harvey and Jaeger [1993] suggest specifying the autoregressive lags greater than or equal to 2 is necessary for the cycle to be periodic.

[7]Gonzalez-Astudillo [2017] estimates an unobserved components model using quarterly state-level GDP data. His model produces both state and national trends and cycles but is estimated over a shorter time horizon as the BEA's quarterly dataset only starts in 2005.

[8]At the suggestion of two anonymous referees, we considered two alternative specifications. The first restricts the

form as:

$$A_n^{-1}\begin{bmatrix} c_{nt}^{y} \\ c_{nt}^{u} \end{bmatrix} = A_n^{-1}\phi_n(L)\begin{bmatrix} c_{nt}^{y} \\ c_{nt}^{u} \end{bmatrix} + \begin{bmatrix} e_{nt}^{y} \\ e_{nt}^{u} \end{bmatrix}, \tag{9}$$

where Okun's coefficient is measured by the inverse of the off-diagonal element of A_n^{-1}. At this stage, we note that the description of Okun's law in our model requires an implicit Wold causal ordering for identification: We have imposed a recursive structure in the decomposition of Ω_n used to identify A_n^{-1}.

Since the model characterized by (3) − (7) treats each state separately, we are explicitly suppressing cross-state dynamics in both the trends and the cycles. It is entirely plausible—if not likely—that states both grow together (i.e., have correlated trends) and experience coincident business cycles (i.e., have correlated cycles). The model does not rule these correlations out; *ex post* correlation of the individual components is still possible. The limitation of the model, however, is that it does not inform us about how (or whether) the shocks to the individual components might be correlated across states. Such a model, albeit interesting, would require simultaneous estimation of a model with $2N$ equations, which is infeasible given the relatively small number of observations available at the state-level.

3 Econometric Methodology

We now outline the estimation of Okun's coefficients, state-level potential outputs, and natural rates. We then discuss how we identify the factors behind the cross-state heterogeneity of the estimated Okun's coefficients. At the national level, output is measured as the quarterly real gross domestic product (GDP).[9] Similar data are available for the states, with the exception that output is measured by gross state product (GSP). The available GSP data incorporates the first part of the BEA's 2013 comprehensive revision released in September 2013.[10] While state-level unemployment

drift term in the unemployment trend to be zero, which is rejected for a number of states. The second included lags of adjacent states' macroeconomic outcomes in the cycles. For a few states, this caused those states' cyclical components to appear like white noise. Thus, to maintain consistency across state specifications, we use the unrestricted drift, no cross-state spillover specification. Results for these specifications are available upon request.

[9] In his original paper, Okun [1962] used gross national product (GNP), which includes net foreign income. The BEA switched from GNP to GDP in 1991 under the belief that GDP more accurately represented the level of national production.

[10] For more information about the data revision, see `http://www.bea.gov/regional/docs/Info2013CompRev.cfm`.

is available monthly, the GSP dataset is available only at an annual frequency. Therefore, for the state-level analysis, we estimate the restricted version of the correlated unobserved components model individually for each state using the annual GSP and the annual average of the unemployment rate from 1977-2012.[11]

3.1 Estimating the UC Model

It is convenient to summarize the model in its state-space representation, where $\xi_{nt} = \left[Y^*_{nt}, u^*_{nt}, \widetilde{c}^{y\prime}_{nt}, \widetilde{c}^{u\prime}_{nt}\right]'$ is the state vector and $\widetilde{c}^{i}_{nt} = \left[c^i_{nt}, c^i_{nt-1}, ..., c^i_{nt-p-1}\right]'$ contains both the current period and lagged values of the transitory component. The measurement equation is $[Y_{nt}, u_{nt}]' = H\xi_{nt}$, where

$$H = \begin{bmatrix} 1 & 0 & 1 & \mathbf{0}'_{p-1\times 1} & 0 & \mathbf{0}'_{p-1\times 1} \\ 0 & 1 & 0 & \mathbf{0}'_{p-1\times 1} & 1 & \mathbf{0}'_{p-1\times 1} \end{bmatrix}$$

and $\mathbf{0}_{p-1\times 1}$ is an $p-1\times 1$ matrix of zeros.

Let $\widetilde{\phi}^i_n = \begin{bmatrix} \phi^i_{n1} & \cdots & \phi^i_{np} \end{bmatrix}$ represent the vector containing the coefficients in the pth order lag polynomial $\phi^i_n(L)$ and define

$$\Phi^i_n = \begin{bmatrix} \widetilde{\phi}^i_n \\ I_{p-1} \quad \mathbf{0}_{p-1\times 1} \end{bmatrix},$$

the companion matrix of the transitory components univariate VAR. The state equation is

$$\xi_{nt} = \mu_n + F_n\xi_{n,t-1} + v_{nt},$$

where

$$F = \begin{bmatrix} I_2 & \mathbf{0}_{2\times p} & \mathbf{0}_{2\times p} \\ \mathbf{0}_{p\times 2} & \Phi^y_n & \mathbf{0}_{p\times p} \\ \mathbf{0}_{p\times 2} & \mathbf{0}_{p\times p} & \Phi^u_n \end{bmatrix},$$

$\widetilde{v}_{nt} = \left[\eta^y_{nt}, \eta^c_{nt}, \varepsilon^y_{nt}, \mathbf{0}'_{p-1\times 1}, \varepsilon^u_{nt}, \mathbf{0}'_{p-1\times 1}\right]'$, and $\mu_n = \left[\mu^y_n, \mu^u_n, \mathbf{0}'_{2p\times 1}\right]'$ contains the drift coefficients.

[11] We also used state personal income (SPI), available quarterly, as a proxy for GSP; however, we were unable to get precise estimates of the components, since the annual data sources are more comprehensive and accurate [von Kerczek and Lopez, 2012].

Let β_n^* represent the Okun coefficient for state n. Following Sinclair [2009], β_n^* can be estimated directly from the covariance matrix Ω_n[12], or alternatively from the $\widetilde{\Omega}_n = E_t\left[\widetilde{v}_{nt}\widetilde{v}_{nt}'\right]$, as

$$\beta_n^* = \frac{\sigma_{n\varepsilon^y\varepsilon^u}}{\sigma^2_{n\varepsilon^u}}, \tag{10}$$

which is analogous to the VAR with a Cholesky decomposition interpretation, (9). This can be seen explicitly, if we define the off-diagonal element of the matrix, A_n, as $a_{n,12}$; then, Okun's coefficient is

$$a_{n,12} = \frac{\text{Cov}(\varepsilon^y_{nt}, \varepsilon^u_{nt})}{\text{Var}(\varepsilon^u_{nt})} = \frac{\sigma_{n\varepsilon^y\varepsilon^u}}{\sigma^2_{n\varepsilon^u}} = \beta_n^*. \tag{11}$$

Once the model is in state-space form, the parameters can be estimated from the data using maximum likelihood and the components are estimated using the Kalman filter with a two period start [Harvey, 1989]. Results in the following sections are generated using a smoothed filter.

3.2 Estimating the Factors Behind Cross-State Heterogeneity

To explain the cross-state differences in the estimated Okun relationships, we regress the estimated Okun's coefficients on a set of state-level variables. Because the dependent variables—the Okun coefficients—are estimated on a state-by-state basis, the sampling uncertainty is unlikely to be constant across states. As a result, the errors in the regression will be heteroskedastic and ordinary least squares estimates will be inefficient. To address the heteroskedasticity in our regression, we have to account both for the estimation error in the regression and for the added variation because of the sampling uncertainty in the dependent variable. Hanushek [1974] first addressed this problem by decomposing the total variation into the sampling uncertainty of the dependent variable and the variation in the residuals to estimate a feasible generalized least squares model.[13]

Following Hanushek [1974] and Lewis and Linzer [2005], we construct a two-stage feasible gen-

[12] This assumes the autoregressive coefficients are the same for the GSP and the unemployment rate for each state.

[13] Hornstein and Greene [2012] illustrate a similar approach, based on Saxonhouse [1976], that estimates a weighted least squares procedure in which the observations are weighted by the inverse of the standard error of the dependent variable, ignoring the estimation error in the regression. Lewis and Linzer [2005] notes that this approach is appropriate only when the share of the total variation in the regression residual due to the sampling uncertainty in the dependent variable is large.

eralized least squares estimator, where the dependent variable β_n is not directly observable but, instead, we observe an estimate

$$\beta_n^* = \beta_n + \vartheta_n, \tag{12}$$

where ϑ_n is a zero-mean sampling error with variance ς_n^2. The objective is to estimate

$$\beta_n = x_n'\delta + \epsilon_n, \tag{13}$$

where $\epsilon_n \sim N\left(0, \sigma_\beta^2\right)$ is the i.i.d. error that would obtain if β_n were known. As β_n is assumed to be observed with sampling error, we can only estimate (13) as:

$$\beta_n^* = x_n'\delta + \nu_n, \tag{14}$$

where $\nu_n = \vartheta_n + \epsilon_n$. Estimates of β_n^* and ς_n^2 are provided by the UC procedure described earlier. Clearly, even though ϵ_n is assumed to be homoskedastic, ν_n need not be. Assuming that the β_n^*s are independent across n, that is $\mathrm{Cov}(\vartheta_l, \vartheta_m) = 0$ for $l \neq m$, we can use a two-step process to estimate σ_β^2. First, let $\mathbf{v} = (\nu_1, \ldots, \nu_N)$ and define $\mathbf{\Omega} = E(\mathbf{v}\mathbf{v}')$. Then write $\mathbf{\Omega} = \sigma_\beta^2\mathbf{I} + \mathbf{G}$, where $\mathbf{G} = \mathrm{diag}(\varsigma_1^2, \ldots, \varsigma_N^2)$. Let $\hat{\nu}_n$ denote the residuals from a first-step ordinary least squares estimation of the regression in (14). Now let $\mathbf{X}$ denote the $N \times (K+1)$ data matrix, which includes a constant. Then, an unbiased estimator for σ_β^2 is given by:[14]

$$\hat{\sigma}_\beta^2 = \frac{\sum_n \hat{\nu}_n^2 - \sum_n \varsigma_n^2 + \mathrm{tr}\left(\left(\mathbf{X}'\mathbf{X}\right)^{-1}\mathbf{X}'\mathbf{G}\mathbf{X}\right)}{N-K}. \tag{15}$$

The second-step estimation of the regression in (14) can be carried out applying weighted least squares. The weights, ϖ_n, are constructed by replacing σ_β^2 with its estimate $\hat{\sigma}_\beta^2$ calculated using the estimates of the dependent variable and its variance, β_n^* and ς_n^2, provided by the UC procedure:

$$\varpi_n = \frac{1}{\sqrt{\hat{\sigma}_\beta^2 + \varsigma_n^2}}.$$

The weighted least squares estimation yields efficient estimates of the regression parameter, δ.

[14] Lewis and Linzer [2005] warns that $\hat{\sigma}_\beta^2$ can be negative in small samples, in which case it can be set to zero.

4 Empirical Results

As a baseline for comparison with the extant literature and a benchmark for the following state-level estimation, we first estimate the model, (3) − (7), using national-level data and compute Okun's coefficient, restricting the national-level time sample and frequency to be identical to our state-level sample. We then describe the results of the state-level estimations. Finally, we will consider the determinants of the Okun coefficient by examining the cross-state variation. To facilitate discussion, we refer to the permanent components as potential output and the natural unemployment rate, respectively. We will also refer to the transitory components as cyclical output and cyclical unemployment.[15]

4.1 National Results

[Figure 1 about here.]

The top panel of Figure 1 shows national potential output and cyclical output estimated from the sample period of 1977-2012. Potential output has a roughly constant upward trend over the sample period. The cycle for output does not exhibit the typical business cycle fluctuations due to our lower frequency data, but does fall during NBER recessions (shaded areas in the figures) and becomes negative for three of the four recessions during the sample period.[16]

The bottom panel of Figure 1 shows the natural rate, which falls steadily since the early 1980s, and cyclical unemployment. Cyclical unemployment does rise after the onset of an NBER recession, but remains elevated even after the end of the NBER recessions, a characteristic of the recent jobless recoveries.

The textbook version of Okun's law states that a one percentage point decrease in the unemployment rate is associated with a 2 percent increase in output [Abel et al., 2013]. Recent studies have obtained similar values for Okun's coefficient: Lee [2000] found Okun's coefficient for the

[15] Our notion of the potential output does not refer to the maximum capacity of output but rather the level consistent with unemployment at the natural rate.

[16] Fernald [2014] estimates that potential output has dropped since 2013, which is consistent with the later decision by the CBO [February 2014] to revise their projections of potential output downward. A recent report by the CBO [February 2015] predicts that while actual output is projected to grow from 2020 to 2025, it is expected to grow at the same rate as potential output.

U.S. to be between -2.09 to -1.84, depending on the estimation technique and Daly et al. [2014] estimated Okun's coefficient to be -2.25. Our estimate of Okun's coefficient over this time period is -2.03, consistent with most of the extant literature.

4.2 State-Level Results

If our aim is to exploit the heterogeneity in the strength of Okun's law to determine its origins, we first need to confirm the existence of the relationship at the state level. We estimated the model separately for each state and obtained qualitatively similar results to those obtained using national-level data. In particular, most states have a nearly constant upward trend in potential GSP—albeit with different levels and trend growth rates across states—and a slight downward trend in the natural rate of unemployment after 1980. Notably, five states (Indiana, Kansas, North Carolina, Rhode Island, and Oregon) have a slight upwardly trending natural rate. Also, the natural rates for Washington, Wisconsin, Nevada, and Georgia exhibit more variation, consistent with some recent studies that argue that changes in demographics, prevalence of unions, and unemployment insurance can affect the natural rate (e.g., Perry et al. [1970] and Adams and Coe [1990]).[17]

Both potential output and the natural rate have similar shapes across most states; on the other hand, there appears to be cross-state variation in the timings and depths of the downturns in the cyclical components. In some cases, states do not experience downturns coincident with the nation at all. Moreover, there are some regional patterns: States in the Northeast display more cyclicality that most other states, while states in the Midwest are only weakly cyclical, not having experienced much of a transitory downturn in the 1991 and 2001 recessions.[18]

In the interest of brevity, we highlight a few of the interesting cross-state decompositions, with the full set of states is available upon request. Figure 2 shows the decomposition for two states (Connecticut and New Mexico) that vary geographically, demographically (population growth), and economically (labor force participation rates, and share of non-manufacturing employment, etc).[19]

[17] We tested for structural breaks in the trends using the Bai and Perron [2003] multiple break point test. While some states appear to have a break, the break timing varies by state and including the break did not change the estimate of Okun's coefficient. For the sake of uniformity, the reported results do not include breaks.

[18] These results are consistent with previous research which finds the timing and magnitude of a state's business cycle may not coincide with the national dynamics [Owyang et al., 2005], and states' business cycles exhibit heterogeneity [Owyang et al., 2009].

[19] Population growth rate was close to zero percent for Connecticut and 1.8% in New Mexico. While labor force participation rate and share of manufacturing was 68.4% and 49.8%, respectively, in Connecticut compared with 60.0% and 54.0%, respectively, in New Mexico.

Both states have upward trending potential output and downward trending natural rates, with New Mexico's natural rate falling faster. Their cycles, on the other hand, appear very different. While Connecticut appears to have cyclicality consistent with the NBER recessions, New Mexico has fewer output downturns but more frequent up-ticks in the unemployment rate.

[Figure 2 about here.]

Figure 3 shows the decompositions of two states that are geographically proximate—Iowa and Missouri—but have some differences in industrial compositions (e.g., Iowa's manufacturing share of employment in 2010 was 13.6%, compared with 9.2% in Missouri). As with most other states, both of these states exhibit an upward trend in potential output and a downward trend in the natural rate. The cyclical features of their unemployment rates are also broadly similar. The business cycle experiences of each state's GSP, however, differ substantially. In particular, Missouri has low frequency fluctuations in output, suggesting that states within the same region can have heterogeneous business cycle experiences.

[Figure 3 about here.]

To compare the state-level results with the national results, we constructed weighted estimates of the potential output and the natural rate of unemployment. The weights for the permanent components are determined by the GSP, and the weights for the natural rate of unemployment is time varying share of the labor force of each state, so that the weights sum to one. These results are compared to measures by the CBO, real potential GDP and the short-term natural rate of unemployment [20]

[Figure 4 about here.]

The top panel of Figure 4 shows the three estimates of potential GDP, which are all very similar. While the CBO's estimate tends to be the highest across the sample, the weighted measure from the state-level data shows the most variation. The measures of the natural rate of unemployment displays distinct differences as seen in the bottom panel of Figure 4. While all three measures are

[20] The CBO also produces a long-term natural rate of unemployment, which is quantitatively similar to the short term measure, except during the Great Recession, when the short-term measure of the natural rate increases.

downward sloping for most of the sample, the CBO's measure is about a percentage point lower than the other two measures, except during the last few observations. Similar to potential GDP, the weighted state-level measure has more variation than the natural rate of unemployment estimated from national data, which shows that there is some cross-state variation of this component. A potential explanation for this difference is that the CBO measure of the natural rate incorporates information from the inflation rate through a model that has a Phillips curve-type mechanism which is absent from our model. Additionally, the CBO measure is constructed to abstract from changes due to demographics and other structural changes. To do this the CBO does not use the overall unemployment rate (used in the UC model), but the unemployment rate of married men or an unemployment rate calculated by assuming constant labor force shares Arnold [2008], CBO [August 1994]. These factors explain the differences between the series. The later period increase in the CBO's natural rate is due to a methodological change where the CBO accounts for a so-called short-term adjustment.

[Table 1 about here.]

Table 1 contains the estimated Okun's coefficients by state; for ease of analysis, Figure 5 contains the same information in the form of a map, where darker shades are associated with larger (in absolute value) Okun coefficients. The estimated Okun's coefficients vary by state: For example, a one-percentage-point increase in the unemployment rate is associated with a 4.38 percent reduction in GDP in North Dakota but only a 1.25 percent reduction in Colorado.[21] While the range of values may seem large, most of the states fall within the range of -1.5 to -3.[22] Although Freeman [2000] did not find regional variation in Okun's coefficients, he used a less granular level of aggregation (eight regions) that may have masked heterogeneous differences [Zellner, 1962, Goodfriend, 1992].

This range of Okun's coefficients by state is similar to the variation found across countries. Lee [2000], using a different methodology to examine 16 OECD countries, found Okun's coefficient to range between -0.3 (Italy) and -12.6 (Japan), with most countries falling in the -1 to -3 range. Perman and Tavera [2007] also found heterogeneity in Okun's coefficients across 17 European countries.

[21]Louisiana has by far the smallest Okun's coefficient in absolute value (-0.4). However, this estimate may be influenced by the aftermath of Hurricane Katrina.

[22]While Blackley [1991] did not estimate Okun's coefficient for all states, he found coefficients ranging from -1.7 to -6.8.

These results allows us to examine whether Okun's law exists at the state level and whether there is heterogeneity in Okun's coefficients. For the first hypothesis, we test whether Okun's coefficients are different from zero, and we find that Okun's law exists for 47 states.[23] To explore the presence heterogeneity, we test whether states' Okun's coefficient is different than the coefficient at the national level. We find that the coefficient is statistically different for 7 states at the 5% significance level.[24] While this is not a large proportion of states, this test is not the best indicator of heterogeneity since the states are part of the national statistics. Therefore, we investigate how the states' coefficients deviate from each other and find that 21.6% of state pairs have coefficients that are statistically different at the 5% significance level, which provides evidence that there is some regional heterogeneity of the coefficients. This variation supports the idea that, with heterogeneous labor policies, industrial structure, and demographics, states can have idiosyncratic responses from the country as a whole.

[Figure 5 about here.]

Figure 5 does reveal some regional patterns. States in the Mideast region generally have lower (magnitude) Okun's coefficients. States that border with Canada have a higher coefficient in absolute value. Alternatively, the Southeast tends to have larger (magnitude) coefficients on average. The next section will investigate these differences across states.

5 Explaining the Heterogeneity

The previous section confirms the existence of an Okun-type relationship for each of the states and demonstrates their heterogeneity. In this section, we exploit this heterogeneity to suggest the theoretical underpinnings for Okun's law. Previous studies have attributed the cross-country heterogeneity in the coefficients to differences in production, labor participation, and regulations [Kaufman, 1988, Moosa, 1997, Ball et al., 2013]. The main differences across state labor markets are differences in the characteristics of the labor force, such as the proportion of educated workers, and the proportion of young or female workers. Another important difference is the distribution

[23] Okun's coefficient was not statistically significant at the 5% significance level for Alaska, Louisiana, and New Mexico.

[24] These states are Alamaba, Colorado, Georgia, Louisiana, Nevada, Rhode Island, and Washington.

of employment across industries within states. Institutional differences across states are less pervasive that differences across countries and have diminished considerably over time. Some of the institutional differences that still remain are differences in the rate of unionization and differences in state minimum wage laws, among others. These factors could also be the cause of heterogeneity in U.S. state-level Okun's coefficients.

5.1 Determinants of Okun's Coefficient

In searching for potential determinants of the cross-state heterogeneity in Okun's coefficients, we follow primarily Blackley [1991] and Kennedy [2009] and consider indicators of labor market characteristics at the state level.[25] The goal is to identify variables that describe the dynamism and flexibility of state labor markets and may represent the channels through which cyclical deviations in the unemployment rate may interact with deviations in output. Intuitively, we think that in more rigid labor markets, unemployment rate changes necessitate a larger magnitude of Okun's coefficient to induce changes in output growth, while in more flexible labor markets output growth should be less responsive to changes in the unemployment rate.

[Table 2 about here.]

Following Blackley [1991], we consider two direct proxies of labor market rigidity: the percentage of the workforce who are union members and the employment share in non-manufacturing industries. First, the higher the rate of unionization in the labor market, the more difficult it is for firms to make adjustments to the labor factor and, therefore, changes in the unemployment rate may have a larger impact on output growth. Second, a larger share of non-manufacturing is an indicator of a more diversified state economy, suggesting that output fluctuations may be less responsive to fluctuations in the unemployment rate.

Blackley [1991] also considers two characteristics of the labor force: the share of young people in the labor force (those aged between 16 and 25 years) and the share of women in the labor force. Some authors [Lynch, 1983, 1989] have argued that younger members of the labor force are less attached to the labor market than their older peers and may have higher levels of unemployment;

[25] Some of these characteristics have been identified, although not directly tested, as possible determinants of cross-country variation, also by Paldam [1987], Kaufman [1988], Moosa [1997], Lee [2000], Freeman [2001].

they may also experience more frequent and longer unemployment spells [Clark and Summers, 1982]. These observations suggest that a larger share of younger workers may be associated with less flexible labor markets and therefore this variable may proportionally influence the magnitude of Okun's coefficient.[26] Blackley [1991] and Kennedy [2009] argued that a higher female share in the labor force is associated with more rigid labor markets noting that, more often than men, women tend to leave unemployment by exiting the labor force; and Darby et al. [1985] noted that women exhibit longer unemployment spells.

We consider also the average annual rate of population growth. The rate of population growth represents a higher availability of the labor input in the state's production function. Finally, we also consider the share of the population with a college education. Similar to population growth, the share of college-educated people is an indicator of the availability of skilled labor in a state's labor market.

Because we use a cross section regression in this exercise, we have to set the timing at which we measure the regressors. The sample period for the unobserved components analysis is 1977–2012. Therefore, the most straightforward approach is to set the state covariates at the beginning of the sample or prior to the sample period. We choose to measure state variables as of 1970 to coincide with the population census, as we measure population growth between the 1970 and 2010 censuses. We also believe the results should be more sensitive to the initial conditions of the labor force.[27]

Table 2 presents summary statistics for the state covariates as of 1970 and 2010. Population and industry employment data are from the Census Bureau. Labor force data are from the Bureau of Labor Statistics, and union membership data are provided in Hirsch et al. [2001].

5.2 Results

[Table 3 about here.]

The first column of Table 3 presents our baseline estimation results using the Okun's coefficients estimated in the two-step procedure described Section 3.2, which provides the corrected standard

[26] At the national level, Owyang and Sekhposyan [2012] and Zanin [2014] also found that Okun's coefficient can vary by the age of the unemployed population.

[27] Indeed, when measuring the regressors as of the end of the sample, only the rate of union membership remains statistically significant. Similarly, estimating the effect of the determinants when these are expressed in changes between 2010 and 1970 yields insignificant effects.

errors of the estimated coefficients. As the states' Okun's coefficients, the dependent variable, are negative for all observations, we will interpret the results in this section in terms of the effect on the magnitude of a state's Okun's coefficient.

We find that a higher degree of unionization is associated with a statistically significant increase of Okun's coefficient. More precisely, we find that a 10 percentage point increase in union membership in 1970 is associated with a 0.30 increase in Okun's coefficient. This finding is consistent with the cross-country literature, which finds that higher union density increases unemployment and decreases labor supply [Nickell, 1997, Blanchard and Summers, 1986], which increases the labor market rigidity.

Similarly, an increase the employment share in non-manufacturing by 10 percentage points in 1970 is associated with an increase in a state's Okun's coefficient by 0.47 on average. This is at odds with the conventional view that manufacturing injects more volatility into output [DeLong and Summers, 1986, Filardo, 1997], but is consistent with the idea that industry diversification (as indicated by a larger services sector) can reduce output volatility.

Education, measured by the share of state population with a college degree, has the largest magnitude in our regression. We find that a 1-percentage-point increase in the share of the state population with a college education in 1970 will lead to a decrease of Okun's coefficient of 0.11. To illustrate, if New Mexico had a one-standard-deviation higher share of college educated population (i.e., 2 percentage points greater) in 1970, we would expect their Okun's coefficient to rise to -1.27 from -1.49. Our finding is consistent with the interpretation that higher education is an indicator of more flexible labor markets [Barro and Lee, 1993].

While population growth was not statistically significant in our sample, the coefficient has the expected negative sign, suggesting a proportional relation between this variable and the magnitude of Okun's coefficient. Intuitively, a higher availability of labor (represented by a higher rate of population growth) might obviate the need for more flexible labor markets to generate large changes in output from relatively small changes in the unemployment rate via a larger Okun's coefficient.

Regarding the characteristics of the labor force, we did not find evidence of a significant association between the share of young workers or the share of women in the labor force. Consistent with the views of Blackley [1991], however, we find that the signs of the estimated coefficients suggest a proportional effect on the magnitude of Okun's coefficient from both of these characteristics of the labor force.

6 Conclusions

In this paper we focus on the regional variation of Okun's coefficient by state. We estimate Okun's coefficient separately for each U.S. state using an unobserved components (UC) framework, which has two main advantages: allowing potential output and the natural rate of unemployment to be time varying and providing the ability to estimate the coefficient in one step. This method also allows us to take into account the uncertainty of estimating the potential output and natural rate of unemployment; thereby providing accurate estimates the coefficients and standard errors. We find that Okun's coefficients varies by state with estimated coefficients ranging from -4.378 (North Dakota) to -1.254 (Colorado) with some regional patterns present. Our results show that Okun's law exists at the state level (with 47 states having statistically significant coefficients) and there is variation of Okun's coefficient by state (21.6% of state pairs are statistically different).

We exploit this variation in Okun's coefficients to examine the potential factors that explain the Okun relationships, given that the state-level analysis controls for national policies. Additionally, our estimation method takes into account the estimation error in the regression and the sampling uncertainty in the dependent variable. Our results illustrate that indicators of labor market flexibility, lead to a smaller Okun's coefficient, while indicators of labor market rigidity lead to a larger Okun's coefficient (in absolute value). In particular, a one percentage point increase in educational attainment, measured by the share of the state population with a college degree, is statistically significant and leads to a decrease of Okun's coefficient by 0.11. We also find that a higher rate of union membership and a higher concentration of employment in non-manufacturing industries are both associated with a higher magnitude of Okun's coefficient, which is indicative of more rigid labor markets.

The usefulness of Okun's law for monetary policy depends on its stability and ability for broad inference. These results highlight the fact that national level policy, such as monetary policy, can have heterogeneous effects within the U.S. for two reasons. One is because the relationship between output and the unemployment rate varies across states and shows some regional patterns. Therefore, if policymakers use national data to inform their decisions, their enacted policies can have varying degrees of effectiveness due to the regional variation of Okun's coefficients and underlying determinants. This paper formally investigates the causes of this regional dispersion of Okun's law and finds that educational achievement, unionization rate, and employment share in non-manufacturing has a statistically significant effect on the coefficient. This state-level heterogeneity in Okun's coefficients could increase social and political tension, similar to the concern of Hutengs and Stadtmann [2013] in the Eurozone. This political dissonance could be amplified by the regional variation noted this paper. While most institutional differences across labor markets have diminished over time, considerable differences remain in terms of demographic characteristics of the labor force and industrial composition. Our analysis does not suggest changing the nature of the policy prescription per se, but does have implications for how the states will react to policy. In particular, some states or labor markets may be more responsive to policy, depending on their different characteristics.

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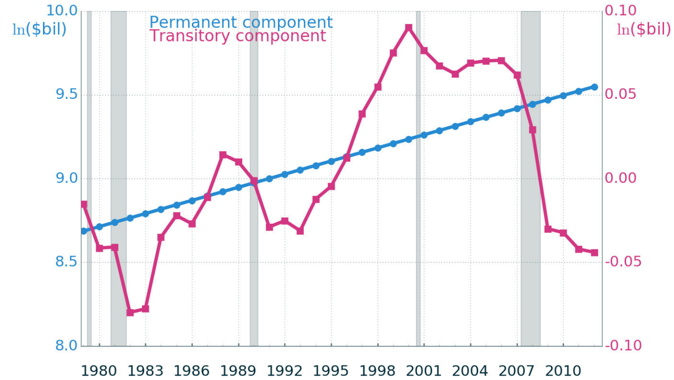
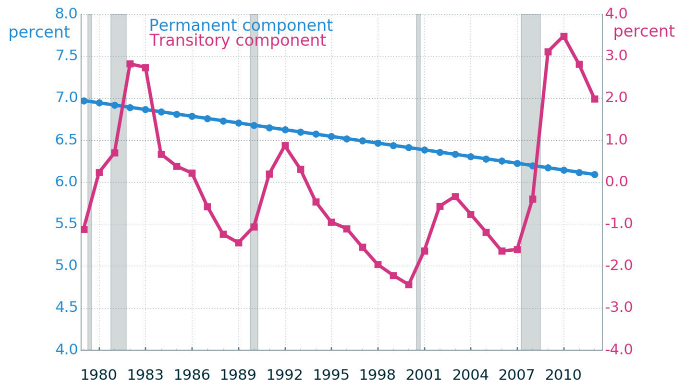
List of Figures

Figure 1: U.S. GDP and Unemployment Components

(a) GDP

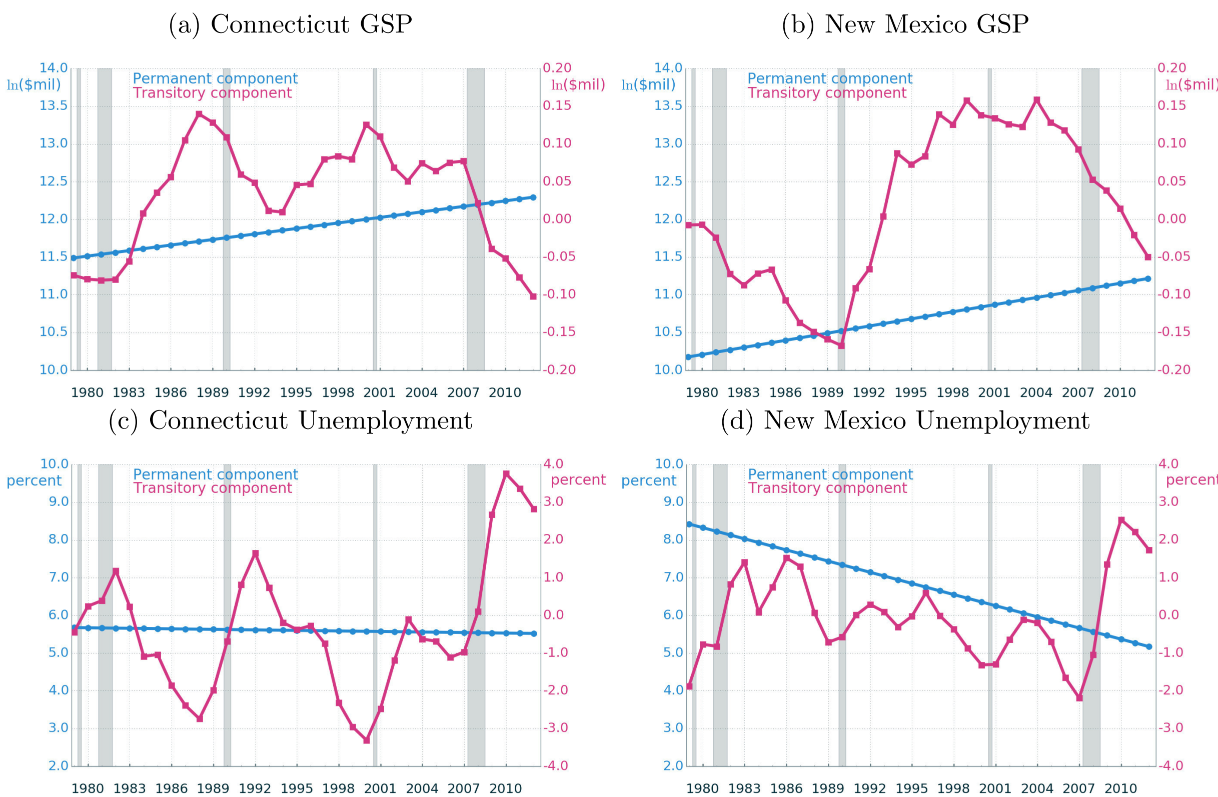


(b) Unemployment



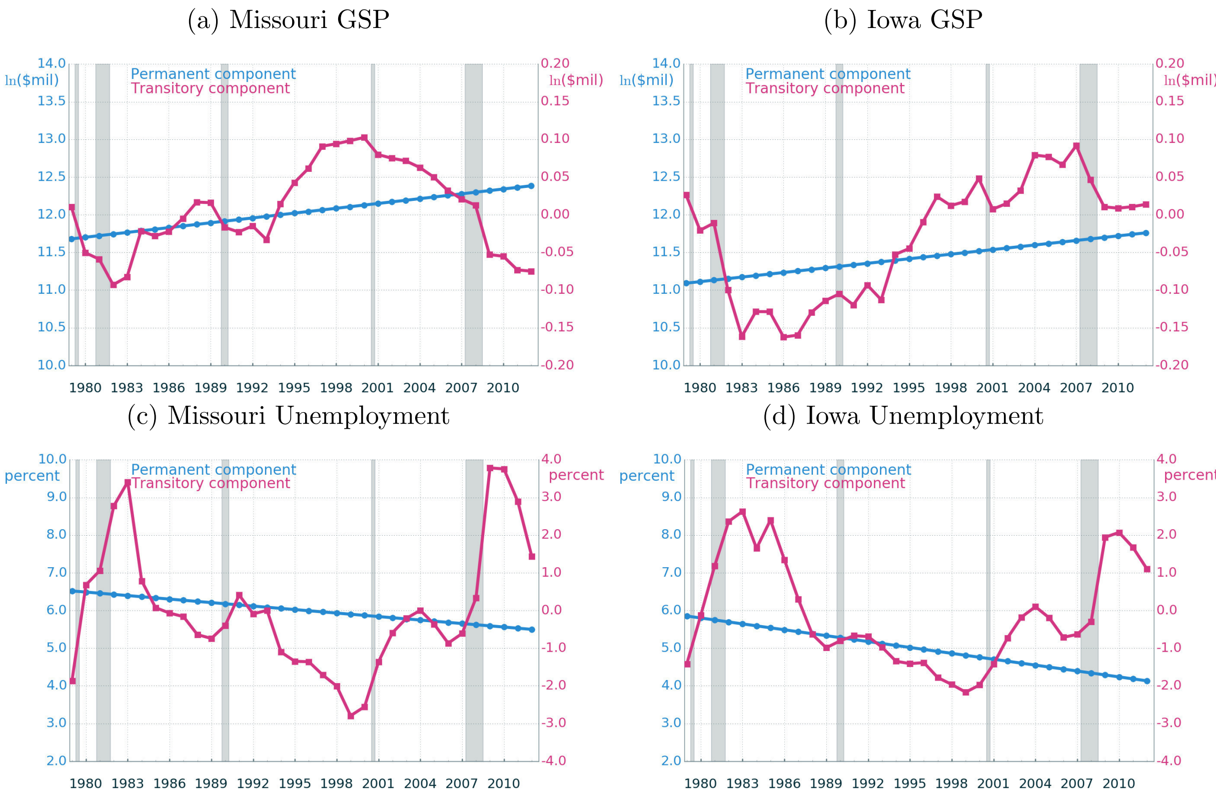
The top panel shows the permanent (solid blue, left axis) and transitory (solid red, right axis) components of log real GDP (in billions). The bottom panel shows the permanent (solid blue, left axis) and transitory (solid red, right axis) components of the unemployment rate measured in percentage points. The shaded areas are recessions as defined by the NBER Business Cycle Dating Committee.

Figure 2: Output and Unemployment Components of Example States: CT and NM



The top two panels show the permanent (solid blue, left axis) and transitory (solid red, right axis) components of log real GSP (in millions) for Connecticut and New Mexico, which vary geographically, demographically, and economically. The bottom two panels show the permanent (solid blue, left axis) and transitory (solid red, right axis) components of the unemployment rate for Connecticut and New Mexico measured in percentage points. The shaded areas are U.S. national recessions as defined by the NBER Business Cycle Dating Committee.

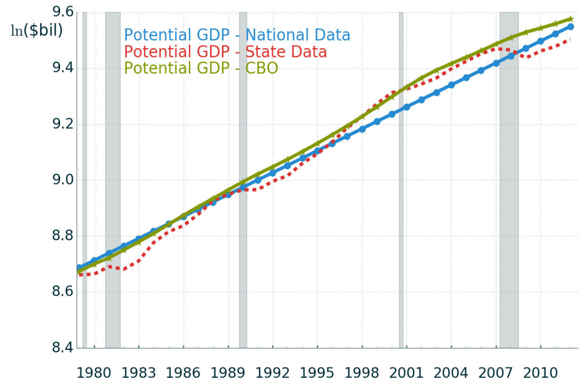
Figure 3: Output and Unemployment Components of Example States: MO and IA



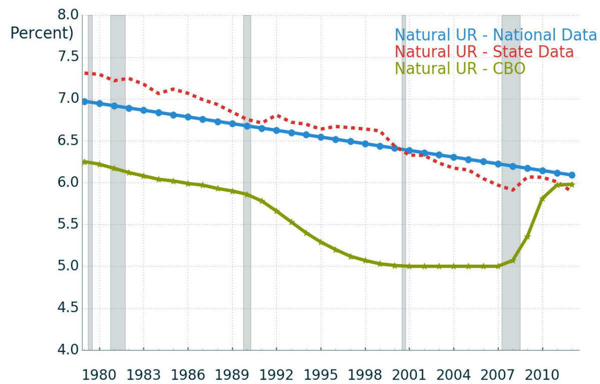
The top two panels show the permanent (solid blue, left axis) and transitory (solid red, right axis) components of log real GSP (in millions) for Missouri and Iowa, which are geographically proximate, but have differences in industrial compositions. The bottom two panels show the permanent (solid blue, left axis) and transitory (solid red, right axis) components of the unemployment rate for Missouri and Iowa measured in percentage points. The shaded areas are U.S. national recessions as defined by the NBER Business Cycle Dating Committee.

Figure 4: U.S. Potential GDP and Natural Rate of Unemployment

(a) Potential GDP

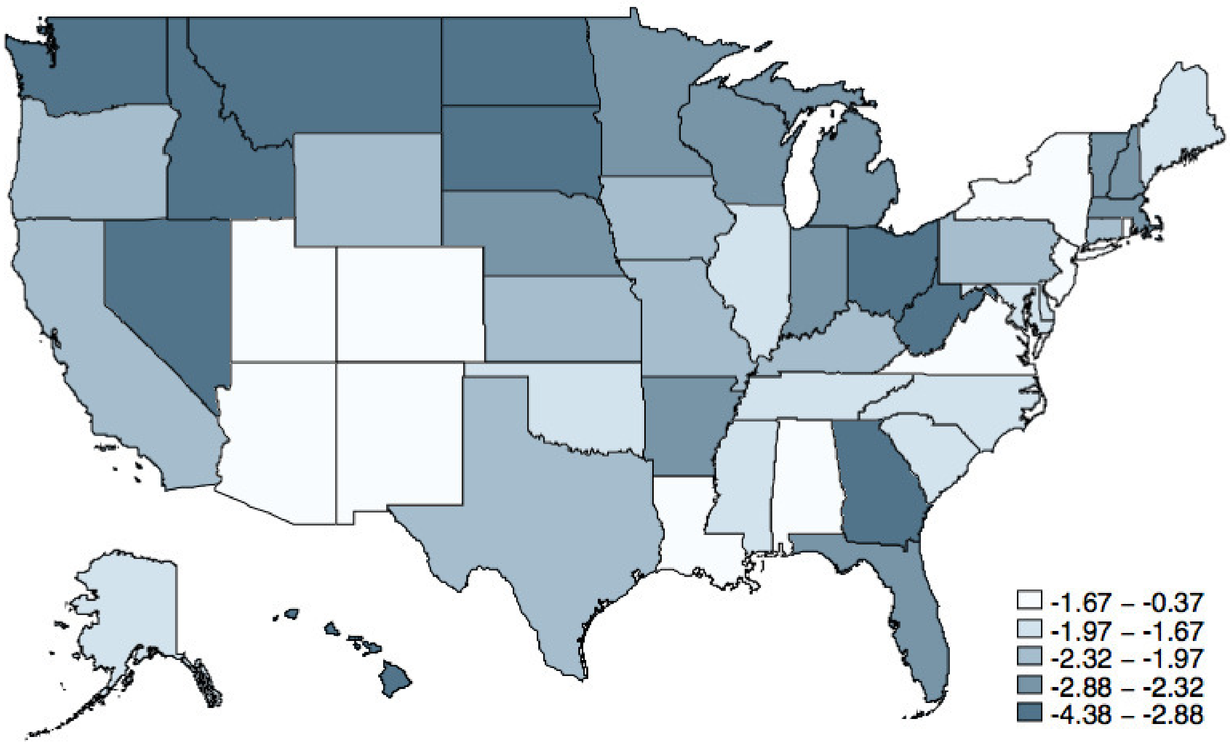


(b) Natural Rate of Unemployment



The top panel shows the potential GDP measured from the national data (solid blue), state-level data (dashed red), and from the CBO (ticked green) in log real GDP (in billions). The bottom panel shows the natural rate of unemployment measured from the national data (solid blue), state-level data (dashed red), and from the CBO (ticked green) measured in percentage points. The shaded areas are U.S. national recessions as defined by the NBER Business Cycle Dating Committee.

Figure 5: Variation of Okun's Law by State



The map shows magnitude of Okun's coefficient in the baseline unobserved components model specification.

List of Tables

Table 1: Okun's Coefficients

State	Okun's Coefficient	Std. Error	State	Okun's Coefficient	Std. Error
Alabama	-1.45	0.18	Montana	-3.18	0.63
Alaska	-1.70	1.64	Nebraska	-2.33	0.70
Arizona	-1.61	0.37	Nevada	-3.69	0.56
Arkansas	-2.57	0.49	New Hampshire	-2.82	0.46
California	-2.12	0.21	New Jersey	-1.60	0.22
Colorado	-1.25	0.23	New Mexico	-1.49	0.77
Connecticut	-2.10	0.36	New York	-1.64	0.38
Delaware	-1.71	0.72	North Carolina	-1.79	0.23
Florida	-2.38	0.17	North Dakota	-4.38	1.85
Georgia	-3.70	0.77	Ohio	-2.96	0.97
Hawaii	-3.10	0.69	Oklahoma	-1.96	0.30
Idaho	-3.08	0.56	Oregon	-2.31	0.45
Illinois	-1.87	0.18	Pennsylvania	-2.07	0.21
Indiana	-2.44	0.23	Rhode Island	-1.31	0.25
Iowa	-2.26	0.87	South Carolina	-1.73	0.15
Kansas	-2.06	0.33	South Dakota	-3.31	0.80
Kentucky	-2.16	0.30	Tennessee	-1.85	0.26
Louisiana	-0.37	0.36	Texas	-1.98	0.33
Maine	-1.79	0.28	Utah	-1.59	0.31
Maryland	-1.79	0.27	Vermont	-2.50	0.31
Massachusetts	-2.41	0.25	Virginia	-1.55	0.29
Michigan	-2.57	0.25	Washington	-4.36	0.80
Minnesota	-2.47	0.41	West Virginia	-3.66	0.95
Mississippi	-1.74	0.25	Wisconsin	-2.41	0.32
Missouri	-2.26	0.24	Wyoming	-2.05	0.52
United States	-2.03	0.17			

The table shows the estimated Okun's coefficient and its standard deviation for the baseline unobserved components specification.

Table 2: Summary Statistics: Cross-State Covariates

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**
Labor Market Flexibility Indicators				
Union membership 1970	0.25	0.09	0.09	0.42
Union membership 2010	0.11	0.06	0.03	0.24
Labor force: share age<25 1970	0.22	0.02	0.18	0.29
Labor force: share age<25 2010	0.13	0.01	0.11	0.18
Labor force: share female 1970	0.38	0.02	0.33	0.41
Labor force: share female 2010	0.48	0.01	0.45	0.51
Employment share nonmanufacturing 1970	0.53	0.05	0.38	0.70
Employment share nonmanufacturing 2010	0.68	0.05	0.55	0.76
Demographic Indicators				
Population: compound avg. growth 1970-2010	0.01	0.01	0.00	0.04
Population: share education college 1970	0.11	0.02	0.07	0.15
Population: share education college 2010	0.28	0.05	0.18	0.39
Observations = 50				

All regressors are shares in decimals (0.01 is 1.0%).

Population data are from the Census Bureau.

Labor force indicators are from the Bureau of Labor Statistics.

Union membership data are from Hirsch et al. [2001].

Industry employment data are from County Business Patterns.

Table 3: Determinants of Variation in Okun's Coefficient

	(1) uc
Union membership 1970	-3.03**
	(1.20)
Labor force: share age<25 1970	-7.28
	(5.53)
Labor force: share female 1970	-2.60
	(6.09)
Pop. share college educ. 1970	10.67**
	(4.56)
Pop. comp. avg. growth 1970-2010	-13.47
	(13.00)
Emp. share nonmanufac 1970	-4.65**
	(2.13)
Constant	2.66
	(3.16)
Observations	50
$\overline{R}^2$	0.21
F	3.19
$\hat{\sigma}^2$	0.18
χ^2	15.48

This table reports the coefficients for the 2-stage-feasible-least-squares regressions of the state-level Okun's coefficient, estimated using the unobserved components, on the cross-state covariates. Standard errors are in parentheses. The * denotes $p < 0.1$, ** denotes $p < 0.05$, and *** denotes $p < 0.01$.