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Using state level employment thresholds to explain Okun's Law

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Abstract

In this paper we implement a non-dynamic panel threshold model for fifty U.S. states to better understand the factors determining changes in Okun's Law. We test for asymmetries in Okun's Law controlling for changes in industry employment. We find changes in output on unemployment are least sensitive for states with relatively large employment within government, construction, and natural resources sectors and lower employment levels in financial, professional and business services and manufacturing sectors. States with lower manufacturing employment have a less sensitive output to unemployment relationship, but the reverse does not apply. States with larger shares of employment within manufacturing sectors do not have a significantly more sensitive relationship compared to the national average.

JEL Codes: E3; R1; J6

Keywords: Okun's Law; United States; Unemployment; Output; Thresholds

1 Introduction

Okun (1962) first documented the long standing relationship between output and unemployment. Today most macroeconomic textbooks state for every one-percent decrease in output will cause unemployment to increase by one-third to one-half percent.[1] Okun's Law is often referred to as a three-to-one or two-to-one relationship. Today many researchers are using Okun's Law to better understand the dynamics surrounding the recovery following the financial crisis. In particular a large debate has centered around whether the United States is currently experiencing a "jobless recovery". According to the Congressional Budget Office, following the start of the Great Recession in 2009 the recessionary gap peaked at -7.5% of potential GDP and by the end of 2012 improved to -5.7%. Prior to the Great Recession the natural rate of unemployment was estimated at 4.8%, assuming Okun's Law held we would have expected actual unemployment to reach 8.4%.[2] The actual unemployment rate was significantly higher and peaked at 10% in October of 2009. Does the divergence in Okun's Law necessary imply a permanent change in the output, unemployment relationship?

Daly and Hobijn (2010) find strong labor productivity growth allowed firms to lay-off a large numbers of workers while holding output relatively steady, this resulted in a more sensitive relationship between output and unemployment.[3] The authors show the productivity gains, especially in manufacturing, have resulted in a nearly one for one relationship between deviations in output and unemployment. Following the results of

Daly we expect states with a larger share of employment in sectors combined with strong productivity growth to have a higher Okun's coefficient (i.e. a more sensitive relationship).

Gordon (2010) breakdowns Okun's Law to measure how productivity and aggregate hours respond to cyclical fluctuations over time. The authors find the response in aggregate hours has increased after 1986 but productivity has decreased. The latter result carries particular importance as the authors find productivity no longer exhibits pro-cyclical fluctuations. The authors contribute the shift to increases in immigration, imports, and medical care costs and a decline in real wages and labor market protections.

Owyang and Sekhposyan (2012) analyzes Okun's Law over time with attention on the Great Recession. They find Okun's Law differs when comparing across the business cycle. During normal times they find the correlation between real output and unemployment to be approximately -0.4 but strengthens to -0.55 during recessions. Cazes et al. (2013) use Okun's Law to analyze the deviations in unemployment rates following the global financial crisis. They find for most countries Okun's coefficient increased sharply but for Germany and Netherlands there was a dramatic decrease over the short term. They find countries with a greater level of employment protection legislation experienced a smaller response in unemployment to changes in the business cycle. This was particularly true for Germany. Ball et al. (2013) analyzes Okun's Law in twenty advanced economies since 1980. They find the relationship does vary substantial across countries but do not find evidence of a "jobless recovery". The authors find considerable differences across the countries which they contribute to idiosyncratic features of national labor markets, but not differences in employment protection legislation.

We add to the existing literature by explaining departures in Okun's Law through a regime switching model controlling for varying measures of industry employment levels. We implement a non-dynamic panel threshold model introduced by Hansen (1999) to a panel of fifty states from 1990 through 2012. The motive behind our paper is relatively straight forward. Ball et al. (2013) claim differences in Okun's Law across countries are contributed to idiosyncratic features of national labor markets. Whereas others claim the departure in Okun's Law is from labor market protections (Gordon (2010)) and productivity gains (Daly and Hobijn (2010)). We believe industry composition can explain the idiosyncratic component as well as productivity shocks. For example, we expect states with relatively large employment shares within manufacturing sectors to have a more sensitive relationship. Strong productivity growth and fewer labor market protections make manufacturing employment more sensitive to cyclical fluctuations. In addition to manufacturing, states with relatively large employment within service (financial, professional, and business) areas will also have a more sensitive relationship. We expect states with larger employment within government and education sectors to have a relatively insensitive relationship. Some sectors are more vulnerable to layoffs during an economic downturn and can increasing hiring during an expansion at a faster rate.

Grouping states by industry structure will capture a more precise measure of Okun's Law when compared to estimating the relationship across states. Stefano et al. (2013) show that states with similar industry structures are more likely to have a synchronized business cycle. Implicitly, grouping by industry structure assumes both productivity and demand shocks will show up through employment levels within each industry, independent of state borders. If a state has implemented a particular policy, i.e. changes in minimum wages or personal income taxes, this would only affect the state in question in the short run. Under the assumption of perfect labor mobility workers will move into states that offer employment in their sectors. Given the large literature on business cycle synchronization and the robust finding of regional business cycles we believe using panel data procedure pooling on employment levels to be an important extension in understanding changes in Okun's Law.

The threshold modeling procedure uses underlying variables (i.e. industry employment levels) to find the optimal breakpoint. We find Okun's coefficient is lowest (in absolute value) for states with relatively greater employment within government, construction, and natural resource sectors and lower employment in financial, professional and business services, and manufacturing sectors. In other words, states with larger employment shares within government sectors experience a smaller response in unemployment to changes in output. Whereas, states heavily dependent on financial and professional services and manufacturing employment have a more sensitive relationship. Further we include a lagged dummy variable to measure the impact on unemployment rates in the eight quarters immediately following a recession. We find states with a smaller share of government employment have significantly higher unemployment rates than states with a larger share of government workers. After eight quarters following a recession states with a relatively larger share of professional service, financial services, construction, and government employment were likely to have lower unemployment rates. Additionally, states with a smaller share of employment in natural resources and manufacturing had significantly lower unemployment rates in the eight quarters following the end of a recession.

The rest of this paper is organized as follows: Section 2 provides a short overview of Okun's Law, discusses some key issues estimating the relationship, and provides a brief review of the literature. Section 3 reviews the data construction for state level estimation of output and employment shares and outlines the threshold estimation process. Section 4 reviews the baseline results. Section 5 goes through the threshold results by employment sector. Finally, section 6 concludes.

2 Okun's Law

Okun's original paper analyzes the regression between the changes in the log of real gross national product (RGNP) and the unemployment rate. To estimate this relationship Okun regressed the quarterly change in the log of RGNP on the change in unemployment from 1947q1 to 1960q4:

$$\Delta u_t = \alpha_d + \beta_d \Delta y_t + e_t \tag{1}$$

where u_t is the unemployment rate and y_t is the log of RGNP. Okun first found $\widehat{\alpha} = 0.3$ and $\widehat{\beta} = -0.3$. The interpretation for $\widehat{\beta}$ is a one-percent decrease in the RGNP growth rate will cause unemployment to increase by 0.3 percent, or a three-to-one relationship between changes in output and the unemployment rate. Over time the relationship has slowly shifted into the two-to-one relationship which is commonly reported in textbooks.

Throughout this paper we will refer to Equation 1 as the difference specification (denoted by d in Equation 1). Okun also estimated a level specification:

$$u_t = u_l^* + \beta_l (y_t - y_t^*) + e_t \tag{2}$$

where the constant term, u_l^*, measures the natural rate of unemployment and $(y_t - y_t^*)$ is the output gap. Okun assumes potential output, y_t^*, follows a 3.5 percent trend line. Later studies have relied more on time-series filtering measures to decompose output into trend and cyclical components. Okun finds $u_t^* = 3.72$ and $\beta_l = -0.36$. These results are consistent with his findings of a three-to-one relationship estimated in Equation 1. For our purpose, Equation 2 will be denoted as the level specification which is denoted by $_l$ in Equation 2.

A number of papers have analyzed Okun's Law in a country specific framework. For the United States Knotek II (2007) analyzes changes in Okun's coefficient in conjunction with changes in the business cycle. He finds the output-unemployment relationship to be less sensitive (i.e. the coefficient is smaller in absolute value) during expansions but significantly more sensitive during recessions. He also finds evidence that the contemporaneous correlation has decreased over time, but correlation between unemployment lagged growth rates has increased. Herzog (2013) is the first to estimate Okun's Law across states. They find considerable differences in Okun's coefficient which they link to voter preferences. Cuaresma (2003) estimates Okun's Law in a regime-dependent specification that allows for an asymmetric effect of output growth on unemployment. Essentially, we are using a similar approach for a panel of states that allows for asymmetric effects within industry employment levels.

There have been a number of studies that have analyzed Okun's Law across regions using panel data specifications. Maza and Villaverde (2007) and Villaverde and Maza (2009) analyze Okun's Law across Spanish regions. The authors find the inverse relationship between unemployment and output remains but the coefficients range from -0.80 to -0.95 which are three times lower than Okun's original estimates. This suggests a more sensitive relationship between output and unemployment. Marieestelle and Facchini (2013) finds Okun's Law holds for fourteen French regions but breakdowns for eight regions and identifies regional factors to explain the disparities. Huang and Yeh (2013) use a pooled mean group estimator that allows the authors to estimate the short- and long-run relationship across countries and states. The authors find unemployment and output are cointegrated and the unemployment-output linkages are negative and significant across both dimensions. In addition to papers focusing directly on cross regional differences, a number of researchers have explored Okun's Law across larger regional blocks. Fouquau (2008) uses a non-dynamic panel threshold model to test the relationship among 20 OECD countries. The authors find evidence supporting a nonlinear relationship with four specific regimes tied to varying levels of cyclical unemployment where the coefficient displays the most sensitivity at the lowest and highest levels of cyclical unemployment. Harris and Silverstone (2001) estimates Okun's Law across seven OECD countries testing for asymmetry in the relationship. The authors find failing to correct the asymmetries across the business cycle will result in a rejection of Okun's Law.

It has been well documented that Okun's coefficient varies across business cycles and displays a nonlinear relationship across varying levels of unemployment and output growth. The work of Long and Plosser (1987) and Jimeno (1992) show sectoral-specific shocks tend to dominate and only impact the aggregate economy with a lag. Recently, Foerster et al. (2011) show the importance of sectoral shocks have more than doubled in importance explaining the variation in industrial production since the

Great Moderation. Given the importance of sectoral specific shocks using sector specific employment levels will provide us with a more reflective and useful measure of Okun's Law.

3 Empirical models and data

In our analysis we primarily focus on the non-dynamic specification, i.e. Equation 2, using quarterly data from 1990 through 2012 for the fifty states. Employment data by industry was not collected until 1990 which limits us to 23 years of observations. Nonetheless, Starting in 1990 will allow us to capture the dynamics over two complete business cycles plus the recovery from the Great Recession.

The biggest challenge when estimating Equation 2 at the state level is constructing an appropriate measure of real GDP and potential output. At the state level, real gross domestic product is produced on an annual frequency. Total personal income is the only variable captured on a quarterly frequency. The challenge in using total personal income occurs when converting the variable to real income. The Bureau of Labor Statistics does not produce inflation measures by state but by large metropolitan statistical areas and geographical regions. Instead of attempting to find an appropriate conversion of total personal income for each state we use the economic coincident index produced by the Federal Reserve Bank of Philadelphia, created by Stock and Watson (1989), and applied to states by Crone and Clayton-Matthews (2005). The economic coincident index is produced on a monthly frequency and is constructed to follow the trend for each state's real gross product. The long-term growth rate of the coincident index will match the long-term growth of real gross state product. Using the state index allows us to capture the cyclical variation on a higher frequency but maintains the same long-term growth for each state and provides an accurate measure of state level output gaps.

The employment measures are from the Bureau of Labor Statistics. Data for the unemployment rate are obtained from the Labor Force Statistics produced in the Current Population Survey (CPS). The data for employment by sector are from the Current Employment Statistics (CES) database for State and Area Employment, Hours, and Earnings. We include data from 9 unique sectors plus the employment to population ratio. The industries we use are construction; manufacturing; trade, transportation, and utilities (trade); natural resources (natural); financial activities (financial); professional and business services (services); education and health services (education); leisure and hospitality (leisure); and government.

3.1 Estimating the output gap

We estimate the output gap through two different methods. First we obtain the output gap by regressing the log of the coincident indicators on a constant, trend, and quadratic trend for each country independently:

$$Log(CI)_t = \beta_0 + \beta_1 Trend + \beta_2 Trend^2 + u_t \tag{3}$$

The residuals from regression 3 are captured individually across states and compose the output gap.

Second, we use the Hodrick-Prescott filter to estimate the trend and cyclical components for each state. The HP-filter extracts the trend component, τ_t, by minimizing:

$$min_{[\tau_t]} \sum_{t=1}^{T}(y_t - \tau_t)^2 + \lambda \sum_{t=1}^{T}((\tau_{t+1} - \tau_t) - (\tau_t - \tau_{t-1}))^2 \tag{4}$$

where λ is referred to as the smoothing parameter. A greater value for λ results in the trend being more linear, all else equal. We use $\lambda = 1,600$ which is common for quarterly data.[4] We elect to use the filter to estimate potential output and not the natural rate of unemployment. Instead, we estimate the natural rate of unemployment as the constant in Equation 2. This approach follows Owyang and Sekhposyan (2012).

One concern with the HP filter centers around estimating the end of sample trend. The HP filter exaggerates the change in the trend at the end of sample. In fact, under both smoothing parameters we find the average growth rate for potential output following the Great Recession to be less than 1%. Following Ball et al. (2013) we alleviate this concern by extrapolating the estimated trend from 2004 to 2007 forward through 2012. Averaged across states this gives us a trend growth rate of approximately 2.5% which mirrors the national growth of potential real GDP estimated by the CBO.[5]

3.2 Employment data

Although the employment measures do not directly enter the regression estimation, but serve as a sorting variable for creating the threshold break points, it is important to accurately construct the employment ratios. An ideal employment measure for the nine sectors of interest (government, financial services, professional and business services, construction, natural resources, manufacturing, education and health services, leisure and hospitality, and trade, transportation, and utilities) would be the employment within each sector relative to the working age population for each state. Unfortunately data are not readily available for the latter. This leaves us with choosing between the state labor force and total population for each state. We estimate the models using both measures, but primarily focus our results in this paper on the sector employment to state population ratio. We chose total population over labor force to help control for states impacted by the discouraged worker effect.

Suppose a state had a relatively large share of employment in manufacturing sectors which during the last decade has been in steady decline. Many workers unemployed in manufacturing have shifted into the discouraged worker category. Using total employment in manufacturing relative to the labor force will understate the decline in the manufacturing share relative to other sectors. Using the employment to population ratio will accurately reflect the decrease in manufacturing employment. This issue is magnified when comparing across states. States with a relatively large discouraged worker effect may have employment to labor force ratios increase even if employment is decreasing in a particular sector (assuming a relatively large discouraged worker effect leading to a decrease in the labor force).

One drawback of using the state population emerges when states have a large dependency ratio which could result from a relatively large population under the age of twenty or older than 65. This is a particular concern for Arizona and Florida, two states with large retirement populations. Overall, the results are relatively consistent across both employment measures.

3.3 Threshold estimation

Hansen's non-dynamic threshold procedure has been applied in many different areas. Hansen originally applied the procedure to test whether financial constraints affect investment decisions. More recently the procedure has been applied in saving-investment literature by testing for thresholds in country size (see Ho (2003)). Cecchetti et al. (2011) applied the procedure to test for thresholds in the effects of increased government debt on economic growth. Aghion et al. (2009) use the procedure to test for the existence of thresholds in saving rates within a standard growth regression. The non-dynamic threshold procedure does have some attractive features in that the optimal thresholds are estimated through a least squares estimator. But the statistical inference is only applicable to balanced panels without a dynamic component. Fortunately our data and Equation 2 fits into this class of models.

The single threshold procedure requires comparing the residual sum of squares from the restricted regression, Equation (2), to the unrestricted regression which allows for a single threshold:

$$u_t = u^*_{i,t} + \beta_0(y_{i,t} - y^*_{i,t})I(q_{i,t} \le \gamma) + \beta_1(y_{i,t} - y^*_{i,t})I(q_{it} > \gamma) + e_{it} \quad (5)$$

where q_{it} is the scalar threshold variable (sector specific employment ratios), and $I(\cdot)$ is the indicator function that takes a value of one when the threshold condition in the bracket is satisfied, zero otherwise. The error term is assumed to be independent and identically distributed with mean zero and finite variance σ^2. Mean deviations are taken to control for country specific effects measured by μ_i.

Following Hansen's recommendation, the threshold sample is trimmed by 10 percent of the highest and lowest values.[6] Trimming assures adequate observations within each threshold regime. For our sample, $N = 4450$, which restricts each regime to have at least 450 quarterly observations. Restricting the threshold regime size to be at least ten-percent of the total observations helps to minimize potential bias caused by single state outliers. Next the optimal threshold value is selected to minimize the residual sum of squares. After selecting the optimal threshold value, γ_1, it is important to determine if a threshold effect is statistically significant. The null hypothesis of no threshold effect is:

$$H_0 : \beta_0 = \beta_1,$$

where $\beta_0 = \beta_1$ is tested by a likelihood ratio test. The likelihood ratio test for the first stage threshold estimate is:

$$F_1 = \frac{S_0 - S_1(\hat{\gamma}_1)}{\hat{\sigma}^2} \quad (6)$$

where $\hat{\sigma}^2 = \frac{1}{n(T-1)} S_1(\hat{\gamma}_1)$, S_0 are the residual sum of squares from the restricted regression, $S_1(\hat{\gamma}_1)$ are the residual sum of squares from the unrestricted regression, and $\hat{\gamma}_1$ is the threshold parameter that minimizes the residual sum of squares. The null hypothesis is rejected for large values of the likelihood ratio. Once the single threshold is estimated the process of estimation extends easily to models with two and three thresholds breaks.

Second, when estimating the second threshold we adopt a sequential estimation procedure following Bai (1999). If the first threshold is significant we proceed into estimating all possible combinations for a double threshold model. Hansen assumes the original threshold value is fixed while estimating the second threshold. If there is evidence of a second threshold then he proceeds to reestimate the first threshold. The primary reason for choosing the latter approach concerns computing time.[7] Given the relatively large data set we elect to still use the sequential estimation procedure but adopt Hansen's recommendation of using the grid 10.00%, 10.25%, 10.50%, 10.75%....89.25%, 89.50%, 88.75%, 89.00% to minimize over number of quantiles estimated.

To determine the second threshold break, the following model is estimated:

$$u_t = u^*_{i,t} + \mu_i + \beta_0(y_{i,t} - y^*_{i,t})I(q_{it} \le \gamma_1) + \beta_1(y_{i,t} - y^*_{i,t})I(\gamma_1 < q_{it} \le \gamma_2) + \beta_2(y_{i,t} - y^*_{i,t})I(\gamma_2 < q_{it}) + e_{it} \quad (7)$$

Assuming the first threshold is given, the optimal second-stage threshold estimate is found by minimizing the residual sum of squares for Equation 7. The likelihood ratio test of one versus two thresholds is be based on the statistic:

$$F_2 = \frac{S_1(\hat{\gamma}_1) - S_2(\hat{\gamma}_2)}{\hat{\sigma}^2} \quad (8)$$

where $\hat{\sigma}^2 = S_2(\hat{\gamma}_2)/n(T-1)$. The null hypothesis of $\beta_0 = \beta_1 = \beta_2$ is rejected for large values F_2. The asymptotic distributions for F_1 and F_2 are non-standard. Under the null hypothesis the thresholds are not identified, Hansen suggests a bootstrapping procedure to simulate the asymptotic distribution and p-values for the likelihood ratio test.[8]

4 Data and results

Tables 1 and 2 provide an overview of key summary statistics. Table 1 shows the distribution for each employment sector where the values are expressed as the total number of people employed in that sector relative to the state population. For comparison we also present the distribution for the total employment to population ratio. The two sectors with the largest share of employment, on average, are government services and trade, transportation, and utilities. The threshold procedure works best if there is considerable variability across the threshold variable. Comparing values between the 10th and 90th percentiles we can see that for most sectors the 90th percentile is nearly twice as large as the tenth percentile. This provides us with ample variability to use the threshold procedure.

Table 2 presents the means by state across the nine sectors and the total employment to population ratio. This table also shows the variability across states. For example, employment within the manufacturing sector ranges from an average high near ten percent in Wisconsin and Indiana, but a low of approximately two percent in Alaska,

Table 1 Summary statistics by percentiles

	Min	10th per.	25th per.	Median	75th per.	90th per.	Max
Employment to population	34.8	40.3	42.6	45	47.7	50	59.6
Government	5.4	6.6	7	7.8	8.4	9.4	13
Financial services	1.4	1.9	2.1	2.5	2.9	3.4	6.2
Prof./Bus. services	1.6	3.1	3.8	4.8	5.6	6.4	8.4
Construction	1.2	1.6	1.9	2.2	2.6	3	5.7
Natural resources	0	0	0.1	0.2	0.5	1.1	5.4
Manufacturing	0.9	2.3	3.8	5.4	7.1	8.7	12.5
Education and health	2.7	3.9	4.6	5.4	6.4	7.7	10.3
Leisure and hospitality	2.2	3.5	3.8	4.2	4.5	5.3	15.6
Trade, trans, utilities	6.4	7.7	8.3	9	9.6	10.2	13.3

Table 2 Employment means by state

State	Employ/Pop	Gov't	Financial	Services	Const.	Natural	Man.	Educ.	Leisure	Trade
AK	44.5	12.1	1.9	3.6	2.3	1.9	2.1	4.4	4.3	9.1
AL	41.6	8.0	2.1	4.0	2.1	0.3	7.3	4.0	3.3	8.2
AR	41.7	7.2	1.8	3.5	1.8	0.3	8.1	4.9	3.2	8.7
AZ	41.0	7.0	2.8	5.5	2.8	0.2	3.6	4.4	4.3	8.1
CA	40.2	6.7	2.4	5.7	1.9	0.1	4.9	4.2	3.9	7.7
CO	47.6	7.9	3.2	6.6	3.0	0.4	3.9	4.6	5.5	9.0
CT	47.7	6.8	4.1	5.7	1.7	0.0	6.6	7.4	3.5	8.9
DE	50.4	7.1	5.5	7.2	2.9	0.0	4.9	6.1	4.5	9.5
FL	41.6	6.2	2.8	4.8	2.8	0.0	2.8	5.2	5.3	9.0
GA	45.1	7.7	2.6	5.5	2.1	0.2	6.0	4.4	4.0	9.7
HI	45.4	9.4	2.4	5.0	2.4	0.0	1.3	5.0	8.0	9.1
IA	48.4	8.2	3.0	3.5	2.1	0.1	7.8	6.3	4.2	10.2
ID	40.7	8.0	2.0	4.4	2.6	0.4	4.8	4.2	3.9	8.5
IL	46.4	6.7	3.2	6.1	2.0	0.1	6.4	5.6	3.9	9.6
IN	46.5	6.7	2.3	3.9	2.2	0.1	9.7	5.6	4.2	9.4
KS	47.4	9.0	2.5	4.5	2.1	0.3	6.8	5.5	3.9	9.6
KY	42.5	7.4	1.9	3.7	1.9	0.6	6.7	5.2	3.7	8.8
LA	41.4	8.2	2.1	3.9	2.7	1.1	3.8	5.1	4.0	8.5
MA	49.8	6.7	3.4	6.8	1.8	0.0	5.8	8.9	4.3	8.9
MD	44.5	8.5	2.7	6.3	2.9	0.0	3.0	5.9	3.9	8.4
ME	44.9	7.7	2.4	3.6	2.1	0.2	5.6	7.5	4.3	9.2
MI	43.2	6.7	2.1	5.5	1.7	0.1	7.6	5.3	3.8	8.1
MN	51.7	8.1	3.3	5.8	2.1	0.1	7.2	7.0	4.5	10.2
MO	46.7	7.4	2.8	5.2	2.2	0.1	6.0	6.0	4.5	9.4
MS	38.8	8.2	1.6	2.7	1.7	0.3	7.2	3.8	3.8	7.6
MT	42.1	9.1	2.0	3.2	2.3	0.8	2.2	5.5	5.4	9.2
NC	45.6	7.7	2.2	4.8	2.5	0.1	8.6	4.8	4.0	8.7
ND	50.4	11.3	2.6	3.4	2.5	0.8	3.4	7.1	4.6	11.3
NE	51.1	9.1	3.5	5.2	2.4	0.0	6.1	6.2	4.3	11.1
NH	47.7	6.8	2.8	4.3	1.9	0.1	7.2	7.0	4.6	10.4
NJ	45.7	7.2	3.0	6.5	1.7	0.0	4.7	5.9	3.6	10.1
NM	40.2	9.9	1.8	4.6	2.5	0.9	2.1	4.7	4.2	7.3
NV	48.3	6.0	2.5	5.2	4.1	0.6	2.0	3.3	13.9	8.7
NY	44.4	7.8	3.8	5.4	1.6	0.0	3.7	7.5	3.4	7.9
OH	46.5	6.8	2.5	5.2	1.9	0.1	7.9	6.2	4.1	9.0
OK	41.7	8.8	2.3	4.3	1.7	1.0	4.5	5.3	3.5	7.9
OR	44.7	7.9	2.7	4.7	2.2	0.3	6.0	5.2	4.2	9.0
PA	44.7	5.9	2.7	4.8	1.9	0.2	6.3	7.7	3.6	8.8
RI	44.8	6.1	2.9	4.7	1.7	0.0	6.5	8.4	4.3	7.4
SC	43.3	7.8	2.1	4.5	2.5	0.1	7.4	3.9	4.4	8.4
SD	48.0	9.5	3.2	2.9	2.5	0.0	5.3	6.8	5.0	9.9
TN	45.3	7.0	2.3	4.7	2.1	0.0	7.9	5.1	4.1	9.8
TX	42.5	7.4	2.6	4.7	2.4	0.8	4.6	4.8	3.8	8.9
UT	45.2	8.2	2.5	5.5	2.8	0.4	5.2	4.8	4.1	9.1
VA	47.0	8.9	2.4	7.2	2.7	0.2	4.6	4.8	4.1	8.6
VT	47.5	8.1	2.1	3.2	2.4	0.2	6.5	7.9	5.2	9.2
WA	43.7	8.2	2.4	4.7	2.5	0.2	5.2	5.0	4.1	8.4
WI	49.8	7.4	2.7	4.3	2.1	0.1	9.8	6.2	4.4	9.6
WV	39.2	7.7	1.6	2.8	1.9	1.5	3.8	5.5	3.4	7.7
WY	48.4	12.4	1.9	2.8	3.7	3.9	1.9	3.8	5.9	9.5
Total	45.1	7.9	2.6	4.7	2.3	0.4	5.5	5.6	4.5	9.0

Hawaii, Montana, Nevada, New Mexico, and Wyoming. Perhaps the most interesting sector is employment within government. Alaska, North Dakota, and Wyoming have nearly 12 percent of their population employed in public administration, whereas Florida, Nevada, and Pennsylvania have approximately 6 percent of their population employed in government jobs.

Table 3 presents the results for three panel unit root tests. All three tests offer a slightly different alternative hypothesis. Perhaps the most popular panel unit root test follows from Levin et al. (2002) (henceforth LLC). The LLC test follows from the standard augmented Dickey-Fuller test applied to an univariate series. The LLC restricts the coefficient on the lagged dependent variable to be constant across all units of the panel. The alternative hypothesis implies that the autoregressive parameter is constant across all panels. We can see the LLC test confirms the output gap and unemployment series to be stationary. For robustness we also estimate the unit root tests following Im et al. (2003) and Choi (2001) (henceforth IPS and Choi). The IPS test differs from the LLC test in that the IPS test allows the coefficient on the autoregressive parameter to be heterogeneous across panels. The IPS test has an alternative hypothesis that allows unit roots for some but not all of the individual panels. In essence the IPS test is based on the augmented Dickey-Fuller statistics averaged across all panels. We report the mean of the augmented Dickey-Fuller test statistic (t_{bar}) and the standardized t_{bar} statistic, Z_{t-bar}. Under the IPS test we can not reject the null hypothesis of nonstationarity

Finally, we estimate the panel unit root test following Choi (2001). Choi uses a GLS detrending method which follows from Elliott et al. (1996) and an error correction model to specify cross-sectional correlations. Choi reports three test statistics P_m, Z, and $L*$ which follow a standard normal distribution under the null hypothesis.[9] Under the Choi test we reject the null of non-stationarity at the 1% level of significance for both variables.

4.1 Baseline regressions

We present the results for the baseline panel regressions in Table 4. The first three columns present the results for Equation 2 using the HP filter method to measure the output gap. The pooled and state fixed effects models have coefficients that are approximately equal to Okun's findings of a three to one relationship. The coefficients of -0.347 and -0.349 shows that for every one percent decrease in the output gap, unemployment will increase by approximately 0.35%. Once we include both state and quarter fixed effects the coefficient decreases. The relationship is closer to five to one (a five percent change

Table 3 Unit root tests in panel data

Variable	*Unemployment*	*Output Gap (HP)*	*Output Gap (Quad.)*
LLC (2002) - Adjusted t*	-8.0438***	-18.6990***	-22.0075***
IPS (2003) - t_{bar}	-0.7597	-0.2737	-1.5027
IPS (2003) - Z_{t_bar}	6.3896	10.2588	0.1444
Choi (2002) - Pm	9.4451***	45.9971***	66.5524***
Choi (2002) - Z	-8.2248***	-21.2491***	-27.3692***
Choi (2002) - L*	-8.2403***	-28.7373***	-40.6531***

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
(t) denotes a trend is included.
LLC: under alternative hypothesis panels are stationary.
IPS: under alternative hypothesis some panels are stationary.
Choi: under alternative hypothesis at least one panel is stationary.

Table 4 Baseline panel regressions

	OLS	i-FE	i,t-FE	OLS	i-FE	i,t-FE
$Y_t - Y_t^*$ (HP $\lambda = 1600$)	-0.347***	-0.349***	-0.191***			
	(-41.97)	(-15.66)	(-7.22)			
$Y_t - Y_t^*$ (Quadratic)				-0.261***	-0.261***	-0.155***
				(-22.89)	(-28.51)	(-13.25)
Constant	0.0523***	0.0523***	0.0573***	0.0556***	0.0556***	0.0580***
	(254.23)	(245.07)	(45.35)	(213.40)	(5.72e+11)	(40.03)
R^2	0.446	0.598	0.769	0.159	0.216	0.747
N	4450	4450	4450	4450	4450	4450

t statistics in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
White standard errors.

in the output gap will cause unemployment to change by one percent). Columns four through six estimate the same models but use the output gap measure derived as the residual from the quadratic trend regression. The results from the pool and state fixed effects models are nearly identical, coefficients of -0.261, and significantly lower than the results estimated through the HP filter. The results including both state and quarter fixed effects (column 6) are similar to those presented in column three. Proceeding to estimating the threshold procedure we elect to use the output gap derived through the HP filter. These results are more consistent with past literature, the regressions have higher R^2 statistics, and fall closer to Okun's original findings.

5 Threshold regressions

We present the results for the single and double threshold models in Tables 5 and 6. In addition to reporting the coefficients from Equation 2 we also report the likelihood ratio test statistic, p-value, threshold value, and threshold percentile. For example, when controlling for a single threshold in government employment we find evidence a threshold exists at the 80th percentile. States with government employment less than 8.8% of the state population will have a coefficient of -0.357, whereas states with employment in government jobs more than 8.8% of the population will have a coefficient of -0.229. In the single threshold model we see a similar divergence occur in construction, natural resources, and leisure. In the other sectors the employment share in the lower threshold regime tends to have the lower coefficient. The effect is largest in the manufacturing and financial services sectors. In both cases, states with a relatively small employment share in these sectors tend to have a less sensitive relationship between output gaps and unemployment.

Since the likelihood ratio test statistic is large and significant at a 1% level for all nine industries we will spend most of the discussion focused on the double threshold model. We present the results for the double threshold model in Table 6. All nine industries plus total employment to population display evidence of two statistically significant thresholds. To better understand the results will also present frequency tables for each state by regime. The frequency results are presented in Tables 7 and 8.[10]

5.1 Government employment

Consistent with our hypothesis we find increased employment within the government sector results in a less sensitive relationship between changes in output and unemployment. We find evidence of two thresholds in government employment. The thresholds

Table 5 Single threshold model - industry employment to population

	Baseline	Total	Gov't	Financial	Services	Const.	Natural	Manuf.	Education	Leisure	Trade
Output Gap	-0.349***										
	(-80.82)										
$q_{i,t} \leq \gamma$		-0.357***	-0.383***	-0.255***	-0.303***	-0.596***	-0.494***	-0.281***	-0.333***	-0.380***	-0.359***
		(-80.21)	(-83.23)	(-29.39)	(-44.49)	(-50.43)	(-64.39)	(-48.30)	(-69.74)	(-78.70)	(-74.71)
$q_{it} > \gamma$		-0.229***	-0.190***	-0.378***	-0.379***	-0.315***	-0.291***	-0.424***	-0.418***	-0.246***	-0.306***
		(-11.99)	(-18.84)	(-78.17)	(-69.11)	(-72.00)	(-60.02)	(-69.89)	(-42.68)	(-27.62)	(-28.09)
Constant	0.0523***	0.0522***	0.0523***	0.0523***	0.0523***	0.0519***	0.0521***	0.0523***	0.0522***	0.0522***	0.0522***
	(324.91)	(323.77)	(335.98)	(330.73)	(327.69)	(337.88)	(341.42)	(335.44)	(326.31)	(330.23)	(320.63)
R^2	0.598	0.601	0.623	0.611	0.604	0.638	0.638	0.622	0.603	0.613	0.599
N	4450	4450	4450	4450	4450	4450	4450	4450	4450	4450	4450
F-stat		41.76	295.8	155.1	75.22	475.2	475.0	281.7	60.30	174.4	19.10
p-value		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
γ		49.96	8.801	1.944	4.856	1.647	0.115	3.551	6.653	5.346	9.033
Percentile		0.894	0.807	0.140	0.533	0.108	0.296	0.231	0.785	0.899	0.528

t statistics in parentheses, White standard errors.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 6 Double threshold model - industry employment to population

	Total	Gov't	Financial	Services	Const.	Natural	Manuf.	Education	Leisure	Trade
$q_{it} \leq \gamma_1$	-0.334***	-0.402***	-0.219***	-0.303***	-0.606***	-0.496***	-0.281***	-0.366***	-0.351***	-0.342***
	(-61.66)	(-63.56)	(-19.19)	(-44.66)	(-50.45)	(-64.17)	(-48.47)	(-47.32)	(-53.77)	(-57.81)
$\gamma_1 < q_{it} \leq \gamma_2$	-0.477***	-0.362***	-0.350***	-0.363***	-0.378***	-0.316***	-0.454***	-0.247***	-0.416***	-0.432***
	(-35.49)	(-54.51)	(-66.67)	(-60.31)	(-50.16)	(-53.64)	(-55.21)	(-24.32)	(-57.65)	(-38.79)
$q_{it} > \gamma_2$	-0.337***	-0.190***	-0.432***	-0.459***	-0.286***	-0.246***	-0.387***	-0.375***	-0.246***	-0.324***
	(-39.92)	(-18.86)	(-46.76)	(-33.18)	(-54.25)	(-29.57)	(-42.84)	(-63.25)	(-27.79)	(-41.66)
Constant	0.0522***	0.0523***	0.0523***	0.0524***	0.0517***	0.0522***	0.0522***	0.0522***	0.0522***	0.0522***
	(325.24)	(336.73)	(332.77)	(329.04)	(338.82)	(343.26)	(334.72)	(328.22)	(331.72)	(324.04)
R^2	0.607	0.625	0.616	0.608	0.646	0.642	0.625	0.609	0.617	0.604
N	4450	4450	4450	4450	4450	4450	4450	4450	4450	4450
F-Stat	58.78	20.18	54.30	39.85	98.69	46.82	29.59	64.06	44.20	48.52
P-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
γ_1	43.44	7.311	1.896	4.856	1.639	0.109	3.551	5.148	4.080	8.105
γ_2	44.61	8.811	2.675	6.120	1.896	0.606	4.921	5.509	5.326	8.571
$Percentile_1$	0.340	0.353	0.115	0.533	0.103	0.276	0.231	0.422	0.449	0.192
$Percentile_2$	0.455	0.809	0.618	0.863	0.285	0.688	0.431	0.539	0.895	0.334

t statistics in parentheses, White standard errors.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 7 Frequency by State (Alaska - Mississippi)

Industry	Regime	β	AK	AL	AR	AZ	CA	CO	CT	DE	FL	GA	HI	IA	ID	IL	IN	KS	KY	LA	MA	MD	ME	MI	MN	MO	MS
	$q_{it} \leq 43.44$	-0.334	28	83	79	81	89	0	0	0	69	15	11	0	89	0	8	0	55	85	0	28	23	44	0	0	89
Total	$43.44 < q_{it} \leq 44.61$	-0.477	9	6	10	8	0	11	0	0	20	22	9	12	0	12	7	16	25	4	0	12	8	20	0	11	0
	$q_{it} > 44.61$	-0.337	52	0	0	0	0	78	89	89	0	52	69	77	0	77	74	73	9	0	89	49	58	25	89	78	0
	$q_{it} \leq 7.311$	-0.402	0	0	61	78	89	0	89	89	89	11	0	0	0	89	89	0	21	0	89	0	0	89	0	26	0
Gov't	$7.311 < q_{it} \leq 8.811$	-0.362	0	89	28	11	0	89	0	0	0	78	0	89	89	0	0	10	68	89	0	89	89	0	89	63	89
	$q_{it} > 8.811$	-0.190	89	0	0	0	0	0	0	0	0	0	89	0	0	0	0	79	0	0	0	0	0	0	0	0	0
	$q_{it} \leq 1.896$	-0.219	26	0	89	0	0	0	0	0	0	0	0	0	32	0	0	0	27	3	0	0	0	0	0	0	89
Financial	$1.896 < q_{it} \leq 2.675$	-0.350	63	89	0	36	84	0	0	0	15	71	70	18	57	0	89	89	62	86	0	18	76	89	0	16	0
	$q_{it} > 2.675$	-0.432	0	0	0	53	5	89	89	89	74	18	19	71	0	89	0	0	0	0	89	71	13	0	89	73	0
	$q_{it} \leq 4.856$	-0.303	89	89	89	20	4	0	0	0	33	16	39	89	56	0	89	59	89	89	0	0	89	16	5	18	89
Services	$4.856 < q_{it} \leq 6.120$	-0.363	0	0	0	45	60	19	74	5	46	60	50	0	33	33	0	30	0	0	20	30	0	62	53	71	0
	$q_{it} > 6.120$	-0.459	0	0	0	24	25	70	15	84	10	13	0	0	0	56	0	0	0	0	69	59	0	11	31	0	0
	$q_{it} \leq 1.639$	-0.606	0	0	18	0	30	0	34	0	0	10	0	4	0	10	0	0	9	0	32	0	0	41	0	0	26
Const.	$1.639 < q_{it} \leq 1.896$	-0.378	13	16	33	10	13	0	38	0	8	12	3	16	6	25	11	23	20	0	19	0	33	20	39	24	38
	$q_{it} > 1.896$	-0.286	76	73	38	79	46	89	17	89	81	67	86	69	83	54	78	66	60	89	38	89	56	28	50	65	25
	$q_{it} \leq 0.109$	-0.496	0	0	0	0	81	0	89	0	41	15	0	89	0	65	23	0	0	0	89	0	0	66	5	86	0
Natural	$0.109 < q_{it} \leq 0.606$	-0.316	0	89	89	89	8	89	0	0	0	74	0	0	85	24	66	89	64	0	0	0	89	23	84	3	89
	$q_{it} > 0.606$	-0.246	89	0	0	0	0	0	0	89	48	0	89	0	4	0	0	0	25	89	0	89	0	0	0	0	0

Table 7 Frequency by State (Alaska - Mississippi) *(Continued)*

	$q_{it} \leq 3.551$	-0.281	89	0	0	41	12	37	0	15	83	7	89	0	12	0	0	0	0	33	0	75	0	0	0	0	0
Manuf.	$3.551 < q_{it} \leq 4.921$	-0.454	0	0	0	48	29	47	12	28	6	18	0	0	29	13	0	0	10	56	33	14	36	8	0	15	12
	$q_{it} > 4.921$	-0.387	0	89	89	0	48	5	77	46	0	64	0	89	48	76	89	89	79	0	56	0	53	81	89	74	77
	$q_{it} \leq 5.148$	-0.366	54	89	58	74	89	81	0	9	23	89	53	0	77	21	20	30	43	49	0	16	0	46	0	7	89
Education	$5.148 < q_{it} \leq 5.509$	-0.247	17	0	19	15	0	8	0	13	47	0	26	8	12	24	26	12	10	15	0	13	4	11	3	7	0
	$q_{it} > 5.509$	-0.375	18	0	12	0	0	0	89	67	19	0	10	81	0	44	43	47	36	25	89	60	85	32	86	75	0
	$q_{it} \leq 4.080$	-0.351	29	89	89	12	71	0	89	10	0	52	0	22	82	74	22	73	89	32	23	79	24	89	0	13	47
Leisure	$4.080 < q_{it} \leq 5.326$	-0.416	60	0	0	77	18	27	0	79	60	37	0	67	7	15	67	16	0	57	66	10	65	0	89	76	42
	$q_{it} > 5.326$	-0.246	0	0	0	0	0	62	0	0	29	0	89	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	$q_{it} \leq 8.105$	-0.342	0	28	7	36	89	11	3	0	12	0	9	0	12	0	0	0	0	6	0	14	0	43	0	0	89
Trade	$8.105 < q_{it} \leq 8.571$	-0.432	15	44	26	46	0	3	10	12	0	12	9	0	32	0	12	0	31	52	16	41	5	29	0	8	0
	$q_{it} > 8.571$	-0.324	74	17	56	7	0	75	76	77	77	77	71	89	45	89	77	89	58	31	73	34	84	17	89	81	0

Table 8 Frequency by State (Montana - Wyoming)

Industry	Regime	β	MT	NC	ND	NE	NH	NJ	NM	NV	NY	OH	OK	OR	PA	RI	SC	SD	TN	TX	UT	VA	VT	WA	WI	WV	WY
	$q_{it} \leq 43.44$	-0.334	67	13	10	0	3	0	89	12	14	0	75	25	18	12	42	12	13	68	28	0	0	43	0	89	0
Total	$43.44 < q_{it} \leq 44.61$	-0.477	9	13	4	0	7	22	0	0	38	23	14	13	19	24	27	3	10	12	4	6	10	21	0	0	15
	$q_{it} > 44.61$	-0.337	13	63	75	89	79	67	0	77	37	66	0	51	52	53	20	74	66	9	57	83	79	25	89	0	74
	$q_{it} \leq 7.311$	-0.402	0	0	0	0	84	56	0	89	0	89	0	0	89	89	5	0	89	29	0	0	0	0	25	15	0
Gov't	$7.311 < q_{it} \leq 8.811$	-0.362	10	89	0	0	5	33	0	0	89	0	55	89	0	0	84	0	0	60	89	55	89	89	64	74	0
	$q_{it} > 8.811$	-0.190	79	0	89	89	0	0	89	0	0	0	34	0	0	0	0	89	0	0	0	34	0	0	0	0	89
	$q_{it} \leq 1.896$	-0.219	27	0	0	0	0	0	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	89	48
Financial	$1.896 < q_{it} \leq 2.675$	-0.350	62	89	43	0	27	0	9	73	0	62	89	30	34	30	89	24	89	69	55	89	89	89	32	0	41
	$q_{it} > 2.675$	-0.432	0	0	46	89	62	89	0	16	89	27	0	59	55	59	0	65	0	20	34	0	0	0	57	0	0
	$q_{it} \leq 4.856$	-0.303	89	32	89	22	73	0	73	19	23	23	80	41	36	50	69	89	42	38	19	0	89	55	74	89	89
Services	$4.856 < q_{it} \leq 6.120$	-0.363	0	57	0	67	16	26	16	67	66	66	9	48	53	39	20	0	47	51	64	19	0	34	15	0	0
	$q_{it} > 6.120$	-0.459	0	0	0	0	0	63	0	3	0	0	0	0	0	0	0	0	0	0	6	70	0	0	0	0	0
	$q_{it} \leq 1.639$	-0.606	14	0	6	0	19	37	0	0	42	21	33	0	4	42	0	0	0	0	0	0	0	0	6	14	0
Const.	$1.639 < q_{it} \leq 1.896$	-0.378	9	9	9	11	25	29	0	0	47	20	40	26	42	25	11	0	18	0	10	0	0	0	21	40	0
	$q_{it} > 1.896$	-0.286	66	80	74	78	45	23	89	89	0	48	16	63	43	22	78	89	71	89	79	89	89	89	62	35	89
	$q_{it} \leq 0.109$	-0.496	0	56	0	0	89	89	0	0	89	39	0	0	0	89	26	0	0	0	0	0	0	13	89	0	0
Natural	$0.109 < q_{it} \leq 0.606$	-0.316	0	33	61	0	0	0	0	50	0	50	0	89	89	0	63	0	0	0	89	89	89	76	0	0	0
	$q_{it} > 0.606$	-0.246	89	0	28	89	0	0	89	39	0	0	89	0	0	0	0	89	89	89	0	0	0	0	0	89	89
	$q_{it} \leq 3.551$	-0.281	89	0	47	0	0	18	89	89	41	0	11	0	0	0	0	0	0	12	0	18	0	0	0	34	89
Manuf.	$3.551 < q_{it} \leq 4.921$	-0.454	0	12	42	0	0	27	0	0	40	0	55	13	13	22	12	22	11	32	40	26	7	41	0	55	0
	$q_{it} > 4.921$	-0.387	0	77	0	89	89	44	0	0	8	89	23	76	76	67	77	67	78	45	49	45	82	48	89	0	0

Table 8 Frequency by State (Montana - Wyoming) *(Continued)*

	$q_{it} \leq 5.148$	-0.366	32	55	0	16	0	17	52	89	0	8	27	48	0	0	89	0	50	66	61	62	0	59	10	30	89
Education	$5.148 < q_{it} \leq 5.509$	-0.247	15	12	0	10	0	11	16	0	0	10	28	17	0	0	0	9	14	21	18	9	0	16	14	11	0
	$q_{it} > 5.509$	-0.375	42	22	89	63	89	61	21	0	89	71	34	24	89	89	0	80	25	2	10	18	89	14	65	48	0
	$q_{it} \leq 4.080$	-0.351	0	54	12	13	12	89	25	0	89	28	89	22	89	28	18	0	32	82	32	28	0	46	10	89	0
Leisure	$4.080 < q_{it} \leq 5.326$	-0.416	23	35	77	76	77	0	64	0	0	61	0	67	0	61	71	73	57	7	57	61	55	43	79	0	9
	$q_{it} > 5.326$	-0.246	66	0	0	0	0	0	0	89	0	0	0	0	0	0	0	16	0	0	0	0	34	0	0	0	80
	$q_{it} \leq 8.105$	-0.342	0	14	0	0	0	0	89	12	77	0	61	10	0	89	22	0	0	5	0	13	0	13	0	89	0
Trade	$8.105 < q_{it} \leq 8.571$	-0.432	0	22	0	0	0	0	0	15	8	14	28	3	23	0	37	0	0	8	11	14	3	45	0	0	0
	$q_{it} > 8.571$	-0.324	89	53	89	89	89	89	0	62	4	75	0	76	66	0	30	89	89	76	78	62	86	31	89	0	89

occur at the 35th and 81st percentiles with employment ratios of 7.3 and 8.8% of total state population, respectively. The coefficient is lowest (-0.190) for states with government employment rates above the 81st percentile. We can use the frequency tables to better understand which states appear in this regime. The states with a relatively large share of government employment are Alaska, Hawaii, Kansas, Montana, North Dakota, Nebraska, New Mexico, South Dakota, and Wyoming. It is worth point out that many of these states also have relatively larger employment shares within the natural resources and mining sector. The coefficient is highest, implying a more sensitive relationship between output and unemployment for states with the smallest share of employment within the government sector. The states with the majority of their observations appearing in the lowest regime include Arkansas, Arizona, California, Connecticut, Delaware, Florida, Illinois, Indiana, Massachusetts, Michigan, New Hampshire, New Jersey, Nevada, Ohio, Pennsylvania, Rhode Island, and Tennessee. Unlike the high government employment regime there does not appear to be a common link connecting the low employment states.

The magnitude of the differences in the coefficients is striking. For the high employment regime the coefficient is -0.190 but nearly double for the low employment regime. This suggests states with a relatively large employment share within government services experience smaller shocks to unemployment following from cyclical fluctuations in the business cycle. For these states tt will take approximately a five percent change in output for unemployment to change by one percent. The coefficient for the low employment regime is significantly higher in absolute value, -0.402. The coefficient for the low employment regime is more than double which suggests a much more sensitive relationship. For these states, every 2.5 percent change in output relates to a one percent change in unemployment.

5.2 Financial services

Increased employment within the financial sector results in a more sensitive relationship between output and unemployment. The recent business cycle fluctuations have largely been driven by asset price volatility which we suspect to be a key factor behind these results. This sector includes employment within financial intermediaries including insurance companies and real estate. We find evidence of two statistically significant thresholds within financial employment. The thresholds occur at the 11th and 61st percentiles, with employment shares of 1.9 and 2.7% of the population. Over time, states having consistently large employment shares within the financial sector include: Colorado, Connecticut, Delaware, Florida, Iowa, Illinois, Maryland, Minnesota, Missouri, Nebraska, New Jersey, and New York. Okun's coefficient for these states is -0.432. States with a relatively small employment share within the financial sector have a coefficient half as large at -0.219. These states include: Arkansas, Mississippi, New Mexico, and West Virginia.

5.3 Professional and Business Services

We expect states with a relatively large share of employment within service sectors to have a more sensitive relationship between output and unemployment. Many service jobs tend to be pro-cyclical, these would include employment with legal services, accounting, architectural, scientific research and development, and administrative services. We find evidence of two thresholds at the 53rd and 86th percentiles with employment shares of 4.8

and 6.1%. Okun's coefficient is increasing as employment within service sectors increases. The coefficient is lowest (-0.303) for states with a relatively small share of employment in services. These states include: Alaska, Alabama, Arkansas, Iowa, Indiana, Kentucky, Louisiana, Maine, Mississippi, Montana, North Dakota, South Dakota, Vermont, West Virginia, and Wyoming. Although we find the coefficient to be statistically different, it is worth noting the coefficient does not vary greatly across the three regimes.

In the high service employment regime the coefficient increases to -0.459, approximately 50% greater than the coefficient found for the low employment regime. States with relatively high service employment include Delaware, Massachusetts, Maryland, New Jersey, and Virginia.

5.4 Construction

Contrary to our hypothesis, increased employment within the construction industry resulted in a less sensitive relationship between output and unemployment. Given the majority of the data are prior to the Great Recession this result is relatively consistent. Construction employment had been relative noncyclical until the housing collapse in 2008. We find evidence of two thresholds occurring at the 10th and 28th percentiles with employment shares of 1.6 and 1.9%. Given the relatively low threshold percentiles the key result only applies to states with an extremely small construction share of employment. Most of the observations in the low employment regime occur from 1990 through 1993 and 2011 through 2012.[11] States with relatively low construction employment in the later period include: Arkansas, California, Connecticut, Georgia, Illinois, Kentucky, Massachusetts, Michigan, Mississippi, New Hampshire, New Jersey, New York, Ohio, Rhode Island, and Wisconsin. For these states the coefficient is relatively high at -0.606.

The more sensitivity result is likely stemming from large layoffs within the construction industry in the years prior to appearing in the low regime sample. Although a large number of observations in the low regime occur in 2011 many of these states had larger employment shares from 2000 through 2008. For example, California had an employment to population share in excess of 2.5% prior to 2009. In 2009 the employment share dropped to approximately 1.80% and thereafter fell further to 1.5%. For many states, large decreases of employment within the construction industry are driving the more sensitive relationship and higher unemployment rates following the global financial crisis.

5.5 Natural resources and mining

Some of the more interesting results come when we estimate thresholds within natural resources and mining. A priori we do not have a strong suspicion over the magnitude of the coefficients. We find evidence of two thresholds occurring at the 28th and 69th percentiles with employment shares of 0.10 and 0.60 percent. The relationship becomes less sensitive as employment increases in natural resource sectors. Overall, the share of employment within the natural resource sectors is relatively small but nonetheless explains a large variation in Okun's coefficient. States with a large employment share have a coefficient of -0.246. These states include: Alaska, Delaware, Hawaii, Louisiana, Maryland, Montana, Nebraska, New Mexico, Oklahoma, South Dakota, Tennessee, Texas, West Virginia, and Wyoming. Interestingly, many of these states also have relatively large employment shares within the government sector.

States within the low employment regime include: California, Colorado, Iowa, Massachusetts, Missouri, New Hampshire, New Jersey, New York, and Rhode Island. These states have a coefficient of -0.496. It is important to note that many of these states also have high employment in other sectors that also correspond with a more sensitive relationship, mainly the financial and construction sectors.

5.6 Manufacturing

Manufacturing employment been in the spotlight of our economic recovery. The high unemployment rates for many states throughout the midwest is result of large declines in manufacturing employment over the last fifteen years. As expected we find the relationship is more sensitive for states with employment in the middle and high employment regimes. We find evidence of two regimes at the 23rd and 43rd percentiles with employment shares of 3.5 and 4.9% of the population. The coefficient is highest, -0.454, for the middle regime, but not greatly different than the pooled estimate of -0.35. The coefficient decreases to -0.387 for the high employment regime. Despite the recent struggles of the states heavily dependent on manufacturing employment this does not appear to be driving a more sensitive relationship between output and unemployment.

For many states, the decline in manufacturing has been a continual problem since the late 1990s and despite the high unemployment rates throughout Michigan, Wisconsin, Indiana, Ohio, and Minnesota they do not appear to be caused by a decline in manufacturing employment. As employment in manufacturing declined throughout the early 2000s, many ex-manufacturing workers were able to find employment within construction and service sectors. The higher unemployment rates, which in this case do not correlate with a more sensitive relationship, are likely the result of job losses in these latter sectors. Another possible explanation lies within the context of wage contracts. Many manufacturing sectors are protected through employment protection causes in union contracts.

States in the low employment regime have a significantly lower coefficient of -0.281. These states include: Alaska, Hawaii, Maryland, Montana, New Mexico, Nevada, and Wyoming. Many of these states were also in the high government and natural resource employment shares. We cannot conclude if the less sensitive relationship is the result of lower employment in manufacturing or higher employment in government and natural resources. We can conclude that states with lower manufacturing shares have a less sensitive output to unemployment relationship, but the reverse does not apply. States with large shares of employment within manufacturing sectors do not have a significantly more sensitive relationship when compared to Okun's coefficient pooled across states.

5.7 Education and health services

We hypothesize that education and health services will have a more sensitive relationship associated with states that have a smaller employment share. During recessions many states are forced to layoff workers within this sector. We find evidence of two thresholds which occur at the 42nd and 54th percentiles with employment shares of 5.1 and 5.6% of the population. States in the middle regime have a less sensitive relationship (-0.247) relative to the low and high regimes. The latter two have coefficients that are consistent with the pooled estimate, -0.366 and -0.375, respectively. Given the overall small number of observations within the middle regime we don't suspect employment within education and health services to have a large economic impact on the coefficient.

5.8 Leisure and hospitality

Leisure and hospitality sectors are highly cyclical, for that reason we hypothesize that increased employment within these sectors would result in a more sensitive relationship. We find evidence of two thresholds occurring at the 45th and 90th percentiles. Interestingly the high employment regime also has the most insensitive relationship. States in this grouping include: Connecticut, Florida, Hawaii, Montana, Nevada, and Wyoming. These states have a coefficient of -0.246 which is considerably lower than the pooled estimate.

5.9 Trade, transportation, and utility

The last employment sector that we analyze is a collection of many different industries including: retail and wholesale trade, transportation, and utilities. Given the emphasis on wholesale and retail production, we expect the relationship to become more sensitive with increased employment in these sectors. We find evidence of two thresholds occurring at the 19th and 33rd percentiles, but overall the coefficients do not vary largely across these thresholds. The low and high regimes have coefficients of -0.342 and -0.324, respectively. These are consistent with the pooled sample. The middle regime has a slightly higher coefficient of -0.432.

5.10 Industry thresholds and recessions

In addition to understanding the relationship between Okun's coefficient and industry employment levels we are also interested in understanding how sector level employment affects unemployment rates following a recession. We use our results from the double threshold model and incorporate a recession dummy variable, D_{t-i} that takes a value of one in the *ith* quarter of the recession and zero otherwise. We use the NBER dating of the business cycle to determine the end of each recession (1991q1, 2001q4, and 2009q2). We include the dummy variable with eight lags to measure how unemployment responds given a state has an employment level in a particular threshold regime. The inclusion of eight lags allows us to measure unemployment a full two years after the official end of a recession.

The results for each industry are presented Table 9. The first row estimates the baseline regression with the included recession dummy variable. Okun's coefficient remains unchanged and on average shows a very slow response to unemployment rates following the recession. As the economy recovers unemployment will decrease in accordance with Okun's coefficient but the dummy variables show a shift up in the baseline unemployment, the constant term. In the next set of rows are the results broken down by industry regimes. There are three sets of results for each industry. These results correspond to the three unique regimes found through the double threshold model. Using three sets of regressions also allows us to measure a unique constant term for each regime. The constant term can be interpreted as the natural rate of unemployment.

One interesting result is that many of the industries show an increase in unemployment following the end of the recession. Partly this is a result of using a national business cycle measure with state unemployment. States are likely to have a slightly different business

Table 9 Double threshold model with regression dummy variables

Industry	Regime	U^*	β	D_{t-1}	D_{t-2}	D_{t-3}	D_{t-4}	D_{t-5}	D_{t-6}	D_{t-7}	D_{t-8}
Baseline		0.0502	-0.3305	0.0057	0.0049	0.0043	0.0063	0.0064	0.0061	0.0053	0.0043
	$q_{it} \leq 7.311$	0.0533	-0.3848	0.0037	0.0035	0.0033	0.0064	0.0064	0.0062	0.006	0.0053
Gov't	$7.311 < q_{it} \leq 8.811$	0.0504	-0.339	0.0072	0.0059	0.0052	0.0057	0.0059	0.0063	0.0043	0.0033
	$q_{it} > 8.811$	0.0446	-0.1691	0.0047	0.0045	0.0039	0.0053	0.0054	0.0051	0.0044	0.0028
	$q_{it} \leq 1.896$	0.0583	-0.1789	0.0031	0.0041	0.0051	0.0105	0.0102	0.011	0.0081	0.0065
Financial	$1.896 < q_{it} \leq 2.675$	0.0513	-0.3227	0.0079	0.0065	0.0056	0.0057	0.0062	0.0058	0.0055	0.0042
	$q_{it} > 2.675$	0.0473	-0.4458	0.0023	0.0014	0.0007	0.0025	0.003	0.0022	0.0021	0.0018
	$q_{it} \leq 4.856$	0.0505	-0.2749	0.0066	0.0052	0.005	0.0069	0.0075	0.0072	0.0061	0.005
Services	$4.856 < q_{it} \leq 6.120$	0.052	-0.3529	0.0068	0.006	0.0047	0.0048	0.0044	0.004	0.0036	0.0027
	$q_{it} > 6.120$	0.0466	-0.4481	0.0043	0.0036	0.0034	0.0024	0.0007	0.0005	0.0002	-0.0007
	$q_{it} \leq 1.639$	0.0633	-0.4444	0.0032	0.0054	0.0049	0.0063	0.007	0.0087	0.0072	0.0068
Const.	$1.639 < q_{it} \leq 1.896$	0.0547	-0.3378	0.0085	0.0047	0.0042	0.003	0.0031	0.002	0.001	-0.0002
	$q_{it} > 1.896$	0.0479	-0.2712	0.0055	0.0043	0.003	0.0041	0.0043	0.0041	0.0038	0.0026
	$q_{it} \leq 0.109$	0.0534	-0.4931	0.0022	0.0014	0.0007	0.0027	0.0022	0.0031	0.0029	0.0024
Natural	$0.109 < q_{it} \leq 0.606$	0.049	-0.2985	0.0061	0.0054	0.0049	0.0068	0.0071	0.0066	0.0059	0.0046
	$q_{it} > 0.606$	0.049	-0.2243	0.0044	0.0037	0.003	0.0066	0.0069	0.0068	0.0057	0.0046

Table 9 Double threshold model with regression dummy variables *(Continued)*

	$q_{it} \leq 3.551$	0.0516	-0.2605	0.0059	0.0053	0.0047	0.0058	0.0056	0.0052	0.0037	0.002
Manuf.	$3.551 < q_{it} \leq 4.921$	0.0541	-0.3312	0.0057	0.0053	0.005	0.0062	0.0056	0.0047	0.0035	0.0033
	$q_{it} > 4.921$	0.0493	-0.3935	0.0016	0.0006	-0.0004	0.004	0.0046	0.0047	0.005	0.0045
	$q_{it} \leq 5.148$	0.0532	-0.3447	0.0056	0.0051	0.0043	0.0069	0.0077	0.0074	0.0062	0.0052
Education	$5.148 < q_{it} \leq 5.509$	0.0487	-0.2433	0.0097	0.0076	0.0054	0.0048	0.0053	0.0058	0.0056	0.0038
	$q_{it} > 5.509$	0.0483	-0.3704	0.0044	0.0035	0.0028	0.0042	0.0037	0.0037	0.0034	0.0025
	$q_{it} \leq 4.080$	0.0539	-0.3393	0.0065	0.0062	0.0062	0.008	0.0082	0.0078	0.0068	0.0059
Leisure	$4.080 < q_{it} \leq 5.326$	0.0484	-0.4138	0.0034	0.0024	0.0015	0.002	0.0023	0.0021	0.0018	0.0012
	$q_{it} > 5.326$	0.045	-0.2561	0.0032	0.0018	0.0001	-0.0007	-0.0005	-0.0004	-0.0016	-0.0028
	$q_{it} \leq 8.105$	0.0594	-0.3223	0.0068	0.0065	0.0061	0.0072	0.0071	0.0068	0.0053	0.0037
Trade	$8.105 < q_{it} \leq 8.571$	0.0569	-0.2743	0.0031	0.0026	0.0031	0.0044	0.0042	0.0036	0.003	0.0025
	$q_{it} > 8.571$	0.0469	-0.307	0.0042	0.0036	0.0022	0.0042	0.0048	0.0048	0.0042	0.0035

White standard errors are used.
U^* & β are significant at the 1% level.

cycle relative to the national economy. Even still, this result is not surprising. Looking at the United States as a whole the NBER dated the end of the recession in 2009q2. The national unemployment rate during 2009q2 averaged 9.3% but continued to increase and peaked at 10% in 2009q4. This pattern is similar for the other recessions observed in the data. Nonetheless the inclusion of the lagged dummy variable will capture the increase in unemployment rates following the "official" end of the recession.

Perhaps the most interesting case if for government employment levels. States with a smaller share of government employment not only have a more sensitive relationship to changes in output but also have significantly higher unemployment rates than states with a larger share of government workers. After eight quarters following a recession states with a relatively larger share of professional service, financial services, construction, and government employment were likely to have lower unemployment rates. Additionally, states with a smaller share of employment in natural resources and manufacturing had significantly lower unemployment rates in the eight quarters following the end of a recession.

The most extreme differences appear in the financial, professional services, and construction sectors. States with a relatively large share of employment within financial and professional services tend to have a more sensitive relationship to changes in the output gap but this also shows up as a lower natural rate and a much quicker recovery following the end of the recession. Both of these industries tend to be free of labor market rigidities which helps to explain the speed at which unemployment decreases. States with a relatively low measure of construction employment have a higher natural rate and Okun's coefficient but a slower recovery captured by the relatively high coefficients on the dummy variables.

Another interesting case emerges for states with relatively larger employment shares within manufacturing. These states have a higher Okun's coefficient but following a recession unemployment rates are relatively flat but increase drastically in months five through eight. One explanation could be the existence of labor unions that fight to keep workers employed longer where as many service workers are at will employees and can have jobs terminated earlier during the recession.

6 Conclusion

In this paper we show that Okun's Law largely depends on the overall employment make-up for each state. States with a less sensitive relationship between unemployment and output have a larger share of employment within government, natural resources and mining, construction, and leisure and hospitality with lower employment shares in financial services, professional and business services, and manufacturing. The coefficient across the pooled sample is consistent with Okun's original findings of a three-to-one relationship between changes in the output gap and unemployment. We find the relationship weakens to a five-to-one relationship for states with relatively large employment within government and natural resource sectors. The relationship strengthens to a nearly two-to-one relationship for states with relatively smaller employment within government and construction sectors, and larger employment within financial and professional services.

There is evidence that time period does matter. We find that many of the regimes not only relate to employment share by sector but also specific time periods. This was seen especially in the estimates for the construction sectors. Most of the low regime, highly sensitive results came through states following the housing collapse from 2010 through 2012.

In the broader scope of the literature these results can be seen as a way to further understand the dynamics between cyclical fluctuations in the business cycle and unemployment rates. As many researchers are focusing on productivity gains to explain the recent divergence in Okun's coefficient we find considerable evidence to suggest that the overall construction of a state's labor market is equally important.

Endnotes

[1] See Mankiw (2010), Romer (2006), or Abel et al. (2008) for textbook examples.

[2] For a summary of estimating the natural rate of unemployment see Weidner and Williams (2011).

[3] Because of the negative relationship, throughout the paper we will refer to the coefficient as an absolute value. An increase in absolute value of the coefficient, implies for a given change in the output gap, unemployment will change by a larger amount.

[4] For robustness we also use $\lambda = 16,000$. These results are available upon request.

[5] For robustness we have also estimated the results assuming a constant trend of 2%, 2.25%, 2.75%, and 3% from 2008 through 2012 and are quantitatively similar to those presented below.

[6] The results are consistent when trimming by 5% or 15%.

[7] Under total observations of N and a minimum $\pi * N$ observations in the threshold grouping would require estimating $2 \times \pi \times N$ regressions for a single threshold model. In the case of $N = 4600$ we estimate 3,680 regressions under the single threshold procedure. The double threshold model requires a greater need for computing power. The total number of regressions estimated for the double threshold model equals: $\sum_{i=1}^{(1-3\pi)N} i$, for the case of $N = 700$ the double threshold model requires estimating 5,185,810 regressions.

[8] See Hansen (1999) for complete details of the threshold procedure and test statistics. Graphs of confidence intervals are available upon request.

[9] For details of all three unit root tests we suggest reading Maddala and Kim (1998).

[10] For robustness we estimated the threshold models using the lag of the employment variables. The results are nearly identical to those reported here and can be provided upon request.

[11] Time frequency charts are available upon request.

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The IZA Journal of Labor Policy is committed to the IZA Guiding Principles of Research Integrity. The author declares that he has observed these principles.

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