State Level Tests of Okun's Coefficient

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By

Brian P. Kennedy
Bachelor of Science
University of Wyoming, 1989

Director: Carlos Ramirez, Professor
Department of Economics

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George Mason University
Fairfax, VA

DEDICATION

This is dedicated to Duangmanee Laovakul, without whom this, and so much else, would not have been possible.

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ABSTRACT

STATE LEVEL TESTS OF OKUN'S COEFFICIENT

Brian P. Kennedy, Ph.D.

George Mason University, 2009

Dissertation Director: Dr. Carlos Ramirez

Okun's Coefficient states that there is a three to one relationship between output and unemployment, a relationship that policy makers can exploit. Numerous studies conducted at the national level have confirmed the overall validity of this empirical proposition, even while calling into question some of the details. Using U.S. State level data, this paper tests for Okun's coefficient over the period of 1977- 1997, and 1997 – 2007. This paper finds that Okun's coefficient does exist at the state level, though it is generally lower than national U.S. measures, averaging about 1.5 to 1, a result that is in line with other recent regional studies, but which differs from previous U.S. studies. Pooled data also strongly suggests that Okun's coefficient in the U.S. is asymmetrical, negative output changes are associated with larger changes in employment than positive ones, though this result is sensitive to how one defines downturns. No strong evidence of a structural break was found.

Additionally, this paper tests the resulting coefficients against a variety of labor supply and demand variables, to see which ones influence the existence and size of the relationship. These results support the generally accepted notion that high unionization rates, large manufacturing sectors, and high tax rates lead to a higher Okun's coefficient. The size and composition of the labor force is also important. As more women and youth enter the work force, unemployment rates become less responsive to output growth. Political issues did not seem to have much effect, though some government policies did. Evidence is presented of interstate migration as an explanation of dynamics in Okun's coefficient, though no statistically significant results were found.

Finally, an extended form of Okun's coefficient, one that accounted for variance in capital stock and capital and labor utilization rates, was tested for the ten most populous U.S. states. These tests gave a lower estimate for Okun's coefficient – as most macro theories with diminishing marginal returns to labor, would predict. However, they did not seem to add much explanatory power to our original estimates, and in most cases gave a less robust result.

Chapter 1: Introduction

Okun's coefficient has been a mainstay of modern macroeconomic thinking for over 35 years. Okun's original paper in 1970 was actually a fairly straightforward and simple paper, he regressed unemployment on output for quarterly U.S. data from 1955 to 1968. His regression techniques were (by today's standards) not particularly complex, and his results were both significant and robust; he found a 3:1 negative relationship between unemployment and output. A three percent increase in output was associated with a one percent decline in the unemployment rate, ceteris paribus.

While initially not as influential as the Phillips curve, over time Okun's coefficient has become established as one of the central stylized facts in applied macro-economics, where as often as not it is referred to as Okun's Law. Numerous studies have been conducted on it, and while there is some dispute as to its magnitude, (the general consensus today is that it is closer to 2:1 than 3:1), linearity, stability and symmetry, few doubt that it does exist as a real relationship. And this belief in some form of Okun's coefficient is not limited to professional and academic economists, but also to policy makers and politicians. Economic growth leads to lower unemployment. Much more so than the Phillips curve, Okun's coefficient has stood up to the test of time.

This strong belief in Okun's coefficient, and its empirical certainty, is in marked contrast to its theoretical foundations. As Alan Blinder wrote in 1997[1],

> "….Okun's law is even more atheoretical, if not indeed antitheoretical. This simple linear relationship between the percentage change in output and absolute change in the unemployment rate presumably embodies productivity, labor-force participation, and production-function considerations. On the surface, it seems to contradict the concavity of the latter. None-the-less, it seems to close the loop between real output growth and changes in unemployment with stunning reliability."

Not only is the coefficient difficult to reconcile with business cycle theory, but there is also no theoretical reason to suppose that it will be a stable constant. For example, Adams and Coe (1989, 43-44)[2] wrote

> "There is, of course, no necessary reason why the Okun's coefficient should be stable over time. Variations in the coefficient might reflect a number of factors."

Both of the above sentiments were recognized by Okun himself. Okun realized that the relationship between output and unemployment would hold true only if other factors in the macro-economy were held stable. Changes in labor market rigidities, factor

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[1] Blinder, Alan S. "Is there a Core of Practical Macroeconomics that we should all believe?" The American Economic Review, Volume 87, Issue 2, Papers and Proceedings of the Hundred and Fourth Annual Meeting of the American Economic Association (May, 1997), 240-243.
[2] Adams, Charles, and David T. Coe, "A Systems Approach to Estimating the natural Rate of Unemployment and Potential Output for the United States" IMF Working Paper, 89/89 (1989).

productivity, utilization rates, the NAIRU, or unemployment benefits, (to name just a few) could all change Okun's coefficient over time.

Given the weak theoretical understanding of why the coefficient is greater than one, and has been so stable, it is somewhat surprising that a larger literature on it has not been produced specifically on this variable. For every one article on the Okun's coefficient, there are five on the Non-Accelerating Inflation Rate of Unemployment (NAIRU), or twenty on the Phillips curve. Yet Okun's coefficient is as firmly embedded in practical macroeconomics as any other empirical relationship.

Until recently, very little effort was to made to measure Okun's Coefficient at any level other than the national. This made sense to certain extent, since it was national policy makers and economists who would be most concerned with it. Additionally, data at the subnational level did not exist for a long time, and even after it began to be collected, it was some time before a long enough set of time-series data was available to conduct statistically significant tests on.

In the last several years, several sub-national tests of Okun's coefficient have been conducted. These tests are useful for two reasons. To begin with, they provide data and information to regional policymakers, such as governors in the U.S., who play a role in the setting of macro-economic policy at the regional level. Sub-national tests of Okun's coefficient can help to guide them in their decisions.

Secondly, by looking at regional data, it is possible to make predictions about future values for Okun's coefficient at the national level. If Okun's coefficient is different across different states and regions, it is then possible to look at what factors cause it to be so. If these factors are changing at the local level, eventually that change will be reflected in future estimates for Okun's coefficient at the national level. For example, if U.S. states with a larger manufacturing sector have a higher value for Okun's coefficient than other states, it seems reasonable to expect that the relationship for the U.S. as a whole will decline as total manufacturing in the country declines as a percent of GDP.

1.2 Estimating Okun's coefficient, and Theoretical Foundations

Okun's original estimate of the relationship between output and unemployment took one of two forms, a first difference equation or a gap equation. The first difference equation is represented as:

$$2.1) \qquad \Delta y_t = \beta_0 - \beta_1 \Delta u_t + \varepsilon_t$$

Where Δy_t was the change in output, β_0 is the intercept, $\beta_1 \Delta u_t$ estimates the change in unemployment, and ε_t is an error term. Differencing could be achieved in any one of several ways, though Okun and other early authors usually used the logs of the variables being tested. Other early differencing methods included comparing percent changes, quadratic forms for y, or other mathematical transformations.

Alternatively, the coefficient could be determined from a "gap" equation, in the form of

$$2.2) \qquad y_t - y_t^* = \beta_0 - \beta_1(u_t - u_t^*) + \varepsilon_t$$

where the star denotes the long run equilibrium value of the variable. In this formulation, the test is looking at the difference between the observed short run value of the variable, and the long run trend of the variable.[3] This method allowed for different forms of detrending to be employed, an advantage as macro-economists gained a greater understanding of business cycle dynamics, and developed more robust tools for extracting long and short run information from time series data.

In Okun's original paper, and for a long period after, either specification was used, and they gave very similar results. Most recent studies have used the second form of the equation, as will be discussed in the next sections. Using the gap method in conjunction with modern detrending methods on two widely watched and reported variables, has given economists an opportunity to test Okun's coefficient over a wide set of countries and time periods.

A comment on the atheoretical nature of the coefficient is appropriate here. In the above form of the equation, we find that output decreases of two or three percent increase the unemployment rate by one percent. This seems to violate the notion of diminishing returns that most macroeconomic models of the economy have. One would expect in a downturn, that firms would release the marginally least productive worker first. In such a situation, the decline in employment as a percent of the workforce should be greater than the decline in output, other things being equal.

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[3] Many different ways of estimating the long run value of unemployment and output exist, and in some cases the method used does seem to have an impact upon the final estimates of Okun's Coefficient. Following most other Authors, I have chosen to use several different methods.

That this is not the case clearly indicates that Okun's coefficient is measuring more than just the relationship between output and employment. As Okun himself said

> "clearly, the simple addition of one percent of the given labor force to the ranks of the employed would increase employment by only slightly more than one percent… If the workweek and productivity were unchanged, the increment [increase] to output would be only that one plus percent. The three percent result implies that considerable output gains in a period of rising utilization rates stem from some or all of the following: induced increases in the size of the labor force; longer average weekly hours; and greater productivity.[4]

Other suggested reasons for Okun's coefficient being above 1% include a whole host of real business cycle (RBC) and new Keynesian explanations. RBC explanations include, but certainly are not limited to, technology changes and shocks, absolute and relative changes in labor and capital productivity, or time preference (optimization) decisions that change labor force participation. New Keynesian theories includes literature on labor hoarding, worker effort, unionization and other labor market rigidities. While this literature has certainly advanced economists' knowledge of changes in both output and unemployment, this literature has not to any great extent addressed the relationship between the two that Okun observed.

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[4] Okun, A. 1970 pg 140

A more theoretically rigorous model of Okun's coefficient therefore[5], would be one based on a model of the economy that actually included a production function. An example of such a model would be

2.3) $y_t - y_t^* = ά(c - c^*) + βγ(l - l^*) - βγ(u - u^*) + βδ(h - h^*)$

In the above, c is the utilization rate of capital, l is total employment, u is the rate of unemployment, and h is hours worked; in all cases a * indicates the trend variable, which can be calculated in a variety of ways. In this formulation, output can deviate from its normal full capacity equilibrium when capital utilization is above its trend, or when the labor force or hours worked are higher than normal, as well as when unemployment varies.

A model of this sort allows one to look not only at how unemployment effects output, but also to directly estimate the impact of the other variables given in estimating the coefficient. The difficulty of this (and many other more complex specifications) is in the empirical testing. The unemployment rate is a (relatively) easy variable to measure, labor force working hours and effort is much more difficult to measure, especially in the aggregate. Capital utilization is likewise a difficult variable to measure, how "utilized" is a printer that sits in an office, busily not printing anything, 99 percent of the time? And even if you could measure these things, how does one measure the long run trend of these variables?

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[5] Equation 3 is based on Prachowney (1993), and will be more thoroughly discussed later.

Two alternatives to the above have been tried. One has been to calculate Okun's coefficient as a function of other macro-variables that are also believed to be stable, or at least predictive. To give two quick examples, attempts have been made to model Okun's coefficient as a function of the Phillips Curve, on the assumption that the money supply influences output, or to incorporate the Non Accelerating Inflation Rate of Unemployment (NAIRU) into these estimates.

A different alternative to the above is to calculate the coefficient, and then to look at possible "micro based" variables that may influence it. A tremendous literature has grown up looking at, and measuring, variables that impact the unemployment rate or output growth. But few of them look at how these variables impact the relationship between output and employment, which is again surprising considering how important this relationship is in the models of macro-theorists – and to practical policymakers.

Most modern treatment of Okun's coefficient have concentrated on even more rigorous specifications of output and unemployment, incorporating advances in econometric methodology, detrending techniques, and longer time series, to further refine measures of Okun's coefficient. While valuable, these techniques are reaching the point of diminishing returns, they tend to look at the same data, U.S. quarterly or OECD quarterly data, which is then used to generate estimates of Okun's coefficient. Estimates for the U.S. now almost all fall between 2.1 and 2.5, regardless of the method used.

This paper attempts to advance the state of knowledge by estimating Okun's coefficient using new data, as opposed to using more complex econometric tests on existing data. The Bureau of Economic Analysis (BEA) has two datasets on the U.S., one ranging from 1976-1997, the other from 1997 – 2007, that measure gross state product for all 50 U.S. states, and for the eight larger BEA defined Regions. Likewise, the Bureau of Labor Statistics (BLS) tracks unemployment at the state level, and for the nine larger regions that they define. This paper uses that data to estimate Okun's coefficient, and then looks at other variables measured at the state level, to see what kinds of variables impact Okun's coefficient at the State level.

Chapter 2: Literature Review

Broadly speaking, recent studies of Okun's Coefficient have done one or more of the following three things. They either looked for new variables that influence it, they look for new datasets or longer datasets to test it on, or they apply new econometric methods to existing data to see if the results are robust or in some way misspecified.

The early literature was devoted first to testing Okun's coefficient itself, and then to seeing if it also applied to other countries. Okun's original test only went from 1955 to 1968, and covered the U.S. Since then, other authors have tested for other OECD countries to see if they have a similar relationship, and of what magnitude. Recently, tests have been done using U.S. state and regional data as well, other studies have looked at regional data in other countries. All of these tests have tended to confirm the existence of a coefficient, though difference exists between countries, and regional studies give less clear results.

Most of the later literature has been devoted to using progressively more sophisticated econometric methods to either refine the estimate, to see if it has changed, or to see if it is mis-specified. These tests involve using better (or at least, different) filters to determine trend variables, differing methods to calculate the actual coefficient, and more sophisticated tests for covariance and cointegration. These tests (to the extent that they can be generalized) look for a variety of things, such as evidence of a structural break in the variable, or to see if it is asymmetric or non-linear. While these tests are important, they have probably reached the point of diminishing return. They take the same data sets (U.S. or OECD quarterly data over some range) and then apply new methods to it. The results by and large seem the same (though the math is harder).

Other studies have looked for other variables that may be important. Some of these studies formally model the coefficient in theoretical form, with additional variables that theory suggests will be important, such as capacity usage, changes in the size of the labor force, the Phillips curve or NAIRU, added in directly. Others have taken a more ad hoc approach, calculating the coefficient for the polity in question and then seeing if other variables, such as unemployment compensation, tax rates, or the size of the manufacturing sector, are significant determinants of the value of or the variance in the coefficient between regions or over time. While the number of studies that look at variables that impact only one side of Okun's relationship (output growth or unemployment) is vast, the number of studies that relate these labor or output influencing variables to Okun's coefficient is fairly small.

These tests have identified a number of important issues involved in the actual calculation of Okun's Law. The first issue is whether or not the relationship is contemporaneous or lagged, since this has both theoretical implications as to what sort of underlying model of the economy is correct, and whether or not the econometric tests should be static or dynamic. Secondly, do other variables, such as capacity utilization, growth in the labor force or variance in hours worked make a difference to the short run relationship represented by Okun's coefficient, as opposed to the long run trends of the variables themselves? Likewise, what sort of data is appropriate for testing the coefficient, and what do the different econometric tests say. And finally, how can the results of these tests be reconciled with dominant theories of the business cycle?

2.1 Early Extensions of Okun's coefficient – OECD Countries

After Okun's original contribution, most early papers concentrated either on further testing it in the U.S., or on seeing if it existed in other countries as well. Without going into detail, this would include papers by Weber (1984), Evans (1989), and Smith (1974). A paper worth citing in more detail is "The Robustness of Okun's Law: Evidence from OECD Countries", by Jim Lee[6] (2000), who tested the robustness of the law using data from sixteen OECD countries. Previous studies had found that the coefficient differed for different countries, from a low of about 1.45 in Great Britain, to a high of almost 30 in Japan[7]. Lee tested for these variables again, using data from 1955 to 1996, using both a first difference and a gap equation. Recognizing the most serious problem with the gap estimation method, deriving the trend variable in order to see how the observed variable has deviated from it, he used three different techniques to derive the long run values of output and unemployment. He used the Hodrick-Prescott (HP, 1997) filter, the Beveridge-Nelson (BN, 1981) method, and a Kaman filter framework,

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[6] Lee, Jim The Robustness of Okun's Law: Evidence from OECD Countries, Journal of Macroeconomics, Spring 2000, Vol. 22 No 3, pp 331-356.
[7] Hamada, Koichi, and Yoshio Kurosaka. "The Relationship between Production and Unemployment in Japan: Okun's Law in Comparative Perspective." European Economic Review 25 (June 1984) 71-105.

based on estimates of each nation's NAIRU (these filters will be discussed in more detail in the next section, and appendix X).

Lee's tests gave a range of values depending on the type of test he used and the country tested for. Whether he used a gap equation or first differencing, most of his results were broadly similar, while some filters did give a greater range of results between countries, all of the countries kept the same ordinal ranking. More significant, however, was that his tests did indicate a fair amount of variance between countries. When using first differencing, the U.S. had a coefficient estimate of 1.84, with an R^2 of 0.72. Japan had the highest coefficient, of over 4, while Italy had a coefficient under 1. Almost all of the countries tested for did show significant results, though all countries also had lower R^2s than did the U.S.

By and large, his tests did show some difference in the coefficient between countries, while confirming that it existed for all of them. This result was in line with results later achieved by Donald Freeman[8] (2001), who tested Okun's law against ten industrial countries using panel data. Freeman found that the coefficient seems to be approximately 2:1, and that the coefficient had changed over time, though he could not reject the null hypothesis of no structural break. Similar to Lee, he also found that European economies had a lower coefficient than the U.S.

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[8] Freeman, Donald G. "Panel tests of Okun's Law for Ten Industrial Countries" Economic Inquiry Vol 39 No. 4 2001, pp 511-523.

2.2 Okun's coefficient; Longer forms

In 1993 Prachowny conducted a study where he specified the link between employment and output in greater detail. He developed a model that took into account not only the level of capital and labor, but also their rate of utilization. After some simplifications and assumptions, he tested for Okun's coefficient using the expanded gap equation method below.[9]

$$2.4 \quad y_t - y_t^* = \acute{\alpha}(c - c^*) + \beta\gamma(l - l^*) - \beta\gamma(u - u^*) + \beta\delta(h - h^*)$$

Where c is the utilization rate of capital, l is total employment, u is the rate of unemployment, and h is the hours worked; in all cases a * indicates the trend variable, in this case the mean value over the periods used for the test. In this formulation, output can deviate from its normal full capacity equilibrium when capital utilization is above its mean, or when the labor force or hours worked are higher than normal, as well as when unemployment varies. From this, Prachowny derived an econometric test (the below is in logs)

$$2.5 \quad \Delta(y - y^*) = ß_1\Delta(c - c^*) + ß_2\Delta(l - l^*) - ß_3\Delta(u - u^*) + ß_4\Delta(h - h^*)\ \varepsilon_t$$

where $ß_1$ represents capital utilization, $ß_2$ represents changes in the size of the labor force, $ß_3$ represents unemployment, and $ß_4$ represents hours worked. He then tested this equation against two U.S. national quarterly data sets, one from 1947:1 to 1986:2, the other running from 1965:1-1988:4. He found that while $ß_2$ was not significant, $ß_1$, $ß_3$, and $ß_4$ all where.

[9] A full derivation of this equation is given in section seven.

Thus, he found that Okun's original coefficient was actually measuring several things. The traditional interpretation of Okun's coefficient as being somewhere between a 3:1 and 2:1 relationship between employment and output was incorrect. Prachowny estimated instead that the actual coefficient was only .66:1, the rest of the change was due instead to either to an increase in the capacity utilization of capital (1.2:1, $ß_1$), or to increased hours worked by workers (1.6:1, $ß_4$), mostly through increased overtime. Assuming a constant return to scale, Prachowny's estimate of a .66 increase in employment, along with increases in capital and its usage, and labor hours worked, led to a 1 percent increase in output. This corresponds very well to labor's assumed contribution to output to output. His estimate of capital utilization was much higher, however, than the .33 that would have been expected.

Freeman (2001, cited above) also incorporated elements of the above model into his tests of the data over a panel of ten countries. Freeman found that both capital utilization and labor force variables did have a significant impact on estimates of Okun's coefficient, inclusion of these variables seemed significant, and led to a lower estimate of the coefficient in the European countries he tested for. Even taking into account the criticisms of Prachowny's method made by Attfield and Silverstone (cited below), Freeman found Prachowny's method to have superior explanatory power than simpler estimates used elsewhere.

2.3 Okun's coefficient: Econometric Refinements and Modifications

Prachowny's method has been criticized in several ways, most of these criticisms were summarized by Clifford Attfield and Brian Silverstone in 1997[10]. They found that Prachowny's tests were biased because he assumed (and tested for) a random walk in output and employment, but he did not then test for cointegration. To use a concrete example, if the amount of overtime was correlated with the rate of capital utilization (a very reasonable conjecture), then $ß_1$ and $ß_4$, the first and fourth terms in Prachowny's test, will actually be measuring the same thing. Thus, they will be biased upwards, and the third term $ß_3$, which measures changes in unemployment, will be biased downwards.

Attfield and Silverstone corrected for this potential cointegration, and then reran Prachowny's tests using the same data sets. For one data set, they found that Okun's coefficient was approximately 2.25:1, in line with standard estimates. For the other data set, they found little evidence of cointegration.

Attfield and Silverstone later expanded upon this critique, and tested for Okun's coefficient using a cointegration framework[11]. They began with a simple gap form of Okun's coefficient, and then used the Beveridge and Nelson method of calculating the values of the trend component;

2.7 $$y^*_t = y_t + E_t(\Delta y_{t+1} - \mu_{\Delta y}) \quad \text{and} \quad u^*_t = u_t + E_t(\Delta u_{t+1} - \mu_{\Delta u})$$

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[10] Attfield, Clifford L.F. and Brian Silverstone, "Okun's Coefficient: A comment," The Review of Economics and Statistics, Volume 79, Issue 2 (may, 1997) pg 326-329. Christian Weber (discussed later) also implicitly criticized aspects of Prachowny's test, but the core of the criticism is contained in Attfield and Silverstone.

[11] Attfeild, Clifford L.F. and Brian Silverstone, "Okun's Law, Cointegration and Gap Variables" Journal of Macroeconomics, Summer 1998, Vol. 20 no 3, pp 625-637.

where $\mu_{\Delta y}$ is the mean of the long run rate of growth, and $\mu_{\Delta u}$ is the long run change in the unemployment level. They then use the above equation for permanent magnitudes to proxy for the "potential" magnitudes, and subtract that from the observed (or "cyclical") magnitudes to estimate the gap equation. They observe that Okun's coefficient can also be obtained by looking at the coefficient of cointegration, which will give an extremely consistent estimate of the coefficient.

Using the above method, they then tested for the value of Okun's coefficient using quarterly data from Great Britain between 1959 and 1994. They found Okun's coefficient to be 1.45:1 in that test, lower than the coefficient in the U.S. (this is consistent with other tests, Great Britain usually has a lower coefficient than other developed countries). The method of using co-integration to estimate Okun's coefficient has since been adopted by other authors. While estimates conducted in this way are extremely consistent, it is difficult to extend the test in any way, such as to incorporate additional values.

Touched upon in many of the above papers, but most recently and clearly studied in Imad Moosa[12] (1999) "Cyclical Output, Cyclical Unemployment, and Okun's Coefficient; A Structural Time Series Approach", is the question of what sort of econometric method should be used to estimate Okun's coefficient, and what sort of methodology is appropriate in the estimation (or creation) of the long run values for output and employment, from which a gap variable was then calculated. Moosa goes

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[12] Moosa, Imad A. "Cyclical Output, Cyclical unemployment, and Okun's Coefficient; A Structural Time Series Approach", International Review of Economics and Finance, Vol 8 (1999) pp 293-304.

into the importance of looking at the method used to determine actual and potential output and unemployment, since the method for calculating them will have a significant effect upon estimates of Okun's coefficient.

When using quarterly data, should the data used be seasonally adjusted or not?[13] Almost all of the studies conducted begin with a test for a unit root, even though seasonal adjustment of the data can bias unit root tests.[14] Or when using quarterly data, how many lags should be included to capture all of the effects any given change in output might have for employment?

Several different methods of calculating potential and actual output and employment can be used, Prachowny for example, followed Giorno et al (1995)[15] in their method, which was to use a Hodrick-Prescott filter (1980, 1997)[16] to decompose output into a trend and cyclical component. This method uses a deterministic trend component, which can potentially give spurious results since it ignores the stochastic nature of the permanent variables. Many later studies use the Beveridge-Nelson method[17], which defines permanent output and unemployment as the long-term stochastic trend variates in $y^*_t = y_t + E_t(\Delta y_{t+1} - \mu_{\Delta y})$ where $\mu_{\Delta y}$ is the mean of the long run rate of growth. In this equation, the

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[13] This point was first made Attfield and Silverstone, "Okun's Coefficient: A comment", pp 327.
[14] Ghysels, Eric and Pierre Perron, "the Effect of Seasonal Adjustment Filters on Tests for a Unit Root," *Journal of Econometrics* 55 1993, pp 57-98.
[15] Giorno, Claude, Pete Richardson, Deborah Roseveare and Paul Van Den Noord. "Potential Output, Output Gaps and Structural Budget Balances" *OECD Economic Studies 24* (1995) pp 167-209.
[16] Hodrick R, and E.C. Prescott "Post-War U.S. Business Cycles: an Empirical Investigation" Carnegie-Mellon University, 1980
[17] Beveridge, Stephen and Charles R. Nelson "A New Approach to Decomposition of Economic Time Series into Permanent and Transitory Components with Particular Attention to Measurement of the "Business Cycles"." *Journal of Monetary Economics 7* (1981) 151-74.

"trend can be thought of as the infinitely long run forecast of the variables given the information known at time t".[18]

Moosa however, uses a slightly different method of obtaining the long run trend variables. He uses a system similar to one used by Harvey (1985, 1989)[19]. This system, an Autoregressive Distributed Lag (ADL) model, is better able to deal with any seasonal changes that may be affecting data, and does not need to worry about any possible structural breaks, since it is a dynamic rather than a static regression. Most importantly, it allows one to break the coefficient into two components, a long run and short run component. Several other reasons for using this particular form are also given[20], though they are not relevant to this study.

Moosa used the Gordon Data set (U.S., quarterly, 1947:1 to 1992:2), detrended using the above systems. He first ran a fairly standard OLS regression, where he assumed that all the effects are contemporaneous, which he found to be significant (with an approximate relationship of about 3:1) but serially correlated. Rather than "correcting" the regression, he instead chose to re-specify, including a lag term to incorporate long term effects. He tried lags between two and five, and found that the serial correlation largely disappeared even with only two lags. Interestingly, he found

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[18] King, Robert G., Charles I. Plosser, James H. Stock and Mark W. Watson. "Stochastic Trends and Economic Fluctuations." *American Economic Review 81* 1991 819-840 In this particular study, the Authors are using a multivariate decomposition rather than a bivariate one, but the principle remains the same.

[19] Harvey, A.C. Forecasting, Structural Time Series Models and the Kalman Filter: Cambridge; Cambridge Uiversity Press 1989.

[20] Harvey, A.C., and A. Jaeger: Detrending, Stylized Facts and the Business Cycle. *Journal of Applied Econometrics, 8*, pp 231-247.

that the long run estimate of Okun's coefficient was very close to the static estimate most other studies had found, (implying that most of the effects are incorporated within a year), but that the short run relationship was fairly small. He also found no evidence for a structural break.

While Moosa found no evidence for a structural break, several other authors did. Static tests of the coefficient usually indicate that a structural break may have occurred in 1973, at which point the coefficient became lower than it had been in previous periods. An example of testing for this, mentioned above, include Moosa (2001), Weber (1985), Blanchard and Quah (1989), and Lee (2000). A variety of tests and data sets have been used to search for a structural break, with differing results. In general, studies using only U.S. data tend to support the hypothesis of a structural break more strongly, but the time series used seems important.[21] Studies which include European or other OECD countries give more varied results.[22]

A different econometric issue that has recently been studied is the possibility that Okun's coefficient is asymmetric. Most business cycles show sharp but limited duration downturns, followed by relatively longer periods of slightly above average growth. Since there seems to be asymmetries between output and unemployment increases and

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[21] Time series that include data from the mid 1970's to the late 1980's seem to indicate a structural break at some during the years 1973-75. Tests that include data from 1990's usually does not, which I interpret as the economy responding more "normally" after the 90-91 recession. Thus the structural break indicated by many studies conducted in the 1980'and early 1990's did in fact not happen, and would disappear if the tests were rerun adding later data. Since the data sets I used did not run this far back, I have not tested for this, however, and only advance it as a tentative hypothesis. The estimates from Europe and the U.S. tend to diverge more after the mid 1970's (hysteresis), which may also explain some of this.

[22] Hysteresis would explain some, but not all, of the differences seen. Great Britain consistently seems to have a lower estimate, most other countries a larger one. This is an issue that has not received enough attention in the literature.

decreases, it seems reasonable to suggest that there could also be asymmetries in Okun's coefficient. Given recent work testing for asymmetries in the Phillips curve[23], and the link many economists believe exists between the two empirical laws, several authors have taken this subject up. Richard Harris and Brian Silverstone[24] (2002), Jim Lee (2000, mentioned above) and M. Viren (2001)[25] all addressed asymmetry in recent papers.

Viren uses a model where short run unemployment changes are the result of changes in output, divided into positive and negative changes. He also uses a long run version that adds population and a time trend. In his study, he finds evidence to suggest that Okun's coefficient is not symmetric. Rather, downturns are associated with a relatively larger negative change in employment, but output growth is associated with a smaller positive change in employment. Several possible explanations for this observation suggest themselves.

One possibility is that changes in unemployment respond with different lags to changes in output. For example, if firms are quick to fire in a downturn, but slow to hire in an upturn, then the total effects over the long run would be the same, but in the short run it would appear that the law was asymmetric, depending on how lags were handled in the model. It should be noted that it is not necessary that firms deliberately hire at

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[23] G. Debelle and D. Laxton "is the Phillips curve Really a Curve? Some Evidence for Canada, the United Kingdom and the United States" IMF Staff Papers (1997) 44, 249-282, or D. Laxton, D. Rose and D. Tanbakis "The U.S. Phillips Curve: The Case for Asymmetry (1999) Journal of Economic Dynamics and Control, 23 1459-85

[24] Harris, Richard and Brian Silverstone; Testing for Asymmetry in Okun's Law: A Cross-Country Comparison JEL Classification E24, C2

[25] Viren, M. "The Okun Curve is Non-Linear" *Economics Letters 70*, 253-257

different rates during upturns and downturns, rather firms could adjust hiring only when some threshold change in output was reached, either positive or negative, which would tend to occur more quickly during downturns, which are usually sharper.

Another possible explanation is changes in economies over time. Viren found more evidence of asymmetry in European economies than in the U.S. However, given the hysteresis that has plagued European economies since the mid 1970's, at least some of the asymmetry may be due to structural changes in their economies, rather than cyclical adjustments.

Harris and Silverstone (1995) use a different method to test for asymmetry in their paper. They use a gap equation to test for Okun's coefficient, using data from seven countries. They test for cointegration between terms. In six of the seven cases they found significant cointegration, which they then use to calculate the coefficient, using a method similar to the one Attfield and Silverstone used in their 1995 and 1997 papers (cited above). Specifically, after testing for and rejecting the hypothesis that the data (with or without a structural break) was stationary, they proceeded on the assumption that the data was non-stationary. They created an error correction model that distinguished between positive changes in output and negative changes in output. They used this model to test for whether Okun's coefficient was the same in cases of positive output changes as it was for cases of negative change.

Their tests indicated that Okun's coefficient operated much as expected during downturns, but not during upturns. The lag between changes in output and changes in employment was much larger during upturns, and varied greatly across the seven countries studied. Furthermore, changes in output were not always associated with changes in unemployment in the expected manner, in two cases an upturn in the economy resulted in (temporary) increases in unemployment.

Questions about structural breaks and asymmetries in Okun's law naturally lead to the question of its linearity: could it be a non-linear relationship, or one that moves about over time. A recent example of a model of this sort was employed by Ho-Chuan Huang and Shu-Chin Lin in 2007[26], they used a model of Okun's coefficient based on a variant of Prachowny's estimation. Instead of treating Okun's coefficient as something to be directly estimated, they instead treat it as an unknown parameter to be estimated along with other unknown parameters in the model. They use a Bayesian approach, specifically a Gibbs sampler, to estimate a moving Okun's coefficient. Using this approach, they find that Okun's coefficient has risen and fallen over time, in relation to lagged trend productivity growth. Thus, in periods of high productivity growth such as the 1960s and 1990s, Okun's coefficient is decreasing, while at other times it is rising. They found that varied between something below 2:1, and almost 3:1, though at no point was it ever negative.

A different test on linearity was recently conducted by Jim Malley and Hassan Molana[27], who look at seven European countries to see if labor effort (and its consequent impact on unemployment rates) changes Okun's coefficient. They find that in six of the

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[26] Ho-Chuan Huang and Shu-Chin Lin, Smooth-time-varying Okun's Coefficients" Economic Modeling 25 (2008) 363-375.
[27] Malley, Jim and Hassan Molana, "Output, unemployment and Okun's law: Some evidence from the G7, Economic Letters 101 (2008) pp 113-115.

seven European they test for, economies seem to oscillate between a "high-effort" and a "low-effort" state, depending on unemployment rates. They then calculate that the threshold rate of unemployment that triggers the economy the move from the high-effort to the low-effort state is very close to the estimated NAIRU for these countries, implying that policymakers attempting to reduce unemployment through typical demand-side stimulus policies may not in fact have any impact in those countries that have entered a "low-effort" state.

2.4 Okun's Coefficient; Testing below the National Level

For a very long time, all tests of Okun's coefficient were conducted at the national level. Only recently have new tests been conducted at the sub-national level. One of the first such tests was conducted by Paul Blackley (1991), who attempted to measure Okun's coefficient by testing for it using annual U.S. State data.[28] He obtained yearly data for the 26 largest states, between 1970 and 1986, and used a difference model to test for Okun's coefficient. He found that for all but one state, the value ranged from 2.0 to 4.0, with the average being about 3.1, a little higher than most national level studies had shown.

His test was significant is several ways. By using state level data, rather than aggregate national data, one would normally expect a larger measure in the variable, since the larger estimates in Okun's coefficient are due at least in part to

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[28] Blackley, Paul R. "The Measurement and Determination of Okun's Law: Evidence from State Economies" *Journal of Macroeconomics*, Fall1991 Vol 13 No 4 pp 641-656.

> "the greater openness of state as compared to national labor markets, [resulting in] output growth that more easily attracts labor force growth through migration at the state level, and therefore a more rapid rate of GSP growth [that] is needed in order to generate a 1 percentage point reduction in the unemployment rate. "[29]

More importantly, by testing using state data he was able to find factors in labor markets that significantly changed the coefficient. On the demand side, he found that the greater the importance of manufacturing, the larger the coefficient. This was due in part to the relative rigidity of the manufacturing industry labor market, characterized by employees who are far more likely to remain in place waiting for a job to return when faced with a cyclical increase in unemployment. Additionally, an increase in manufacturing output is usually associated with an increase in other sectors, manufacturing output and employment increases have a larger "multiplier effect" than is the case for other sectors of the economy. These factors overwhelmed any effects that one would have seen from the fact that the manufacturing sector can generally be characterized by a larger number of long term labor contracts, or by the long run increase in unemployment in this sector we would have expected due to increases in productivity.

There are also several factors on the supply side that he found to be important. The number of young workers, and the number of female workers, both had a significant effect. More young workers meant a lower coefficient, a larger increase in output was

[29] Ibid, pg 645

needed for any increase in employment. Likewise, the size of the female population had a similar effect. In both cases, it seems that the young and female workers had a lower overall productivity than male workers, and were more likely to leave the labor market, or to remain unemployed for long periods. Finally, he also found that tax rates, and unemployment compensation differences, had a significant effect.

In 2001, Freeman[30] used annual U.S. data from 1977 to 1997 to measure Okun's coefficient in the eight economic regions where the Bureau of Economic Analysis and the Bureau of Labor Statistics track output and employment. He used a gap method, employing the Baxter-King Bandpass filter and a quadratic trend to detrend data. He also conducted parallel tests on national data to check his results.

Again, like Blackley, he found significant evidence for Okun's coefficient at the regional level, and that the differences between regions were measurable and statistically significant. He found the average regional measure to be 2.22, 3 regions were below 2, one region (the Plains States) was 3.57. While the regions exhibited differing coefficients, he could find no apparent pattern as to why, for example his results gave no evidence that Northern or Eastern U.S. labor markets were less flexible than labor markets in other parts of the country. He also pooled his results which gave him broadly similar results to his national tests.

While Blackley and Freeman are the only two authors to have studied Okun's coefficient below the national level in the U.S., others have done so for other countries,

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[30] Freeman, Donald G. "Regional Tests of Okun's Law", International Advances in Economic Research, August 2000, Vol. 6, No. 3.

and found differing results. Studies in Greece, Spain and Canada have all found evidence for Okun's coefficient, but the evidence was much less clear. In the case of Greece, Dimitris Christopoulos (2004)[31] tested for Okun's coefficient in 13 Greek regions, using panel data and a cointegration test. He could confirm the existence of Okun's coefficient in only 6 of the 13 regions, the largest (and statistically most significant) result he obtained was 1.7 for Crete – isolated from the rest of Greece, and having the lowest unemployment rate of any region. All other regions had measures below 1, significantly lower than conventional national estimates of Okun's coefficient, and Okun's coefficient could not be confirmed in Greece's most populous regions. Christopoulos interpreted this as evidence that hysteresis, de-industrialization and urbanization have markedly changed the coefficient at the regional level in Greece.

Jose Villaverde and Adolfo Maza [32] used annual data from 1980 to 2004 for 17 Spanish regions to conduct a gap method estimation of Okun's Coefficient. They chose to detrend the data three ways, using a quadratic trend, a HP filter and a BK filter. They were able to confirm the existence of Okun's coefficient for 15 of 17 regions (11 of 17 using the BK filter), but similar to the Greek and Canadian studies, they found the coefficient to be much smaller than national estimates put it. The values they achieved ranged from 0.32 to 1.55, with the average for Spain as a whole being 0.92. They ran a Moran I statistical test to see if they could detect any regional pattern to the differing coefficients, they could not, though two large urban areas seemed to be dominating their

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[31] Christopoulos, Dimitris K. "The Relationship Between Output and Unemployment: Evidence from Greek Regions", Papers in Regional Science 83, pp 611-620, 2004.
[32] Jose Villaverde and Adolfo Maza, "The Robustness of Okun's law in Spain," 1980 – 2004.

results. They also found that overall development did not seem to explain differences in Okun's coefficient, but that regional productivity growth did seem correlated with them. Regions that experienced higher productivity growth had lower Okun's coefficients than did other regions.

2.5 Summarizing the Literature

While the above literature review does not cover all articles on Okun's coefficient, it covers a fairly significant sample of them. One of the most surprising things about the above is the near uniformity of results, no matter the method, time periods, or complexity – and some of the econometric models are quite complex – the same or similar results are obtained. Okun's coefficient for the U.S. is between 2 and 2.5, for European countries it is somewhat lower. As time has gone by, data sets have become longer, but few new ones have been added.

Aside from Blackley in 1991, all tests of Okun's coefficient at the sub-national level have occurred in the last decade, and only for four countries, the U.S. (regions, not states), Canada, Greece and Spain. The U.S. state tests found Okun's coefficient to be slightly higher than national tests, the U.S. regional tests found it to be about equal to the national rate. The Canadian, Greek and Spanish tests all found it to be lower than the national tests.

Chapter 3: State Level Tests of Okun's Coefficient

3.1 Theoretical Implications of Different Econometric Tests

The articles discussed in section 2 show several different ways in which the coefficient has been calculated in recent years, as well as special factors tested for or looked at, depending on the author's intent. While several different approaches to testing Okun's coefficient have been discussed, it should be noted that the authors are not all simply testing for the same relationship using different methods. Rather, as Weber (1995) put it;

> "these methods represent different conceptual approaches to the output-unemployment rate relationship, not different methods of estimating the same theoretical construct."[33]

Static OLS Tests (such as originally done by Okun) assume a strictly contemporaneous relationship which ignores any short or long run dynamics. It is most appropriate when using yearly data, since lag effects will be minimized. These tests also give a pretty consistent measure, and are useful for cross country comparisons, since the

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[33] Weber, Christian W. "Cyclical Output, Cyclical Unemployment, and Okun's Coefficient: A New Approach" *Journal of Applied Econometrics*, Volume 10, Issue 4 (Oct.-Dec. 1995) pp. 439.

data is readily available and the tests themselves are simple. Static OLS tells us little about the dynamics of the coefficient, and can give potentially misleading results when used with quarterly data, unless other supplemental tests, such as for structural breaks or asymmetry, and for cointegration, are also incorporated.

Dynamic OLS tests, for example the auto-regressive distributed lag model used by Gordon[34] (1984), are concerned almost exclusively with the short run relationship, since the whole of the effect of the coefficient will be incorporated within the first year. Dynamic OLS tests give a better understanding of the short run relationship, such as whether change in one variable leads to change in the other, or if both are actually changing in response to something else. However, they are much more difficult to conduct, and depend greatly upon two data considerations, how the data was detrended, and how the data was seasonally adjusted.

In contrast to this, the cointegration method used by Attfield and Silverstone (1995, 1997) is concerned exclusively with the long run relationship of the variables, explicitly ignoring any of the transitional dynamics that a dynamic OLS might capture. Like dynamic OLS methods, this method is very sensitive to the data sources, both how they are detrended, and how they are seasonally adjusted. Also, this method has difficulty adding further variables for testing.[35] It does avoid some of the potential biases

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[34] Gordon, R.J. "Unemployment and Potential Output in the 1980's" *Brookings Papers on Economic Activity*, 15, 537-564.
[35] Engle, R.F. and C.W.J. Granger (1987) "Co-integration and Error Correction Representation, Estimation and Testing", Econometrica, 55, 251-276. Two non-stationary random walks may be added to see if the result is stationary, but this does not necessarily hold when several non-stationary random walks are being dealt with.

in other OLS methods, so it can give a better estimate when only the long run relationship is important. Thus the three different ways of econometrically testing the law actually have strong implications for what sort of information is being sought.[36]

A final consideration is whether or not to limit the test to Okun's original variables, output and unemployment, or to add additional variables to the test. Theory suggests four variables that are also important; man-hours worked per worker, the size of the labor force, the stock of capital, and the capital utilization rate. This is the approach used by Gordon (1984) and later Prachowny (1993), who both add them into their models in a formal manner, and to a lesser degree Lee (2001) who tests them for significance, though he does not model them formally. Adding these variables has led to serious problems of cointegration and collinearity, and some seemingly bizarre results. Some of the additional variables do appear to be significant however, and cannot be lightly dismissed. Furthermore, the estimate for the coefficient that Prachowny derived, a 0.66 percent change in employment leading to a 1 percent change in output, with the rest of the change in output due to changes in utilization hours worked, and the size of the labor force, is in line with macroeconomics theory predictions of diminishing returns to scale for labor, and is close to the generally accepted value of labor's share of total input into

[36] One final method, not previously mentioned, is the one used by Blanchard (1989) and Blanchard and Quah (1989). Briefly, they test the coefficient as part of a larger set of tests measuring how the economy responds to disturbances, they then characterize shocks to the economy as either supply or demand shocks. They then measured the relationships (including Okun's Law) based upon one step ahead forecasting errors, using a vector autoregression with various Keynesian inspired restrictions on the variables. While an acceptable method of modeling Okun's law as part of a larger system, it is not suitable for the type of study being done here, and will not be further addressed. See Blanchard, O.J. "A traditional Interpretation of Macroeconomic Fluctuations", *American Economic Review*, 79, 1146-1164, and Blanchard, O.J. and D. Quah (1989) "The dynamic Effects of Aggregate Demand and Supply Disturbances", *American Economic Review*, 79, pp 655-673.

the economy. This is far different from the anti-theoretical results that most measures of Okun's coefficient generate.

3.2 Data Considerations: Data Sources and Issues for Calculating Okun's Coefficient for U.S. States

Unemployment data was gathered from the bureau of labor statistics, taken from the Local Area Unemployment Statistics (LAUS) dataset, which in turn gets its information primarily from the monthly Current Population Survey (CPS). They maintain unemployment data, for all states, on a monthly basis, going back to 1976. Blackley, in his 1990 study, used unemployment data going back to 1970 for 26 states, but the data he used was based on "unpublished data from the U.S. Bureau of Labor statistics, based upon the Current Population Survey"[37]. I have been unable to obtain this data, so I restricted myself to the 1976 – 2008 data. Average unemployment rates for the states in that period averaged 5.82 percent, the median was 5.84 percent (Indiana), with highs and lows of 8.44 percent (West Virginia) and 3.45 percent (Nebraska). Interested readers can see summary statistics in the appendices.

The data for state gross products was much more difficult to obtain. The BEA has been collecting the data since 1963, but has changed methodologies several times. Basically, they use survey data in most years, but once every five years (years ending in 2 and 7) they conduct a much more detailed survey of state economies, and use the

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[37] Blackley, pg. 644

resulting information both to update their methodology, and to revise their estimates for the previous several years. The most current estimates of Gross State Product (since renamed) are based on the North American Industrial Classification System (NAICS), which has been in use since 1997 (with minor changes in 2002). This data runs until 2007 (2008 data was released June 8). Before that, BEA gathered the data on the basis of the BEA's Standard Industry Classification (SIC), which collected Gross State Product data from 1963 to 1997. Data from 1963 to 1987 is based on the 1972 SIC, data gathered from 1987 to 1997 is based on the 1987 SIC. Blackley based his state studies, and Freeman his regional studies, on the SIC Data.

The differences between the two datasets are fairly significant. Gross State Product as measured by the SIC more accurately measures Gross State Income. The methodology used tended to overstate state growth rates in three ways. To begin with, it was very sensitive to the inflation rate, during periods of high inflation it overstated state growth. Secondly, as new workers entered the workforce or formal sectors of the economy, it would begin capturing them in its growth numbers, overstating growth. Finally, it tended to overstate growth in cases where previously vertically integrated industries were split up. It should also be noted that the SIC itself also changed methodology in 1987, but this change was much less fundamental. Mostly, it simply redefined what sectors of the economy certain industries were placed in, or it expanded definitions to accommodate changes in the economy. The section on computers and office machinery, for example, were significantly expanded to include new classifications and sub classifications. The effect of this on State Gross Product was minimal however, since this number captured the aggregate of all activity, how the sub activities were defined mattered little.

Due to the aforementioned (and other) perceived methodological problems, in 1997 the BEA made much more substantive changes in how they gathered and calculated Gross State Product. In 2006, they renamed the 1997 – present data series the "Gross Domestic Product by State" series. The methodology used, as implied by the new name, is very similar to the way BEA gathers national GDP numbers.

While the two series seem to match up, the differences between them are fairly deep and substantial. To give just a brief example, the median growth rate for states from 1977 to 1997 as measured using the GSP method based on SIC data and methodology was 7.1 percent (Maine), with several states growing over 9 percent annually – these numbers far exceeded the national economies overall growth rate of slightly more than 3 percent during the period. The median state growth rate for the 1997-2006 data, by contrast, was 2.8 percent (Tennessee), almost identical to the national average for the period, 3.2 percent. The two datasets show significantly different growth rates.

Another difficulty of matching the two datasets concerned matching them up between periods. Superficially, they seem to match up fairly well, some representative Gross State Product numbers for states that do not match up well are given below (Table 3.1).

Table 3.1: Samples of Gross State Product (1992 dollars)

	Alabama		Idaho		New Mexico		South Carolina	
	SIC	NAICS	SIC	NAICS	SIC	NAICS	SIC	NAICS
1996	104213		29388	28781	47829		95447	
1997	109672	110703	31041	30003	48488	46278	101384	107126
1998		114430		32754		50052		110902

Source: Bureau of Economic Analysis, SIC and NAICS datasets

As can be seen, these states show fairly significant difference in output between the two datasets (this is after converting into common currency units). Both Idaho and New Mexico had higher gross state products (GSPs) using the earlier methodology, while Alabama and South Carolina both had lower ones. In fact, 7 states had lower outputs in 1997 using the earlier dataset, the other 43 had higher ones. Comparing the above after converting the later dataset into 1992 dollars, I found there were still problems in getting them to match up.

Two methods of aggregating the data suggested themselves. One method would be to convert both into 1992 dollars (since the first dataset is so much larger), then to calculate the average difference in output between the two datasets, and to the “norm” one or the other dataset so it would match up with the other. The advantage of this is that it would give a larger range of variables to use in regressions, increasing our observations. The disadvantage is quite obvious; the two data sets were gathered using different methodologies.

One simple way of determining if the two sets of data could be aggregated would be to look for changes in the slope of the curve. Using the first dataset, one could estimate what future points would look like, and then see if the later dataset, after being transformed, seemed to match this estimated line. For purposes of estimating Okun's coefficient, the value of output is less important than how much it changes in any given period. Okun's coefficient is not trying to measure output, it is trying to measure the change in output during a period that can be attributed to changes in unemployment. After trying several different ways of splicing the data, and transforming or norming it so it would match, I tested the best method I could come up with by testing both the output variable itself, and Okun's coefficient (using a differencing method) over the period 1977 to 2007, looking for a structural break. While I could often get good results, in a significant number of cases, it proved impossible to reject the null hypothesis that there was a structural break at or around 1997. When using filtering methods to construct gap variables, I was able to get good results, but given the problems with the first method, I suspect those results to be spurious, or at a minimum, problematic.

Given this difficulty, and the fact that the output data was measured in two different ways, I proceeded to test Okun's coefficient for each state, once for the period 1977-1997, and again for 1997-2007.

3.3 Stationarity Tests

As has become common practice when dealing with macro-economic time series, I tested my data for stationarity prior to running regressions. As per Freeman (2001b), I used a Weighted Symmetric (WS) test of the unit root hypothesis, rather than the more common Dickey-Fuller alternative. Pantula et al (1994)[38] found that the WS test was more appropriate when dealing with small data samples. Full results can be found in appendix 9, I will limit myself to a quick overview of the tests here.

Since GSP data went back to 1963, using the full data set from 1963 to 1997 (34 observations) made it possible to reject the unit root hypothesis at the 10% level for 35 states, and in the other states the test statistic was still negative, though the hypothesis could not be rejected with 90% certainty. When using the smaller subsample of 1976 to 1997, again unit roots did not seem likely, but the low number of observations made it difficult to reject unit roots with certainty.

State unemployment data, while going back only until 1976, goes forward until 2008, so again I used this full sample (31 observations) to test for stationarity. I was again able to reject the null hypotheses of stationarity in most cases, though for 13 states I could not. Again, when limiting myself to the 22 years tested (1976 to 1997) it became more difficult to reject unit roots.

Since other authors have already used parts of the time series here to conduct other tests of Okun's coefficient, I proceeded on the assumption of no unit root. No meaningful tests could be run on the 1997-2007 sample due to its short length[39].

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[38] Pantula, S.G., G. Gonzalez-Farias and W. Fuller "A Comparison of Unit-Root Test Criteria, " Journal of Business and Economic Statistics, 12(4), 1994, 449-59

[39] Since writing this, the BEA on June 8th released revised GSP numbers the states in 2007, as well as numbers for 2008. I don't think this has/will make any difference, but will try and account for it before finalizing this section.

3.4 Differencing Tests of Okun's Coefficient

The relationship between a state's unemployment rate and the gap between its observed and potential output levels can be modeled as

3.4.1 $\Delta UR_t = \beta(GSP_t - POTGSP_t)$,

where ΔUR_t is the change in the unemployment rate between the previous period and period t, and GSP and POTGSP are the percentage changes between real (observed) Gross State Product (GSP) and Potential GSP over the same time interval. β gives us an estimation of Okun's coefficient.

Multiplication through by β and adding an error term gives us a stochastic version of the above,

3.4.2 $\Delta UR_t = \alpha + \beta GSP_t + \varepsilon_t$,

The above assumes a constant rate of output growth, which is to say that productivity and labor force growth and/or participation are constant over the time period under discussion. The intercept α is thus equal to - $\beta POTGSP_t$, so our estimate of POTGSPt is equal to $-(\alpha/\beta)$, which is to say that we are assuming a static rate of growth for potential output. Given the expectation that β is negative, our estimate for Okun's coefficient will be $-1/\beta$.

Three comments on the above specification are in order. The first is that this specification, since it does not rely on gap estimation, has the advantage of not requiring any prior assumptions about potential output or the NAIRU. So long as these numbers are steady over time, the model is correctly specified. If either of them shifts significantly, the model will suffer. Given the difficulty of actually trying to calculate gap variables, this is an acceptable assumption for this first set of regressions, though later techniques will use gaps.

Secondly, the above model assumes significant interstate variation in labor markets. If labor can (and chooses to) freely shift between states, we would expect our estimates of Okun's coefficient to be quite close, since labor in a state with a high unemployment rate can shift to a state with a lower one. There is data to suggest that this happens in the U.S., indeed one of the frequent explanations for America's higher growth rates is the mobility of U.S. workers. Certainly, the long term shift of jobs and population from the Northeast and Great Lakes regions to the Southeast, Southwest and Rocky Mountain regions would also point to this conclusion.

That said, there is considerable evidence that differing unemployment rates can exist in spatially close proximity for very long periods of time. One only needs to look at the average unemployment rates of Virginia (4.51) and West Virginia (8.44), ranked 5th best and worst, respectively, to see this. Studies of local labor markets often find persistent spatial unemployment rate differentials, due to differences in local labor markets[40]. So for now I will accept this proposition.

A final issue concerns the timing of changes in output and unemployment. It is now fairly well accepted that unemployment is a lagging indicator. Most current specifications of Okun's coefficient using quarterly data (unless the data is detrended in such a way as to incorporate lags) include one or more lags to account for this. Most

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[40] Marston, Stephen. "Two Views of the Geographic Distribution of Unemployment", Quarterly Journal of Economics 100 (February 1985) 57-79.

models of Okun's coefficient that use yearly data do not include any lags, on the assumption that yearly data captures most of the effect in a single period. For example Perry (1977) estimated the coefficient as being 3.05 percent between 1954 and 1976, he did so using annual data and no lagged terms.

3.5 Differencing Tests Results: 1976-1997 and 1997-2007

Appendix 1 gives all estimates of Okun's coefficient, it also reproduces Blackley's results from 1970-1987. Since most of my significant results occurred in larger states, Table 2 below gives estimates for Okun's coefficient for the 10 largest U.S. states for both 1977-97 and 1997-2007, accounting for approximately 50 percent of U.S. population during the period.

Table 3.2: Okun's Coefficient for the 10 largest U.S. States

		1976-1997				1997-2007		
State	Population	Okun's Cooef	R^2	Signif		Okun's Cooef	R^2	Signif
California	29,760,021	1.77	0.24	0.023**		3.21	0.69	0.003***
New York	17,990,455	1.61	0.263	0.017**		2.16	0.579	0.011***
Texas	16,986,510	2.332	0.127	0.103*		2.603	0.656	0.004***
Florida	12,937,926	1.55	0.143	0.09*		2.36	0.597	0.009***
Pennsylvania	11,881,643	1	0.233	0.026**		0.629	0.222	0.169
Illinois	11,430,602	1.27	0.333	0.002***		1.18	0.639	0.006***
Ohio	10,847,115	1.397	0.358	0.004***		0.295	0.014	0.74

Michigan	9,295,297	1.81	0.549	0***		1.064	0.129	0.308
New Jersey	7,730,188	1.61	0.267	0.016**		0.604	0.247	0.143
N. Carolina	6,628,637	1.56	0.353	0.004***		1.32	0.3	0.101*

Note: * significant at the 90% Level; ** 95%; and *** 99%.
Source: Calculated by Author.

Estimates of Okun's coefficient for the period 1977 to 1997 gave significant to the 90th percentile results in 27 out of 51 states, 18 of the 25 most populous, and all ten of the U.S.'s most populous states, (8 of these 10 with 95 percent or better confidence) only four of the ten least populous states had significant results. For the shorter time period of 1997-2007, only 17 states had significant results, 6 of the 10 most populous states did, none of the 10 least populous. In both cases, the 10 most populous states represent somewhat more than half of the U.S. population.

That we are more likely to see significant results for Okun's coefficient in larger states is not all that surprising a result, given labor mobility in the U.S. The labor market in smaller states (and thus our measured unemployment) will tend to be swamped by the effects of larger states. To put it more concretely, when output in California falls, some small percent of California's workers head for Nevada – but the impact on Nevada is large. When output in Nevada rises, the amount of labor it attracts from California is likewise significant – in the context of Nevada. But the unemployment rate in California drops by a tiny amount.

It should be noted that these results are the opposite of Christopoulos's results in Greece, where he found that Okun's coefficient existed in non-populous parts of Greece but not in the more urbanized areas. Interestingly, his Greek study found the highest Okun's coefficient, with the highest r^2, to exist in Crete, the results I obtained gave Hawaii a 3.72 value with a 99 percent degree of confidence, ($r^2 = 0.45$).

The largest significant values for Okun's coefficient during the 1977-1997 period using this method were a 4.13 in South Dakota (r^2 of 0.162, 90 percent conf.) and 3.72 in Hawaii ($r^2 = 0.450$, 99 percent conf.). All other states during the period had Okun's coefficient of less than 2.5. South Dakota's results seem to be an outlier, since the measured coefficient for the two subsamples of 77-86 and 87-97 gave coefficients of 6.55 and -7.01, respectively. Hawaii's results seem reasonable straightforward, the high coefficient represents the geographic barriers associated with entering or exiting Hawaii's labor market.

Nebraska, New Hampshire and Idaho all had coefficients between 2 and 2.5, all other states, including the larger ones, had coefficients between 1.01 and 2.00. In almost all cases, the measured Okun's coefficient for states with significant results was lower than either national estimates, or the estimates that Blackley made for the 1970-1987 period. As a test, I ran this simple specification on both U.S. national data during the above periods, and on available Regional data[41], with the results given below.

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[41] Freeman used this regional data in his tests of Okun's coefficient, though he used a very different method of calculating the coefficient. However, he appears to have mixed BLS and BEA data indiscriminately, since they define the regional economies differently. I have chosen to only use the three regions where BEA and BLS data coincide precisely, except for the Western (pacific) region, where BLS included Nevada, but BEA does not – a trivial difference in the overall unemployment rate, given Nevada's small population relative to the rest of the Pacific states. Full regional results are reported in appendix 7.

Table 3.3: Okun's Coefficient for Regional Data

	Okun's Coef	R^2	Signif.
North East Region	1.907	0.343	0.005
Great Lakes Region	1.483	0.415	0.002
Plains States	2.138	0.256	0.019
West Coast	1.629	0.207	0.038
U.S. Annual Data	2.14	0.690	0.032

Source: Calculated by Author.

It should be noted that these results are now significant to the 99 percent or 95 percent level. Furthermore, the estimated coefficients for the regions range between 1.4 and 2.1, on average somewhat higher than the state level tests this study produced, but still lower than Blackley's results.

Since Blackley's results rely in part on unpublished, unavailable data, it is difficult to say with certainty why results here diverge from his. Two main possibilities suggest themselves, either the data used during the periods changed, introducing bias into the estimation, or Okun's coefficient has changed during this period.

The most likely source of data bias comes from the SIC method of calculating GSP. As stated before, it tends to overstate state growth rates. The problem of overstated growth rates gets larger the further back in time one goes. The median GSP as given in the SIC data for the period 1977-1997 was 7.23 percent, but when the SIC sample is broken down into the 1977-86 and 1987-97 samples, the median growth rates are 9.23 percent and 5.34 percent. The median growth rate for the period 1970 to 1977 was 11.3 percent. Note that standard deviations from these rates did not differ markedly, so any econometric test using the earlier data would show greater swings in State growth rates over the business cycle, biasing estimates of Okun's coefficient upwards.

Secondly, unemployment during this period was most likely less volatile. Labor markets were in general more rigid during this period, due to greater unionization, and a heavier reliance on manufacturing for jobs. Thus, if measured unemployment showed smaller shifts throughout the business cycle, again we would expect a higher coefficient. It should be noted that the first of these arguments is that output volatility is overstated by the data used, the second is that the actual variable (unemployment) has shifted.

To illustrate the data issue presented by the SIC data, consider the following two figures of California.

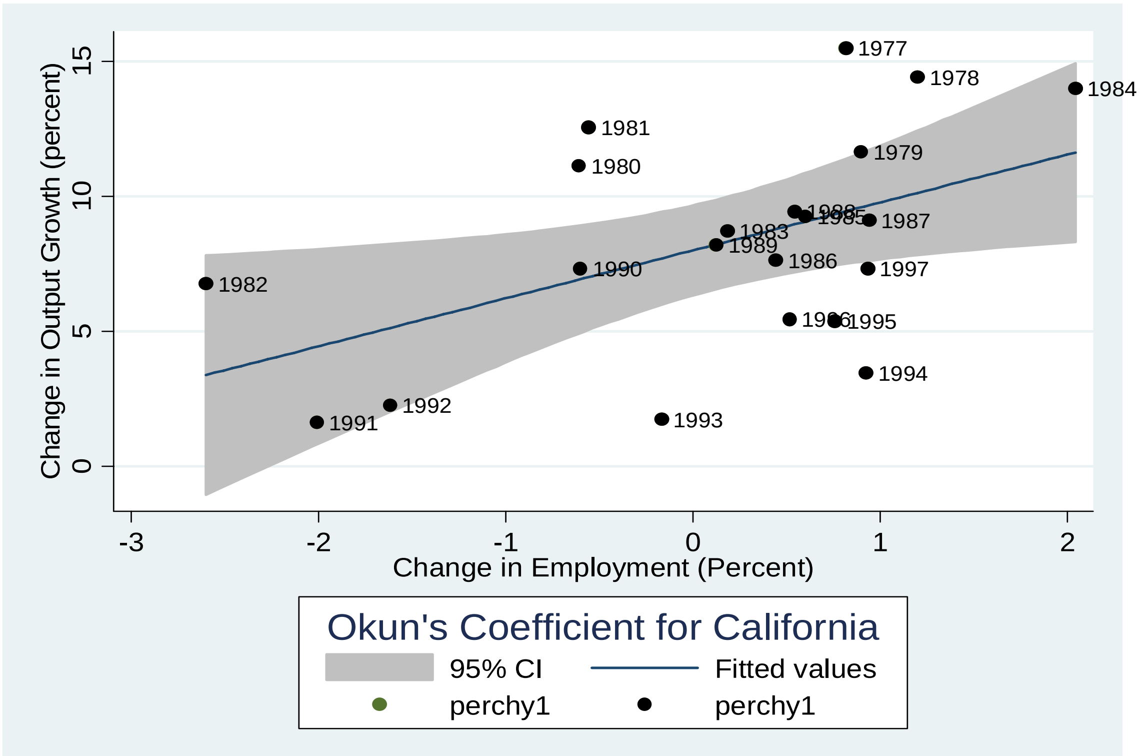

Figure 3.1: Okun's Coefficient for California

The above scatterplot shows a sample of a regression using the differencing method Blackley used. As can be seen above, at no point during the 1976 – 1997 period did California experience negative growth under the SIC methodology of calculating Gross State Product. Furthermore, a quick look at the 1981, 1982 and 1991 datapoints shows the SIC methodology (modified in 1987) showing the 1991-1992 recession as being more severe in terms of output than the 1981-82 recession, hardly intuitive results. While these results are somewhat anomalous (for most states the 1981/1982 recession is an outlier below, not above, our estimated line), the above shows the difficulty that the relatively simple method of differencing used so far has in dealing with the GSP data set being used. A different view of this is shown below.

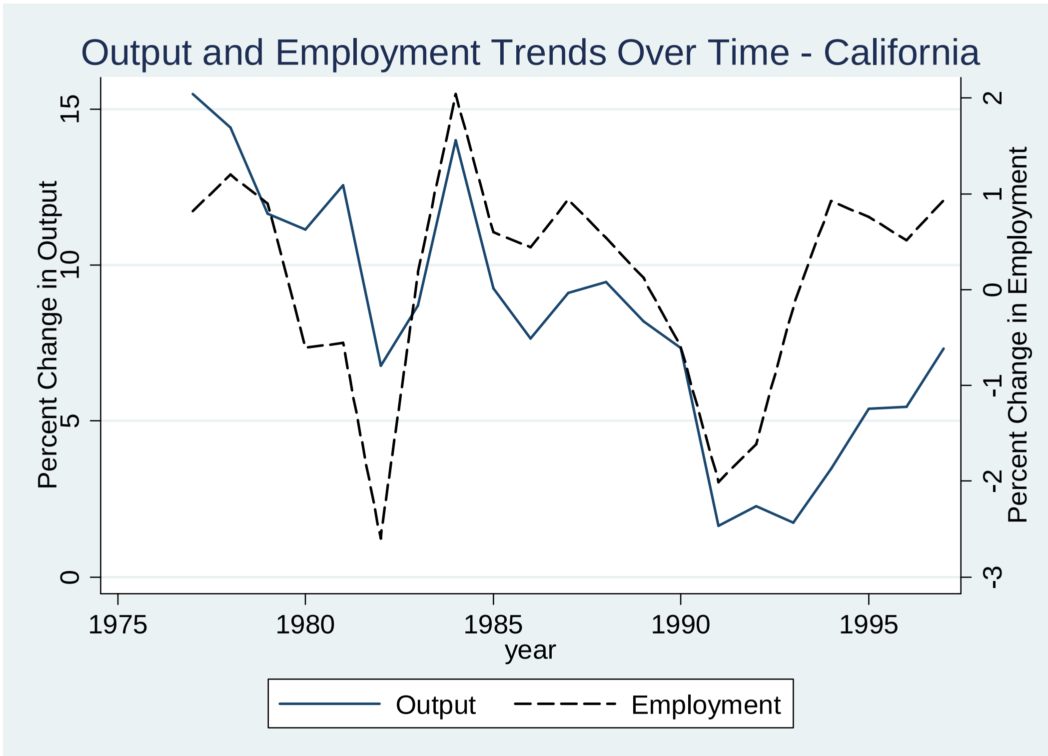

Figure 3.2: : Output Growth and Employment Trends Over Time for California

The above shows clearly that output growth and employment in California are moving together, but also show that output is showing a long term decline in its growth rate over time. Again, growth is far less during the 91-92 recession than during the early 81-82 recession, and the GSP data BEA provides really does show California growing throughout both recessions. That it shows more growth during the much more severe 81-

82 recession is much more a reflection of changes in how the BEA calculated GSP using the SIC over time than it is of any long term decline in productivity growth.

A formal test of this was conducted using a Chow test to reject the null hypothesis that there was a structural break in 1987, in point of fact it is impossible to reject said hypothesis for most states. Adding a dummy variable for the 1987-1997 significantly improved the models fit, for example California's results changed from a coefficient of 1.77 (R^2 of 0.243, 95 percent confidence) to an Okun's coefficient of 1.54 (R^2 of 0.678, 99 percent confidence).

Table 3.4 below shows the results for the twenty five most populous states, representing slightly more than 80 percent of the U.S. population, for the period 1976-1997. Three sets of results are given, results without a break (basically rerunning Blackley's test, but on later data and more states), results with a break to accounting for the 1987 change in methodology, and Blackley's original results from 1970 to 1987.

Table 3.4: Okun's Coefficient for Twenty-five Most Populous States

		1976 to 1997				With data break, 1987				Blackley	
	Population	Coef	R^2	Signif		Coef	R^2	Signif		Coef	R^2
California	29,760,021	1.77	0.24	0.023	**	1.548	0.678	0.005	***	2.353	0.75
New York	17,990,455	1.61	0.263	0.017	**	1.129	0.668	0.016	**	3.322	0.42
Texas	16,986,510	2.332	0.127	0.113	*	3.573	0.363	0.014	**	2.994	0.71
Florida	12,937,926	1.55	0.143	0.09	*	1.117	0.692	0.054	**	3.623	0.42
Penn.	11,881,643	1	0.233	0.026	**	1.028	0.476	0.009	***	2.457	0.7
Illinois	11,430,602	1.27	0.333	0.002	***	1.508	0.591	0.000	***	2.611	0.77
Ohio	10,847,115	1.397	0.358	0.004	***	1.578	0.620	0.000	***	2.404	0.9
Michigan	9,295,297	1.81	0.549	0	***	1.920	0.705	0.000	***	2.933	0.8
New Jersey	7,730,188	1.61	0.267	0.016	**	1.050	0.633	0.036	**	2.899	0.6
North Car.	6,628,637	1.56	0.353	0.004	***	1.587	0.707	0.000	***	2.307	0.73
Georgia	6,478,216	1.46	0.142	0.092	*	1.290	0.695	0.020	**	3.425	0.72
Virginia	6,187,358	1.12	0.079	0.215		1.153	0.769	0.020	**	3.436	0.56
Mass.	6,016,425	0.944	0.021	0.528		1.338	0.786	0.001	***	3.012	0.53
Indiana	5,544,159	1.71	0.389	0.002	***	1.833	0.459	0.001	***	3.205	0.76
Missouri	5,117,073	1.789	0.357	0.004	***	1.933	0.652	0.000	***	3.185	0.65
Wisconsin	4,891,769	1.024		0.027	**	1.232	0.474	0.004	***	2.358	0.78
Tennessee	4,877,185	0.82	0.089	0.187		1.099	0.365	0.050	**	2.915	0.7
Washington	4,866,692	0.755	0.056	0.301		0.906	0.274	0.176		3.164	0.65
Maryland	4,781,468	1.89	0.233	0.027	**	1.548	0.646	0.012	**	3.333	0.67
Minnesota	4,375,099	1.97	0.275	0.015	**	2.168	0.531	0.002	***	3.984	0.56
Louisiana	4,219,973	0.944	0.021	0.528		2.335	0.168	0.160		6.803	0.29
Alabama	4,040,587	0.49	0.04	0.35		0.912	0.452	0.041	**	2.137	0.69
Kentucky	3,685,296	1.28	0.202	0.041	**	1.774	0.408	0.005	***	2.626	0.73
Arizona	3,665,228	1.46	0.27	0.27		1.416	0.613	0.003	***		
South Carolina	3,486,703	1.531	0.313	0.008	***	1.578	0.708	0.000	***	2.294	0.8

Note: *,**, *** represent the 90, 95 and 99 percent confidence intervals.

Source: Calculated by Author, or Blackley (1991).

Okun's coefficient, as calculated with a break, (the second column of coefficients), shows much more robust results than the first set of estimates. 23 of the largest 25 states have results significant to the 95 percent level or above, 32 out of the whole set of 51, with 9 more being significant to the 90 percent level. Equally importantly, R^2 increases in almost every state, often by a significant amount. Most of the above states showed a strong, and statistically significant, Okun's coefficient.

That being said, the measured coefficient for Okun's coefficient is significantly smaller than was the measure that Blackley obtained. Blackley's results generally found Okun's coefficient to be in the range of 2.2 to 3.2, on the higher end of most estimates of Okun's coefficient for the U.S. as a whole (at the time). The results of this study found the results to be more along the lines of 1.2 to 2.2, in the same states that Blackley studied. These results are somewhat lower than U.S. estimates.

Blackley assumed in his work that his higher estimates of Okun's coefficients were due to the ease with which workers could move between states. As he put it

"The average value of Okun's Law is at the high end of the range of national estimates, which is likely due to the greater openness of state as compared to national labor markets. As a result, output growth more easily attracts labor force growth through migration at the state level, and therefore a more rapid rate of GSP growth is needed in order to generate a 1 percentage point reduction in the unemployment rate."[42]

The above does not address the counterpoint – that as a state's GSP declines, some newly unemployed workers will migrate out, meaning the unemployment rate will drop less than expected (which could lead to a smaller or larger Okun's coefficient,

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[42] Blackley, ibid, p. 645

depending on which effect is larger). This point will be addressed in more detail in chapter 4, when I used pooled data to explore issues of asymmetry in Okun's Law.

It should be noted that several of the smaller states with significant results showed higher estimates, but those states were all dependent on the energy sector, and had low R^2s. Likewise, two small states had coefficients below one (but still positive), but again with very small R^2s. The general point remains true. Okun's coefficient seems to have dropped significantly in the U.S. over the course of a decade. In part this may be due to the SIC data issues addressed earlier, or it may be due to changes in the U.S. Economy. Before addressing those, issues, it would be best to estimate Okun's coefficient in some other ways, both to check the robustness of the results obtained using equation 3, and to see if they can offer additional insight.

3.6 Gap Estimation of Okun's Coefficient

In the gap formulation, the relationship between unemployment and output which is the core of Okun's Law usually follows the form of:

3.6.1) $y - y^* = ß(u - u^*) + \varepsilon$,

where y and u are the observed values of output and unemployment at any given time (time subscripts are omitted for simplicity above), y^* and u^* are the potential magnitudes, and ε is an error term. Often the above is calculated in logs, as a means of differencing output data. For quarterly data, lags are usually incorporated, depending on the detrending method. Again, various estimates of the above have given values of ß ranging from between 2:1 and 3:1. Recent estimates of Okun's coefficient for the U.S as whole, computed using Gaps, gives values that range between 2.2 and 2.4[43].

The difficulty with the above method is that there is no way to directly observe y* and u*, which thus need to be calculated in some manner, usually as a function of previously observed values. Modern macroeconomic empirical work has created a number of different methods for calculating y* and u*, basically attempting to break the series into its component parts; trend, cycle, seasonal (for monthly or quarterly data) and irregular. Yearly data eliminates worries about seasonality, but leaves the other three problems in place.

The calculation of gaps is essentially an effort to figure out the cyclical component of a time series. Methods to do so include the removal of linear or quadratic trends, first differencing, or filtering the time series in some way. Popular modern filters include Beveridge and Nelson (1981), Hodrick and Prescott (1997) or Baxter and King (1995). Each of these filters is designed to do a similar thing – remove the long run component (trend) from a time series, leaving the cyclical component behind.

The Hodrick and Prescott (the "HP filter") does this by calculating a smooth trend for the time series, and then subtracting this from the observed trend. (for full details, see Appendix 9) The HP filter minimizes a least squared optimization equation, with smoothness introduced by the addition of a lagrange multiplier term (λ) that penalizes the second difference of the estimated trend. The HP filter is thus a high pass filter, it

[43] Attfield and Silverstone (1997) calculated Okun's coefficient to be 2.27, Moosa (1997) found it to be 2.2.

removes the (calculated) long run trend, the residuals that remain are the high frequency fluctuations. The residuals that remain can be calculated as the business cycle. The λ term that penalized the fluctuations, thus controlling the degree of smoothness achieved in the detrended series, is a parameter that needs to be specified. Normal conventions is for a value of 400 for quarterly data, and 6.25 for annual data – though various authors seem partial to slightly higher or lower values, depending on the amount of "smoothness" they were seeking. I tried several different values for this parameter, but ultimately settled on 6.25.

The HP filter has become very popular in recent years (similar, but more difficult to implement, versions existed before), because it is relatively easy to implement, it smoothes time–series data (differencing data often amplifies deviations from trends,) and it can be used on non-stationary data. Criticisms of this filter include the possibility of it creating "spurious" cycles, and the fact that the parameter does not change over time – appropriate only if the time series data has no significant trend or level changes.

The Baxter and King filter (the "BK filter") is a bandpass filter, it attempts to suppress both high frequency deviations (irregular fluctuations) that remain after first differencing, and the low frequency changes that remain when taking deterministic trends. As such, it does this by calculating a centered moving average over time, as this average changes, long run changes in the trend are accounted for. Optimally one would use a time series of infinite length to calculate the centered moving averages, in practice Baxter and King argue that (for annual data) three years of data at either end of the series is sufficient to begin the filter. The bandpass values I used for this study mirrored

Freeman's (2001) study of BEA Regions, using a phi and pho of two and eight, respectively, thus filtering out short run irregularities (two years or less) and long run trends (the eight year "average" business cycle).

Freeman (2001a) used the BK filter for his tests of U.S. Regional data, Villaverde and Maza used both the HP filter and the BK filter for their tests of Spanish regions, and most recent studies of Okun's coefficient comparing countries uses one or both of these filters. As such, I used both the BK filter and the HP filter, as well as a deterministic quadratic equation, to calculate gaps. The results from the quadratic equation were useless, a visual inspection of the data showed that it was magnifying deviations, not dampening them, outliers came to dominate the results. The BK filter used the first three and last three observations in creating its moving average, so the resulting estimates were for the period 1979 to 1994. I calculated the HP results twice, once for the full period, but also once for the period 1979 to 1994. This had the advantage of giving results that could be directly compared to the BK results, and it also made the results less sensitive to the early and late data. The HP filter constrains the first and last datapoint to 0, often biasing results.

A graphical example of BK filtered data is given below, for Michigan.

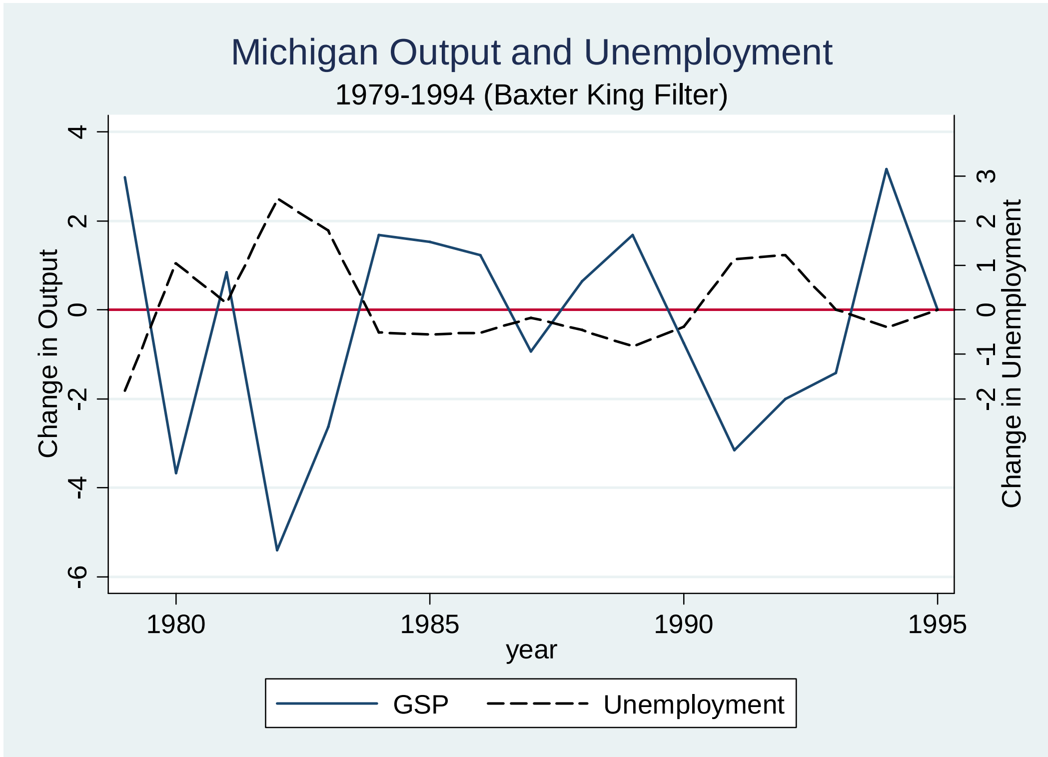

Figure 3.3: Michigan Output and Unemployment

The above shows data as filtered using the Baxter King Filter, for GSP and unemployment for Michigan from the period 1976 to 1997. The first and last three terms are dropped, as they are used in the construction of the moving average. The above shows all the movements one would expect in a time series during the period tested for, the output declines in 1982 and 1991, with the associated increases in unemployment. Output shows greater swings over time than does unemployment, by a factor of about two to one. Michigan is probably the "cleanest" of the states in this regard, but most states showed similar dynamics. Note that broadly speaking, the HP filter generated similar results.

The results for the 25 most populous states are given below, full results can be found in Appendix 3.

Table 3.5: Okun's Coefficient for 25 Most Populous States

		Baxter King Filter				HP filter (1976-1997)				HP filter (1980-1994)			
	Population	Coeff	r2	conf		Coeff	r2	conf		Coeff	r2	conf	
California	29,760,021	1.19	0.429	0.006	***	1.101	0.371	0.003	***	1.142	0.428	0.006	***
New York	17,990,455	0.89	0.261	0.043	**	0.622	0.143	0.083	*	0.87	0.325	0.021	**
Texas	16,986,510	2.12	0.232	0.058	*	1.537	0.088	0.179		1.974	0.184	0.097	*
Florida	12,937,926	0.98	0.342	0.017	**	0.583	0.088	0.180		0.959	0.412	0.007	***
Penn.	11,881,643	1.01	0.552	0.001	***	0.892	0.497	0.000	***	0.911	0.541	0.001	***
Illinois	11,430,602	1.49	0.704	0.000	***	1.400	0.699	0.000	***	1.422	0.722	0.000	***
Ohio	10,847,115	1.61	0.690	0.000	***	1.440	0.704	0.000	***	1.533	0.703	0.000	***
Michigan	9,295,297	2.03	0.805	0.000	***	1.955	0.840	0.000	***	1.967	0.817	0.000	***
New Jersey	7,730,188	1.22	0.368	0.013	**	0.899	0.254	0.017	**	1.246	0.485	0.003	***
N. Carolina	6,628,637	1.54	0.664	0.000	***	1.333	0.543	0.000	***	1.425	0.681	0.000	***
Georgia	6,478,216	1.32	0.229	0.060	*	1.171	0.185	0.045	**	1.589	0.326	0.021	**
Virginia	6,187,358	1.05	0.334	0.019	**	0.936	0.243	0.020	**	1.076	0.468	0.003	***
Mass.	6,016,425	1.37	0.528	0.001	***	1.168	0.407	0.001	***	1.425	0.625	0.000	***
Indiana	5,544,159	2.13	0.641	0.000	***	2.005	0.669	0.000	***	2.069	0.669	0.000	***
Missouri	5,117,073	1.81	0.672	0.000	***	1.742	0.694	0.000	***	1.75	0.679	0.000	***
Wisconsin	4,891,769	1.31	0.666	0.000	***	1.204	0.661	0.000	***	1.261	0.702	0.000	***
Tennessee	4,877,185	1.19	0.360	0.014	**	1.189	0.372	0.003	***	1.205	0.391	0.010	***
Washington	4,866,692	0.52	0.124	0.180		0.449	0.083	0.193		0.37	0.071	0.318	
Maryland	4,781,468	1.57	0.481	0.003	***	1.206	0.282	0.011	**	1.437	0.474	0.003	***
Minnesota	4,375,099	2.59	0.705	0.000	***	1.752	0.459	0.001	***	2.371	0.69	0.000	***
Louisiana	4,219,973	2.39	0.213	0.071	*	2.423	0.199	0.037	**	2.505	0.243	0.052	**
Alabama	4,040,587	0.96	0.496	0.002	***	0.890	0.433	0.002	***	0.912	0.5	0.002	***
Kentucky	3,685,296	1.87	0.578	0.001	***	1.641	0.538	0.000	***	1.796	0.606	0.000	***
Arizona	3,665,228	1.22	0.396	0.009	***	1.099	0.299	0.008	***	1.276	0.39	0.010	***
S. Carolina	3,486,703	1.42	0.694	0.000	***	1.276	0.646	0.000	***	1.333	0.704	0.000	***

Note: *, **, *** represent the 90, 95 and 99 percent confidence intervals. Source: Calculated by Author.

As with the earlier tests, significant results were more common in more populous states than in smaller ones. Two of the three methods used gave statistically significant results in 24 of the 25 most populous states, usually at the 99 percent significance level. Overall, significant results were found for 41, 36 and 40 states, respectively. Okun's coefficient as calculated using the BK Filter were on average a little larger than for either HP filter, but most states showed similar ordinal rankings – while the detrending methods showed differences in Okun's coefficient, they were fairly consistent in the differences. States with a large coefficient in comparison to other states in one measure usually did in all other measures as well. For ease of analyses, I will limit further comment on the above results to those obtained with the BK filter, except where otherwise noted.

Using the BK filter, and limiting our analysis to the 25 largest states that were significant to the 95 percent level, plus Texas which just missed it, we find our R^2s tended to be lower in those states with a smaller manufacturing base, for example Florida and New York both had coefficients just below 1, and had R^2s of only 0.34 and 0.23. Conversely, states that we normally think of as manufacturing heavy, such Illinois, Ohio and Michigan, had both higher coefficients (1.5, 1.6 and 2) and higher R^2s (0.70, 0.69 and 0.80).

Texas had one of the highest coefficients at 2.12, but a fairly low R^2 of only 0.23. A quick visual inspection of Texas (Figure 3.4 below) shows that unemployment varied only a small amount during this period, while output had fairly large swings. The GSP for Texas, as measured by the BEA using the CIS standard, resulted in Texas having large output swings due to the significant changes in the price of oil. Alaska, Wyoming, South Dakato and Nebraska all had significant results, low r^2s, and high Okun's coefficients as well.

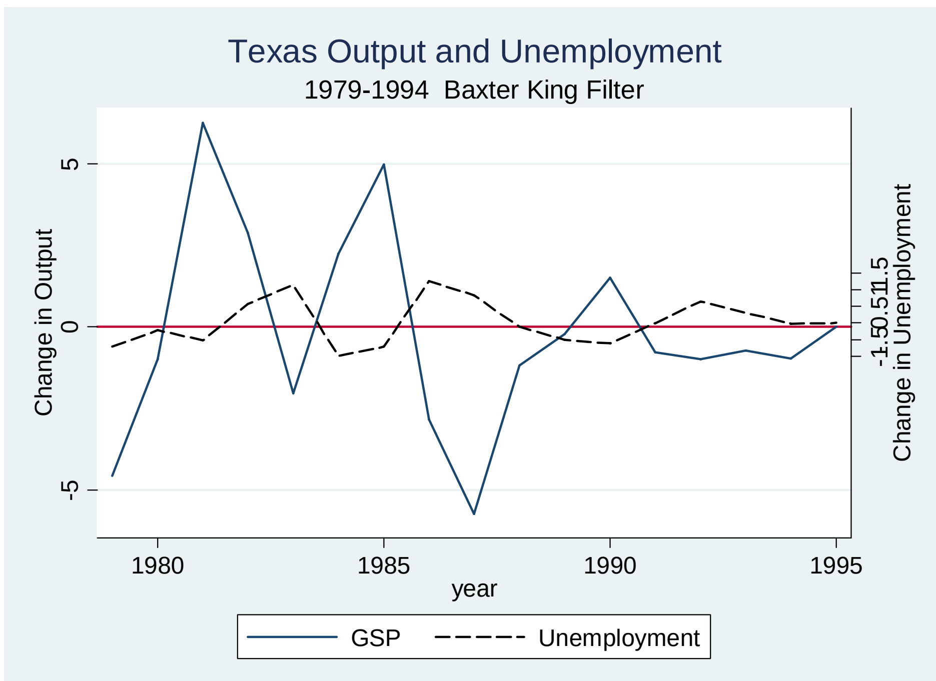

Figure 3.4: Texas Output and Unemployment

Our median value for Okun's coefficient was 1.43 (Kansas), 9 states had coefficients above 2, and 5 had coefficients between 0.6 and 1. Again, as with our previous method, Okun's coefficient at the state level seems to be somewhat below the national level. Again, regional studies in Spain, Greece and Canada all found lower

Okun's coefficients at the regional/provincial level than was the case at the national level, the median coefficient for Greek regions was 0.7, for Spanish regions it was 1.1, for Canadian regions it was 1.9.

Overall, the results generated here strongly support the existence of Okun's coefficient at the state level in the U.S. These results are true for most of the larger states, regardless of the method used to calculate the coefficient. In all cases, the coefficient had the expected sign, and most states had significant results. However, in almost all cases the measured Okun's coefficient was lower than national U.S. estimates for the same period. This is at variance with earlier U.S. state results, or with regional estimates of Okun's coefficient. It is in accordance with regional estimates that have been conducted in other countries. The next part of this paper looks at pooled data to see what insights can be gained.

Chapter 4: Pooled (Panel), Yearly and Nationally Detrended Estimates of Okun's Coefficient at the State Level

The limited length of time for the datasets in use, and the fact that they only use annual data, makes more complicated tests of Okun's coefficient, such as for non-linearity or asymmetries, difficult or impossible. The number of observations in the longer dataset, 22, is insufficient for these sorts of tests. The existence of the data for 50 states, however, means that we have well over 1,000 observations at hand. This section extends tests of Okun's coefficient using Pooled (Panel) data.

Pooled data has been used on a very limited scale to test Okun's coefficient in the past. Both the Greek and Spanish regional studies cited earlier used pooled data, but did so only to reject unit roots in the data. Freeman also used pooled data in his study of U.S. Regions, but his results were not significant. By far the most extensive use of pooled data to estimate Okun's coefficient was Freeman's 2001 study, "Panel tests of Okun's Law for Ten Industrial countries". In it, he used pooled European data to test for Okun's coefficient. He theorized that since the labor data he used had been gathered in a consistent manner by the U.S. Department of Labor, and the output data by the IMF, the data was comparable enough to be pooled.

Given the increasing economic integration of the EU, this seems a reasonable proposition, it is even more appropriate for the U.S. Pooled data offers several advantages over time series estimation of a single unit, or cross sectional estimates of multiple units. The additional degrees of freedom available in pooled data can produce more efficient estimates, and the additional variability in the regressors can mitigate the collinearity problems that are often associated with macroeconomic time series. Pooled estimation can control for time varying omitted factors that may contribute to changing parameters.

Panel data is constructed in the form of

4.1) $y_{it} - y_{it}^{*} = ß(uit - u_{it}^{*}) + \varepsilon_{it}$

where the i and t subscripts refer to state i at time t. Actually pooling the data was not particularly difficult, once individual state time series had already been constucted. Given a choice of methods from chapter three, the long run trend variables were obtained using the BK filter, while this lost a large number of observations at each end of the series, there are still a large (over 800) number of observations to use. Additionally, the BK filter was best able to handle the change in methodology in gathering GSP data by the BEA. Finally, since it has been used in the past by Freeman, it was deemed advisable to continue with it.

Testing for asymmetries in Okun's coefficient can be done by splitting the data in use into two sets, one where output is above trend, the other where it is below, or by doing the same with unemployment. The table below reports the results of doing so for four cases, states that were significant to the 99 percent level, the 95 percent level, the 90 percent level, and all states. Additionally, data was split both on the basis of employment, and on the basis of output. All results were significant at the 99 percent confidence level.

When limited to states with highly significant results, Okun's coefficient was estimated at 1.51, with an R^2 of 0.516, as more states were added, R^2 went down, but Okun's coefficient changed only slightly. When the pooled data was split for positive and negative deviations from potential employment, Okun's coefficient was not significantly different either from the full sample, or between the above and below trend periods.

Conversely, when the pooled data was split on the basis of positive and negative deviations from trend for output, Okun's coefficient was significantly lower, and positive and negative gaps produced results that were significantly different from each other. To give a concrete example, pooled data for the 22 states that had an Okun's coefficient at the 99 percent confidence interval resulted in an Okun's coefficient of 1.51, with an R^2 of 0.516. When that data was split in two on the basis of whether it had a negative or positive deviations from the output trend, Okun's coefficient was only 0.975 when calculated using data below the output trend, and an even lower 0.579 for data that was above the long run output trend.

To further complicate matters, in all cases Okun's coefficient had a much higher R^2 when looking at negative deviations from trend, regardless of whether the trend was output or employment, as opposed to positive deviations. So even when our estimate of

Okun's coefficient remains the same, its explanatory power is significantly higher during downturns.

Table 4.1: Asymmetries in Okun's Coefficient

	Okun's Coef.	R^2	# obs.
99% Significant States (22 states)			
Full Sample	1.51	0.516	352
Positive E	1.455	0.1716	195
Positive Y	0.579	0.1128	151
Negative E	1.584	0.435	157
Negative Y	0.975	0.4691	201
95% Significant States (33 states)			
Full Sample	1.432	0.436	528
Positive E	1.4	0.136	299
Positive Y	0.534	0.083	215
Negative E	1.34	0.313	229
Negative Y	0.856	0.361	313
90% Significant States (41 states)			
Full Sample	1.49	0.323	640
Positive E	1.467	0.085	359
Positive Y	0.552	0.039	260
Negative E	1.483	0.257	281
Negative Y	0.818	0.231	380

All States and D.C.			
Full Sample	1.49	0.201	816
Positive E	1.56	0.054	453
Positive Y	0.544	0.024	338
Negative E	1.52	0.167	363
Negative Y	0.691	0.084	478

Source: Calculated by Author.

The question of why Okun's coefficient, when measuring the cycle in terms of output, is lower during downturns then upturns is a complex one. The conventional view is that unemployment rises faster during a downturn than it falls during an upturn. In part, this is due to the fact that the business cycle seems to consist of periodic sharp movements below trend, and longer periods somewhat about trend. Assuming unemployment responds linearly to output , we would expect the same Okun's coefficient during downturns, unemployment is rising faster because output is falling faster.

Various reasons have been advanced for why Okun's coefficient would be asymmetric, and smaller, during recoveries. Of the two most commonly given, one of them seems implausible for the U.S., that significant labor rigidity as a result of unionization and government regulation prevents firms from releasing unwanted workers during recessions. A more likely, in the U.S., argument is that firms retain workers throughout a recession so that they can be used in the subsequent recovery (labor hoarding), either to retain firm specific knowledge, or to avoid later labor shortages.

Arguments as to why Okun's coefficient would be smaller during periods featuring negative output gaps, which the results achieved so far seem to suggest, include threshold effects and risk aversion. If businesses don't change hiring decisions until some sort of threshold is reached, that would happen faster during downturns, since output changes faster. Risk adversity could also play a role, firms are more worried during downturns than they are optimistic during recoveries.

Since unemployment eventually does respond to increases in output, this strongly suggests that the model of Okun's coefficient in use so far is missing something, lagged variables. Tests of Okun's coefficient for individual states, including lagged variables (both one period of output and unemployment) almost always showed the lagged variables to be statistically insignificant at the 90% level, implying that all, or at least most, of the response in unemployment to changes in output occur within the first year. The limited size of our data set (22 observations, with three variables dropped due to the BK filter used to create the long run estimates of output and unemployment) almost certainly contributed to this result.

Therefore, it is useful to re-specify our model to include lagged variables. A variety of combinations were tried, but only one lagged variable, the first lag of unemployment, proved explanatory for the pooled data. Running a Generalized Least Squared (GLS) random effects model to test Okun's coefficient on the pooled data, gave the results that follow in table 4.2. These results are for the test on pooled data from all states that had an Okun's coefficient that was significant at the 99% level (22 states), similar results were obtained when states at the 95% level were added (33 states). When states that were significant at the 90% level, or states where there was no clear Okun's coefficient, were added, the coefficients all retained the same signs, but often were no longer significant.

Table 4.2: GLS estimate of Okun's coefficient for Pooled Data

All States At 99% Sign.	Dependent Variable	Independent Variables	Z Statistic	Probability	Overall Statistics
Full Sample	Output	Unemployment 1.16 Lagged Unem. - .341	11.10 -3.26	.000 .001	R^2 = .536, 484 Observations,
Expansion (Y Increase)	Output	Unemployment .682 Lagged Unem - .244	5.05 -2.81	.000 .005	R^2 = .157, 202 Observations,
Downturn (Y Decline)	Output	Unemployment .909 Lagged Unem - .130	9.46 -1.14	.000 .254	R^2 = .478, 151 Observations,

Several points about the above table jump out. The R^2 for the full sample (484 observations) and for negative output growth (151 observations) are .536 and .478, respectively, but only .157 for observations where output was above trend. Output declines are much more strongly linked to unemployment changes than are output increases.

Just as important, they seem to happen quicker. Lagged unemployment for all three of our samples has a negative sign, indicating that in the year after changes in output and unemployment, there is a tendency for unemployment to move back towards trend. This tendency was small and insignificant for downturns, while being somewhat larger, and significant, for both the full sample and for the sample using above trend output.

The above is largely in line with Moosa el al's (2004) study. Since they used quarterly data, they were able to calculate that most employment effects are incorporated in three lags, or within one year of a change in output, they did not test to see if Okun's coefficient is sensitive to a different numbers of lags in downturns or upturns. They also found that unemployment was more sensitive to downturns than to upturns, indeed they found a much larger asymmetry than was found here. Likewise, their results for below trend observations tended to be more significant than for above trend periods[44].

The results above support the view that employment responds quickly, and strongly, to downturns, but less so to recoveries. Okun's coefficient is significantly different during the two, in three important ways. It is smaller during downturns, a smaller change in output is required to change the unemployment rate. It has much higher R^2's, the effect is clearer and more direct. And lags are statistically unimportant during downturns, the change in output leads to immediate changes in employment, while increases in output take longer to work their way through the labor market.

4.1 Yearly tests of Okun's Coefficient

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[44] Moosa's study created gaps, and then calculated how many lags were significant. Only after doing so did they split the data to look at the asymmetries. It is interesting to speculate what the results would have been if they had split their data before calculating the significant lags, to see if the quarterly lags that were significant at the national level differed during contractions and expansions.

A different way to test this is to look at the data year to year. Normal tests of Okun's coefficient are conducted over time to estimate the coefficient in one country. Using sub-national data, it is possible to test the coefficient each year, since (in the case of the U.S) 51 observations are potentially available each year.

This assumes, however, that all U.S. states experience the same business cycle, at least temporally. There is reason to doubt this. To begin with, often business cycles seem to be caused by factors that have disparate regional impacts. The 1991 recession was caused in large part by collapse of the U.S. savings and loan industry, which was a larger industry in western states than eastern states. It is generally accepted that the current (2008-2009) recession was caused by a housing bubble, especially in the sub-prime lending markets and the markets for second or third homes. The impacts of this were originally felt in a few overheated markets such as California and Florida, though the effects quickly spread.

Secondly, whatever it is that causes recessions, at the state level they often run their course with varying time lags[45]. Labor market rigidities, government policies, and sectoral differences, can all influence how a state's labor markets respond to downturns and upturns, regardless of the initial cause of a recession.

A visual inspection of changes in the unemployment rate and the rate of output growth using the regional data was conducted. While the regions did seem to follow an overall trend, some regions during each recession did seem to lag, or lead, other regions.

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[45] It is beyond the scope of this study to address the whole causation vs. propagation debate.

A visual inspection of the 51 states was also conducted, but this data was much more noisy. In general, output fluctuations seemed more correlated over time than unemployment fluctuations, especially for smaller states.

Bearing the above in mind, tests of Okun's coefficient on a year by year basis were run using both the differencing method, and using a gap equation. The main advantage of using the differencing method was that it allowed for a year by year test to be conducted from 1977 to 2007, skipping only two years (1998 and 1999) due to the data break between the SIC and NAICS datasets for output. The problem with this was twofold.   To begin with, the output data overstated output growth, especially in the early years. A simple differencing test thus tended to be very sensitive to fluctuations in output. As was seen in section three, or from looking at appendix two and three, the differencing tests did not produce results as good as the gap equations. Thus, there were fewer data points to observe.

Differencing tests were initially conducted in five ways, 1) all 51 states, 2) 25 largest states, 3) 10 largest states, 4) states that had significant results for either the SIC or the NAICS datasets, and 5) states that had significant results for both the SIC and the NAICS datasets. After looking over the results, two additional tests were made, the ten largest states excluding Texas, and the ten states with the largest manufacturing sector as found in section five. All results are reported in the appendixes.

Generally speaking, these results were fairly disappointing. While individual years proved to be statistically significant, less than half of the years tested proved to be significant under any of the tests. Using the ten largest states gave 9 significant results out of 28 observations, excluding Texas from them raised that to 15 of 28, just over half the years. While the data that was obtained suggested that Okun's coefficient was indeed lower during and just after recessions, nothing concrete could be said. Since the Gap equation test proved more fruitful, I will move on to it.

For the sake of consistency, the same tests that were run for the differencing of Okun's coefficient were run for the Gap equation. Both the HP filter and the BK filter were used, the BK filter gave better results so only its results are reported. One pertinent difference between the yearly estimates of Okun's Coefficient using the Gap equation and the Differencing equation stands out – both tests were sensitive to the number of observations, but in different ways.

Generally speaking, the fewer observations used when data was differenced, the better the results, especially when only using the ten largest states, and deliberately excluding the largest outlier, Texas. This is almost certainly a product of the data, the SIC data overestimated gross state product, and to a lesser extent also overstated its variance. Excluding states due to size or the fact that they did not have stable Okun's coefficients to begin with (there was considerable overlap between these two) thus excluded many outliers, the loss of these outliers more than made up for the smaller number of observations.

Since the BK filter serves to smooth out the data by eliminating both the long and short terms trends, the estimates made using a gap equation gave much better overall results, as was true in section three. More observations, even when the additional states being added had not given statistically significant results on their own, tended to give results that were more likely to be statistically significant. In our yearly tests of Okun's coefficient using a gap form of estimation, data was often more closely correlated between different states in the same year, than for individual states across time.

The results for the Gap equation test of all 50 states and D.C. are given below

Table 4.3, Yearly estimates of Okun's coefficient using a Gap equation (BK Filter)

Year	Coeff	R^2	Signif	
1979	1.12	0.081	0.043	**
1980	3.04	0.132	0.009	***
1981	3.25	0.475	0.001	***
1982	0.504	0.056	0.087	*
1983	0.394	0.017	0.349	
1984	0.987	0.014	0.393	
1985	3.25	0.287	0.001	***
1986	2.42	0.338	0.001	***
1987	2.76	0.261	0.001	***
1988	2.97	0.373	0.001	***
1989	2.16	0.16	0.004	***
1990	0.911	0.119	0.013	**
1991	0.54	0.03	0.224	
1992	0.434	0.012	0.482	
1993	1.18	0.139	..093	*

Source: Calculated by Author, *,**, and *** indicate significance at the 90, 95 and 99% significance level, respectively

A couple of things stand out in the above. As was the case using pooled data, Okun's coefficient is significantly lower during downturns, again labor is more responsive to negative changes in output. Interestingly, however, it seems to be statistically less significant during downturns, rather than being more so, as was the case with pooled data. R^2s were generally somewhat lower, but given that different states go into and come out of recessions at different times (as opposed to the pooled data, which specifically divided the data up by whether an observed level of output was characterized by a negative or positive gap between it and its expected long run trend) this is not unexpected. Given that lags did at times seem important using pooled data, I tested the above to see if lagged unemployment was statistically significant.

In three years from the above, lagged unemployment was statistically significant, 1979, 1982 and 1991. In 1979 both unemployment and lagged unemployment were significant at the 90% level, with coefficients of 1.27 and .94, compared to a value of 1.12 when no lag was included. In 1981, both unemployment and lagged unemployment were again significant at the 90% level, with coefficients of 2.91 and 2.71, compared to 3.25 when no lag was used. When lagged unemployment was used in 1982, both unemployment and lagged unemployment just missed the 90% significance level.

1991 showed a different dynamic. Our original estimate for Okun's coefficient, .540, was not significant. When tested using a lag of unemployment as well, the results were coefficients of .790 and -.453 for unemployment and lagged unemployment, the only time opposite signs were obtained. This would seem to indicate that unemployment was lagging more in 1991-1992 recession then had been the case earlier, it also helps explain why results for 1991 and 1992 were not statistically significant, unemployment was lagging longer than in other cases – evidence of a "jobless recovery".

The above data again indicates that Okun's coefficient is asymmetric. It is significantly lower during or just after recessions, and higher during recoveries. While pooled data indicate that a majority of Okun's coefficient is explained from data obtained during recessions, this is not as clear when using yearly calculations.

4.3 Removing National Data from Okun's Coefficient

Up until now, the working assumption of this study has been that U.S. states have distinct values for Okun's coefficient, values that can and do differ from the national value due to labor immobility at the state level. What has not been addressed is the fact that while U.S. states do have significantly different estimated values for Okun's coefficient, none-the-less the U.S. business cycle clearly affects various states at roughly the same time. This is no doubt partially due to spillover effects between states, when California has a housing crises, other states in the area will also be affected.

However, there is also clearly a national component to state business cycles. Monetary policy, federal fiscal policy and regulatory changes, international events, all impact the state economies, and do so in largely the same direction, even if the magnitude of the effects, and the changes in Okun's coefficient, vary. It is useful to look at how state estimates of Okun's coefficient differ from national estimates.

The easiest way to do this is to subtract out the national component of Okun's coefficient from the state component, and to see what is left. By doing so, it is possible to see how a state measure of Okun's coefficient has deviated from the national measure, is it above or below the national measure. Once done for all states, it should be possible to compare the states, to see what regional differences might still exist.

Removing the national component is trickier than it first appears. This is due both to theoretical difficulties, and data considerations. Addressing the data considerations first, in order to directly utilize the national data and trends into any state level estimates of Okun's coefficient, it is necessary that the data gathered was done so in identical ways. For out unemployment data, this is the case.

Unfortunately, for output, this was not the case. The gross state product data was gathered using both the SIC and NAICS methodology, and the SIC methodology itself changed in 1987. Broadly speaking, the GSP data from 1976-1987 was biased upwards, and had a higher variance, than did national GNP or GDP data. The GSP data from 1987-1997 was also biased upwards, though by a much smaller amount, and showed the same variance as the national data. The GSP data from 1997 to 2007 was gathered in an equivelant manner to the national data, though a data break between it and the earlier data was evident in 1997, when BEA recalibrated the GSP data downwards.

Dealing with these data problems was tricky. Given all the difficulties already encountered using differenced data, it seemed best to use a gap form of our equation. Doing this with unemployment data was quite straightforward, BLS annual data at both the state and national level was readily available. The difficulty was in doing this for output. Using a BK filter, it was possible to generate output gaps for a short period of time, at both the national and state level, but the information gained was minimal.

An alternate procedure was therefore used, the SIC and NAICS datasets were combined. The downsides of this are obvious, and are addressed in section three. In this case it was deemed necessary in order to generate a long enough time series, that incorporated the later (and for this test, more reliable) data. Unlike other gap tests used in this study, the HP filter was used for this test. The HP filter was used for three reasons. Firstly, since it does not lose three observations at the beginning and end of the time series it is detrending, it provides a larger number of observations, which would partially smooth over the jump in output that occurred in 1997 due to the different methodologies. Secondly, for technical reasons, HP filters are less sensitive to structural changes that may exist in a dataset[46], and since this dataset certainly has one (or two), it was deemed best to use a detrending method that was less sensitive to that kind of problem. Finally, it gave three extra years of observations at the end of the dataset, 2005-7, reliable data that the BK Filter dropped.

Two tests of Okun's coefficient were tried, both utilizing data from 1977 to 2007, detrended using the HP filter. The state data was gathered as specified above, the national trends were generated using national unemployment and GDP data from 1977 to 2007. The first method attempted to remove both the national trend, and the state trend, from our observed data, and equation that took the form of

4.3) $Y - Y^* - Y^{*N} = U - U^* - U^{*N} + e;$

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[46] Guay, Alain and Pierre St-Amant, "Do the Hodrick-Prescott and Baxter-King Filters Provide a Good Approximation of Business Cycles?" Cahiers de recherche CREFE / CREFE Working Papers **no. 53**

where Y^{*N} and Y^{*U} are the national trends.

The difficulty with this methodology is that it gave extreme results. The resulting values for Y and U, after subtracting out both the state trends (Y* and U*) and the national trends (Y^{*N} and U^{*N}), where quite small, small changes in either led to huge swings in the calculated Okun's coefficient from period to period, none of the states showed statistically significant values for Okun's coefficient using the above.

A different way of calculating this was to simply subtract the national trends from each state's observed values, as given below.

5.4) $Y - Y^{*N} = U - U^{*N} + e$

Where Y^{*N} and U^{*N} are the national trend estimates of Okun's coefficient.

This formulation substitutes the estimated national trend for the estimated state trend each year. This test was conducted twice, once using data from 1977-2008, and once using data from 1987 to 2008[47]. Results for the 1977-2008 only gave significant results for three states.

Limiting our tests to data from 1987 to 2008, significant results were obtained for 13 states. For comparative purposes, I also derived Okun's coefficient for that time period using the state data trends, as detrended using the HP filter, the results are given in the table below.

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[47] Because this test was run later then other tests, it was possible to incorporate the most recent (2008) years GSP data, released by the BEA in mid June.

Table 4.4: Gap Estimates of Okun's Coefficient using National Trend Data

	Using National Data (HP Filter) to detrend					Using State Data (HP Filter) to detrend			
	Coef	R^2	Signif			Coef	R^2	Signif	
California	1.77	0.21	0.023	**		2.34	0.742	0.005	***
Penn.	1.56	0.233	0.033	**		1.45	0.583	0.009	***
Illinois	1.57	0.333	0.082	*		1.44	0.591	0.001	***
Ohio	1.397	0.358	0.065	*		1.67	0.620	0.001	***
Michigan	1.81	0.577	.006	***		2.33	0.705	0.001	***
New Jersey	1.61	0.267	0.091	*		.903	0.633	0.036	**
North Car.	1.56	0.353	0.032	**		1.02	0.707	0.001	***
Georgia	1.46	0.142	0.058	*		1.12	0.695	0.020	**
Virginia	1.12	0.079	0.101	*		.890	0.299	0.080	*
Indiana	1.71	0.389	0.088	*		1.833	0.459	0.001	***
Missouri	1.789	0.357	0.065	*		1.32	0.652	0.001	***
Wisconsin	1.024	0.222	0.077	**		1.68	0.474	0.004	***
Tennessee	0.82	0.189	0.107	*		1.099	0.365	0.050	**

Note: *,**, *** represent the 90, 95 and 99 percent confidence intervals.

Source: Calculated by Author

The above table shows that for the 13 where good results were obtained, in all cases the state data, detrended the same way, gave a more robust estimate of Okun's coefficient. Likewise, in all cases the R^2 was higher. Finally, it should be noted that three of the four largest states, New York, Texas and Florida, did not have significant results. Given the data difficulties already mentioned, it appears doubtful that the available data will allow much further insight to be gained by this set of tests.

Chapter 5: Determination of Okun's Coefficient at the State Level – Other Variables that Impact the Relationship

While the estimates of Okun's coefficient given above are of some interest in and of themselves, Okun's coefficient is primarily of interest due to the fact that it seems to capture the link between output and unemployment. Thus, from a policy-makers standpoint, Okun's coefficient gives them a good rule of thumb for how to decrease unemployment – increase output. National policy makers can thus use all the normal macro-policy tools at their disposal, stimulative or contractionary monetary and fiscal policy in the short term, or various structural reforms (changing marginal tax rates or reforming labor markets) in the longer term.

The policy options available to state level policy makers are more constrained. Monetary policy is not an option. Many states have balanced budget constraints as part of their state constitutions, and the U.S. federal system allows (at least in theory) for effective Tiebout voting. And finally, the states are more varied in their economies than is the U.S. as a whole, policies that might be appropriate for Michigan may be very different than for Texas, Delaware, or Hawaii.

This section looks at other variables that may impact Okun's coefficient, allowing us to more closely predict what economic factors will, or will not, impact its size. The first part of this section discusses the impact of population mobility on the coefficient, including a Markov I test of the coefficient. The second part takes various other variables that give an insight into the relative supply and demand conditions of states, to see if, and how highly, they are correlated with Okun's coefficient.

Section 5.1 Population mobility, Geographic considerations, Moran I test.

As already pointed out in sections 3, the stability of Okun's coefficient is strongly correlated with a state's population, the less populous a state the less likely it is to have a statistically significant coefficient. Additionally, the coefficients that are found for the smaller states show more variance. Generally speaking, small states that are located near larger states (for example, Delaware, the only state to have a negative coefficient) seem to have a smaller value for Okun's coefficient, small states that are located far from larger states (for example, Wyoming), have a larger coefficient – in most cases though the R^2 is low, and the results are not statistically significant.

One way to test for regional differences is to use a Moran I test. Villaverde and Maza[48] did this for Spain, a country with pronounced regional differences. They found in Spain that less developed regions were clustered outside of the Madrid-Catalina industrial heartland. While the test did not give significant results, this was because of 2 (out or 21) outliers, dropping those two regions indicated that Okun's coefficient in Spain did indeed

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[48] Jose Villaverde and Adolfo Maza, "The Robustness of Okun's law in Spain," 1980 – 2004.

have a regional component. This seemed to be due to long term population shifts towards more economically robust areas.

The Moran I test is a weighted correlation coefficient that is used to see if a set of data (in this case, Okun's Coefficient) is spatially random or not[49]. It does so by comparing the variable of interest to a weighted set of values based on the spatial distance between each data point. It then compares the results to see if spatially close regions are statistically more similar than expected when compared to the null hypothesis of no autocorrelation. This test was run by comparing the distance between state capitals to the Okun's coefficient calculated for each state[50]. Only the 48 continuous states were used, given Alaska and Hawaii's extreme distances from the rest of the country.

The test was run three times, first on all 48 contiguous states, using the calculated Okun's coefficient whether it was statistically significant or not. Secondly on only those states with a statistically (at the 90% level) significant Okun's coefficient, and thirdly for the eight BLS Regions. Neither tests using all 48 states showed any regional relationship for the country as a whole. Given the way that large and small states are spread out across the U.S., this is not particularly surprising. A visual inspection of the data showed that, unlike Spain, excluding a few outlier observations would not change the results in any significant way.

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[49] A full derivation of the Moran I statistic is given in the appendixes.
[50] A more accurate test would probably have been possible using each state's largest/most economically important city as the center point, for example NYC instead of Albany for New York State. Distance data for the 48 lower state capitals was available at http://elib.zib.de/pub/Packages/mp-testdata/tsp/tsplib/tsp/att48.tsp, which I used for reasons of convenience.

The above should not be taken to indicate that interstate migration is not significant, only that a Moran I test can't find it. To be significant, low population states would need to be clustered, rather than spread out, for this test to find it. Migration patterns between say, New Hampshire and Massachusetts, are swamped both by extraneous observations, and by cases where labor (the unemployed) seem to be unwilling to move even a short distance, such as West Virginia and Virginia.

While the test at state levels seemed much to noisy to give good results, a regional test could have different results. For 30 years now, U.S. labor markets have been characterized by a long term population shift between the industrialized Northeast and Midwest, towards the southeastern and southwestern states. Freeman, in his 2001 test of regional data for the U.S., did not find any significant differences between regions, except to note that the Plains region had a significantly larger coefficient than did the other states (3.4 for the plains region vs. 1.95 to 2.35 for the other regions), due mostly to the significantly lower amplitude of unemployment changes in that region. However, he did not run any formal tests for regional disparity, and his results for four of the eight BLS regions was probably mispecified due to data problems. Therefore, I also ran a Moran I test for the eight BLS regions.

The test for the regions gave a Z statistic of -1.65, below the statistically significant value of +/- 2 that indicates significance at the 95% level. However, given the small number of observations, good results were always going to be difficult to obtain. This result was very sensitive to where the geographic center of each region was defined, the above result was when I used the capital of the largest state in the region. When instead I used the most populous city in the region (changing Sacramento to L.A., and Albany to NYC, the resulting Z statistic was -1.22. Various other ways of defining the geographic center of each region were tried; all gave negative Z statistics between -1.7 and -1.2. In all cases, they did seem to point towards a geographic component in Okun's coefficient, with the coefficient being somewhat lower in the southeast and southwest, and somewhat higher in the Midwest, the other regions showed no clear pattern. In no case however, did the tests give results that were statistically significant.

5.2. Labor supply and demand.

Values for Okun's coefficient depend primarily upon the supply and demand for labor, given that capital is relatively less flexible in the short run, though sectoral shifts in the economy are also important. The extent of labor force participation, hours worked per worker and labor productivity increases (decreases) as unemployment declines (increases) are all important. Capacity utilization rates in industries are important as well, for example an output expansion in a depressed manufacturing sector is likely to result in a larger decrease in unemployment, as furloughed and laid off workers who never left the work force return to work – as opposed to an increase in employment demand in the retail sector, which will likely attract more workers who either left the labor force, or who were never in it.

How workers, both unemployed ones and ones who left the labor force but can be induced to return, respond to economic growth will determine how much employment rises and unemployment declines for any given increase in output. The more cyclical the demand for the goods a state is producing, and the greater the number of workers in long term contracts (labor market rigidity), the more likely output fluctuations will result in changes in the unemployment rate, resulting in a lower value for Okun's coefficient[51]. Firms that can substitute capital for labor in the face of these rigidities, or ones that can take advantage of increased labor productivity, can increase output without increasing employment, again resulting in higher unemployment[52] and thus a higher measure for Okun's coefficient.

From the perspectives of workers, the expected benefit of future work needs to exceed the costs and forgone earnings of a job search. Economic expansion, ceteres parabis, results in more people entering the job market (increasing the number of unemployed) either through in-migration from other states, or from formerly discouraged workers who re-enter the job market. None-the-less, the number of employed workers is greater during expansions, the number of people who find jobs exceeds the number of new entrants.

How long workers will remain unemployed is also influenced by various government policies. Higher taxes discourage new entrants into a states labor market, and encourages people to leave. The duration of unemployment for an individual worker is correlated with a state's overall unemployment level, the longer people are unemployed the higher the states measured unemployment rate. Factors that encourage workers to remain unemployed, such as generous unemployment insurance payments, will increase the unemployment rate. Likewise factors that encourage workers to hold

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[51] As more responsive unemployment (employment) is to output fluctuations, the smaller Okun's coefficient will be.
[52] This will hold true unless there is a strong multiplier effect across industries,

out for higher benefit jobs, such as manufacturing jobs for which they have unique skills, or enhanced bargaining power, will again make labor markets more sluggish, resulting in a higher value for Okun's coefficient.

In the long run, secular growth in the supply of labor due to increased participation by existing residents, and in migration from out of state workers, will reduce the effect of output increases on the unemployment rate unless there is an even faster growth in labor demand[53]. If labor demand does not grow faster, than we would expect an increase in the magnitude of Okun's coefficient. The size of this effect depends on the how attractive new jobs are at the margin.

Tables 5.1, 5.2 and 5.3 all attempt to measure the above effects. Table 5.1 gives the definition, mean and standard deviation for three measures of demand for labor, the percentage of output in a state from manufacturing, mining, and manufacturing and mining combined.

Table 5.1 Sectoral Factors that Impact Okun's Coefficient

Variable Definition	Source	Mean and Standard Deviation	Coefficient	Coefficient x Standard Deviation
MANUFACTURING – as a percent of Gross State Product	BEA SIC data, averaged from 1977 - 1997	19.8 (6.84)	.012*	.082
MINING – as a percent	BEA SIC data,	2.4	.003	Not significant

[53] Or a significant and sustained decline in productivity, which necessitates hiring more workers to produce the same output, which seems unlikely.

of Gross State Product	averaged from 1977 - 1997	(2.22)		
MANMINE – Mining and Manufacturing as a percent of GSP	BEA SIC data, averaged from 1977 - 1997	22.2 (6.99)	.010	Not significant

The variables above for each state were regressed against our estimates for Okun's coefficient for each state in a generalized least square regression – the unknown sampling error for Okun's coefficient across states made OLS inappropriate. The tests were run on all states, the 25 most populous states, and those states with an Okun's coefficient that was significant at the 95% level, all results reported are for the last set of tests. A * represents a coefficient significant at the 90% level, ** represent coefficients significant at the 95% level. The final column gives our coefficient times the standard deviation, which tells us how much the coefficient is expected to change for a one standard deviation change in the variable.

Seeing how a one standard deviation from the norm impacted Okun's coefficient was used for two reasons. Firstly, it allowed for more direct comparisons between variables, comparing the impact of an increase in the labor force to an increase in the sales tax collected does not yield any obvious conclusions. By looking instead at the impact of a one standard deviation on Okun's coefficient, it is simpler to see what factors that vary between states impact the coefficient. In other words, it is possible to compare how much a one standard deviation increase in one variable will change Okun's coefficient in comparison to a one standard deviation increase in a different one.

MANU is associated with higher cyclical fluctuations in unemployment[54]. In the longer run, we would also expect changes in manufacturing employment to create larger multiplier effects than other sectors of the economy. Productivity gains over time would tend to reduce this, since they would cause firms to demand less labor, but our tests show this effect is overwhelmed by the first. A one standard deviation in the percentage of a states output due to manufacturing (or to put it another way, for every seven percent of a state's output that is due to manufacturing), our estimate of Okun's coefficient increases by .08. Mining did not seem to be correlated with the coefficient, but given the volatility in commodity prices, and the number of small western states that did not have significant results to begin with, this is not surprising.

Table 5.2 gives the data for a variety of labor supply variables.

Table 5.2: Demographic and Labor Supply Variables that Impact Okun's Coefficient

Variable Definition	Source	Mean and Standard Deviation	Coefficient	Coefficient x Standard Deviation
AVU – Average Unemployment Rate (1977-1997)	BLS, CPS data, downloaded from economagic	5.82 (1.14)	-.045	-.0513
LFEMALE – Women as a percent of workforce (1990)	BLS, CPS data, downloaded from economagic	45.78 (1.13)	-.050**	-.056
LYOUTH – Youth (18-24) as a percent of the	BLS, CPS data, downloaded from	21.94 (1.17)	-.098*	-.114

[54] Hyclack and Lynch 1980, Victor and Vernez 1981)

workforce (1990)	economagic			
LUNION – Percent of Workforce Unionized	A Report to Congress on Union Employment, Brookings Institute, 1986	21.3 (8.2)	.071*	.058
LGROWTH – Growth in the Labor Supply (percent of total population)	Calculated from 1990 census data and BLS CPS data	1.40 (.017)	-.601*	-.011

Since longer unemployment is often explained as being a product of hysteresis, AVU tests whether states with higher long run levels of unemployment have higher Okun's coefficients. Various labor market rigidities are often justified on the basis of leading to less variance in unemployment, even if they do increase long run unemployment (the French Model, as it is often popularly alleged). Higher unemployment (whether related to state policies or not) also seems to be self-perpetuating[55], since those who are out of the labor force for prolonged periods loose human capital over time, or become discouraged. Both of these effects would suggest a lower value for Okun's coefficient, since the long term unemployed will be less capable of rejoining the workforce during upturns. The test indeed gave a negative result, though it was not statistically significant.

LFEMALE and LYOUTH measure the percent of the labor force that is female, and that is young. Both groups are generally considered to be more likely to enter and leave the labor force as conditions change, youth because they have not formed strong

[55] It should be noted that all of the tests conducted used data from before the Welfare Reform Bill of 1996, which most likely changed the quantity and nature of long-run unemployment in significant ways.

job or career attachments, and women because a higher percentage of them are second earners. This would suggest that in states with higher percentages of either in the workforce, it will be more difficult to decrease unemployment through economic growth. In both cases, our measured value was negative, and significant, but in the case of YOUTH it was of almost twice the magnitude as FEMALE. Blackley, who also tested these two variables, found a higher value for FEMALE, and a lower one for YOUTH, and found them to give nearly identical results. This suggests that in a very short period of time, female labor force participation is trending towards a similar relationship to men, whereas young workers are becoming even more prone to job switching and/or labor force entry/exit during expansions/contractions then before.

LUNION represents the percentage of workers in labor unions. Labor unions represent significant labor market rigidity, but how they affect Okun's coefficient is less straightforward than one would suspect. Consider an insider/outsider model of unions. During downturns they reduce the number of people who become unemployed, so any given decrease in output leads to a smaller change in unemployment. As workers become outsiders, they become less likely to be hired back during an upturn, again fewer of them will be hired for any given increase in output. However, they are also more likely to remain unemployed, but still searching for work, than other workers, as they seek to regain insider status. Our tests show that unionization rates are significant, and positively related to Okun's coefficient. Two additional points should be noted regarding unionization rates – they declined significantly over the period tested, and they may be cointegrated with MANUFACTURING, since most non-public sector unions are concentrated in states with a large manufacturing base.

Our final labor force variable is LGROWTH, the growth in a state's labor force (in comparison to its population) over time. This variable captures two different effects. One is the change in a state's internal workforce compared to its total population over time, encompassing both the trend towards two income households, which increases this ratio, and the trend towards earlier and longer retirement, and delayed entry into the workforce, which decreases this ratio. The other effect it captures is population movements over time between states, as workers move towards better opportunities, and away from economically less attractive ones. Since non-workers are generally dependents or retirees, who are presumable less sensitive to job openings and closing, LGROWTH will capture at least some of the population movements between states. Our result was significant and negative, indicating that workers do indeed move about in response to changes in opportunity.

Table 5.3 considers four final variables.

Table 5.3: Government Policies that Impact Okun's Coefficient

Variable Definition	Source	Mean and Standard Deviation	Coefficient	Coefficient x Standard Deviation
UINS – Unemployment insurance (benefits times eligibility)	The Brookings Institute, 1988	.32 (.12)	.001	Not Significant

TAXIN – Income tax collected per 1000 earnings	The Tax Foundation: Survey of State Taxes and Rates (1990)	1 (.69)	.043*	.023
TAXSALES – Total state tax revenue per $1,000 earnings	The Tax Foundation: Survey of State Taxes and Rates (1990	1 (.45)	.023*	.010
GOV80 (GOV90) – Whether a states governor was a Rep. or Dem.	World Almanac, 1980, World Almanac, 1990			No relationship found

A great deal of research has been done that indicates that generous unemployment insurance and benefits change behavior on the part of the unemployed. On the one hand, during upturns the unemployed may remain unemployed longer than otherwise expected, since they will be less likely at the margin to accept a new job so long as they are collecting unemployment benefits. On the other hand, they are also more likely to remain in the labor force, to collect benefits, during a downturn, when they might otherwise leave the workforce altogether. As it is, UINS, which measured what percent of a states per capita income could be obtained by a worker receiving maximum benefits for the maximum time allowable, gave a minuscule, and statistically insignificant, result when regressed against Okun's coefficient.

While direct unemployment payments did not seem significant, tax rates were significant. Using data from the Tax Institute, two state taxes were compared to Okun's Coefficient, the State's income tax collection rate per $1,000 in income, and the state's total estimated sales tax revenue (which included non income, non estate state taxes, such as sales, property, and sin taxes) per $1,000 in income. In order make the coefficients somewhat comparable to other tests, an index of the average collections possible (using all states) was created, and then the taxes of each state were compared to it. This gave an average of 1.0, and higher and lower values depending on how much a state's taxes varied from average.

These two measures were selected because states on average derived approximately the same amount of revenue from each, but TAXIN income tax revenue was progressive, while TAXSALES is, in practice, regressive. Additionally, it is possible to avoid sales taxes (to a degree) by shopping elsewhere, but income taxes can only be avoided by actually moving.

The results for TAXIN were substantial and statistically significant, as would be expected. High income taxes discourage the able bodied in a state from entering the workforce, and also keep workers from other states from migrating in. The net result is a smaller labor force than would otherwise be the case. There is less entry into the labor force when the economy expands, and during contractions the unemployment rate rises by more than would otherwise be the case, since the labor pool is smaller.

Surprisingly, the results for TAXSALES were similar to, though of a lesser magnitude, than the results for TAXIN. No particularly good reason for TAXSALES suggests itself as to why it would decrease labor participation, or increase output, unless the larger government sector that they fund, or increased transfer payments made possible by them, were involved.

Finally, GOV80 and GOV90 used a dummy variable to see if the political party affiliation of a state's governor was related in any way to Okun's Coefficient, in neither case were any significant results found.

5.3 National and State Level Policy Implications

There is considerable evidence of heterogeneity across state labor markets, implying that local supply and demand conditions need to be taken into account . The amount of manufacturing in a state's economy was significant, more manufacturing leads to extra jobs. Governors who are lobbying for, and trying to attract, new manufacturing to their states can expect to lower unemployment while doing so, at the cost of greater cyclical volatility.

The results also indicate that economic growth by itself is not always sufficient to create a substantial decline in an area's unemployment rate, since several labor supply variables were found to have significant impacts on the magnitude of Okun's Coefficient. While our Moran I test only gave very tentative support to the hypothesis that population shifts between states are an important factor in the size of Okun's coefficient, our measures of shifts in the size of the labor force compared to the general population were significant. If workers flow from low economic activity areas to areas of higher economic growth, then again simply growing the economy may not be enough to reduce a state's unemployment rate – the new jobs may be taken by workers from other states who migrate in[56]. This issue seems to be of greater concern to the Governors of smaller

[56] This is of course, not necessarily a bad thing. But it is something that should be considered.

states, which consistently showed a less clear, and thus less predictable or usable, Okun's coefficient than larger states. Simply put, any increase output associated with a state like Delaware is likely to create as many jobs for Maryland and New Jersey as it does for Delaware.

The instate composition of workers is also important. More women or youth in the labor market are associated with a lower Okun's coefficient, they leave the labor force during a downturn rather than adding to the unemployment rolls. This effect is much more pronounced for youthful workers (who may in fact be leaving the state), and the importance of this seems to be declining among women workers over time. It may be that women are very much like men in their work patterns now[57].

Surprisingly, while unemployment insurance benefits are widely seen as prolonging bouts of unemployment, they do not seem to have any impact on Okun's coefficient. The same cannot be said about tax rates, which do have an impact. States have significantly different income tax rates, and those with higher tax rates have a more severe unemployment problem during recessions, as higher cost labor is let go. Surprisingly, this was also seen for other taxes, though the effects were less pronounced. While this implies that unemployment rate reductions during expansions will be greater, the disincentive effects of high tax burdens in these states is likely to inhibit the extent of such expansions. At least it doesn't matter who the governor is, no political party affiliations were found to be significant.

[57] Anecdotally, I have heard that the current downturn (2009) has led to a disproportionate increase in the unemployment rate for men, an effect that goes beyond the pronounced downturn in the housing sector.

The above evidence allows us to make some tentative future predictions about changes to Okun's coefficient at the national level. As manufacturing declines as a basis of the U.S. economy, we would expect Okun's coefficient to continue its slow decline, unemployment rates will become less responsive to cyclical downturns. Likewise, more women and youth in the workforce will make unemployment more responsive to changes in output, but these changes will not significantly change the unemployment rate, as these groups leave the workforce. An older American workforce, on the other hand, has the opposite implication.

There may also be a role for targeted federal programs, if unemployment persists in some spatial regions despite economic growth. If states with above average unemployment rates at some level of economic growth experience significant out-migration, than we would expect labor markets to converge over time, making targeted interventions unnecessary – or indeed counterproductive, as they would be subsidizing joblessness. This process seems to be true in smaller states, whose labor markets and output levels seem more volatile than is the case for larger states. On the other hand, the larger states are much more likely to have statistically significant Okun's coefficients, and population flows do not seem sufficient to even out the labor markets in the short term. The differences in Okun's coefficient in the larger states does seem significant, and persistent, but no large state during the 1977-1997 period jumps out as being significantly more or less competently managed than the others, unlike California[58] in 2009.

[58] It is noteworthy that California's estimated coefficient for the period 1997-2007 was over 3.0, one of the highest coefficients observed, indicating real rigidities in the labor market, or significantly weaker economic growth, than is the case for almost any other state.

Chapter 6: Long form Estimation of Okun's Coefficient

The relationship between unemployment and output which is the core of Okun's Law usually follows the form of:

6.1) $y - y^{*} = ß(u - u^{*}) + \varepsilon$,

where y and u are the observed values of output and unemployment at any given time (time subscripts are omitted for simplicity above) in logs, and y* and u* are the potential magnitudes, and ε is an error term.

Following Prachowny (1993), Gordon (1994), I now propose to test a more complex model of the production function, one that does not roll all of the change in output into the change in one measure of the labor market. Instead the relationship between output changes and unemployment changes is derived from a production function for the economy, as well as ancillary relationships in the labor market. The production function (in logs) is characterized by:

6.2) $y_t = \acute{\alpha}(k_t + c_t) + \beta(\gamma n_t + \delta h_t) + \tau_t$

y is output, and $\acute{\alpha}(k + c)$ characterizes the capital market, where k is the stock of capital and c is its utilization rate, $\acute{\alpha}$ is the output elasticity of capital. The labor market is characterized as $\beta(\gamma n + \delta h)$, where n is the number of workers and h is the number of hours they worked, γ and δ are the contribution to total labor that the number of workers and the hours they work make to output, and β is the output elasticity of labor. τ is a disembodied technology factor.

Several comments on the above can be made. γ and δ are necessary terms to ensure that firms differentiate between more workers and more hours per worker. This is relevant if there are increasing returns to scale for full time workers vs. part-time workers, or if long term overtime costs are significantly higher than the costs of hiring additional workers. If firms are indifferent to how extra labor is provided, we can set $\gamma = \delta$, and even more strongly we can set set $\gamma = \delta = 1$ if total labor input is not just an abstract unit of account, but is instead total labor hours.

This equation can be converted into a gap equation of the following form.

6.3) $y = \acute{\alpha}(k - k^* + c - c^*) + \beta(\gamma(n - n^*) + \delta(h - h^*) + \tau - \tau^*$ or

6.4) $y - y^* = \acute{\alpha}(k - k^*) + \acute{\alpha}(c - c^*) + \beta\gamma(n - n^*) + \beta\delta(h - h^*) + (\tau - \tau^*)$

where any variable with a * is the long run value of that variable, and where the time subscript t has been omitted for convenience. The above is a gap-form of Okun's law, except that instead of limiting changes in output to changes in unemployment, changes in output are now due to five factors, total capital and its rate of utilization, total labor and its rate of utilization, and technological progress.

In order to make the above more tractable for econometric testing, let l be the natural log of the supply of workers. Unemployment would thus be defined as $u = (l - n)$, i.e. unemployment is the difference between the total labor supply and the number of people actually working. The long run rate of unemployment, u*, would represent the natural, or NAIRU rate of unemployment, thus u* = (l*-n*). Thus u* represents stability in the labor market. Rearranging u = (l – n) and u* = (l*-n*) into n = (l – u) and n* = (l* – u*), and substituting them into equation 6.4, we get

6.5) $y - y^* = \acute{\alpha}(k - k^*) + \acute{\alpha}(c-c^*) + \beta\gamma((l-u)-(l^*-u^*)) + \beta\delta(h-h^*) + (\tau - \tau^*)$

or

6.6) $y - y^* = \acute{\alpha}(k - k^*) + \acute{\alpha}(c-c^*) + \beta\gamma(l - l^*) - \beta\gamma(u - u^*) + \beta\delta(h-h^*) + (\tau - \tau^*)$

The above is a more complex version of Okun's coefficient, though by placing various restrictions on the parameters we could use it to simulate Okun's coefficient quite well. To begin with assume that the stock of capital grows at a constant rate, and capital is utilized at a constant rate. If that is the case, then $\acute{\alpha}(k - k^*) + \acute{\alpha}(c-c^*)$ drops out of the equation, leaving us with only the labor market conditions and technology. If we assume that $\tau = \tau^*$, or that changes in technology will show up in the residual, then that term drops out as well, leaving us with

6.7) $y - y^* = \beta\gamma(l - l^*) - \beta\gamma(u - u^*) + \beta\delta(h-h^*)$

If we hold hours worked constant, and the size of the labor force constant, all we are left with is

6.8) $y - y^* = \beta\gamma(u - u^*)$,

which, with the addition of an error term, is Okun's original formulation of his law, and is the form it is most often measured in.

While the form of the law given in equation 6.8 is quite tractable, and has proven to empirically robust, the assumptions underlying it are somewhat suspect. Turning to capital first, it is a generally accepted fact that investment spending is highly procyclical. Only if we assume that spending is cyclical but output of capital is smooth can k = k* over the course of the cycle. On the other hand, it seems doubtful that, absent some catastrophic event, the total amount of capital ever drops[59], and given the long lead times between investing in capital and actually having new capital come online, we would expect capital to be fairly constant over the cycle[60]. Therefore, k = k* is probably a reasonable assumption.

This seems less likely to be the case concerning c, the rate of capital utilization. Capital utilization clearly varies over the course of the business cycle, and at times will decline in absolute terms, at least in certain sectors of the economy. Since many sectors of the economy do report variance in capacity utilization, estimates for the gap between c and c* are probably appropriate.

Turning to the labor supply, l, h and u all clearly vary. The total available workforce, l, varies due to such factors as immigration and emigration, demographic changes in the workforce (the number of retirees leaving the workforce vs. the number of new workers entering it), and household decisions about such matters as school vs. work,

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[59] A war might be an occasion where k actually drops. Alternatively, capital does depreciate, and therefore it is at least plausible that the absolute amount of capital in an economy could fall. Since few theories of the business cycle treat an absolute decline in capital (as opposed to labor or technology) as important, I will assume that k=k* unless otherwise noted.

[60] While capital investment is highly cyclical, it is much less clear that the stock of capital is highly cyclical. This is an intuition of mine, however, I need to review the literature on investment in more detail on this issue.

maternity leave, etc. On a national scale, this number probably does not change all that much, especially on a quarterly basis, but given how much more mobile workers are between U.S. states then they are between countries, at the state level it may be important.

Attempts to measure l will be complicated by one additional factor; the extent to which changes in the size of the workforce is responding to changes in output. If workers become discouraged and choose to leave the workforce (i.e. they stop looking for jobs they in fact still desire), l will decline and u will not change. Thus the results may be biased, depending on how one defines what does or does not constitute "voluntary" unemployment. h, the hours worked by workers, also obviously varies over the course of the cycle, it tends to be procyclical, though most of the increase occurs just after a recovery has begun.[61] Potentially, this could be one of the more interesting variables, since both it and unemployment are procyclical lagging indicators, but h lags (we would expect) less. We would also expect h to vary depending upon labor conditions within a state, as unionization rates, the size of the government sector and service sector, and rules about labor flexibility would all contribute to changes in this number[62].

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[61] Usually, as an economy comes out of a recession, hours worked (overtime, or moving part time workers to full time) increases before new workers are hired. Only after output and demand have been shown to have shifted up does new hiring commence, and unemployment decline.

[62] Several of the papers already reviewed found evidence for this. Lee (2001) found evidence in OECD countries, and Blackley (1991) found evidence in state economies, that labor laws had significant impacts upon measures of Okun's Law. How weighted that variance is towards u or h is unclear.

The final number to consider is u, the unemployment rate. In his original testing of the coefficient, Okun recognized that his test was wrapping several variables up into the unemployment rate. Specifically, he believed that

> "clearly, the simple addition of one percent of the given labor force to the ranks of the employed would increase employment by only slightly more than one percent… If the workweek and productivity were unchanged, the increment [increase] to output would be only that one plus percent. The three percent result implies that considerable output gains in a period of rising utilization rates stem from some or all of the following: induced increases in the size of the labor force; longer average weekly hours; and greater productivity.[63]

Since in his original test all of the results were attributed to u, we would expect that any tests conducted where any of the following; $(k - k^*) \neq 0$, $(c - c^*) \neq 0$, $(h - h^*) \neq 0$, $(l - l^*) \neq 0$ are true; would give a lower value of Okun's coefficient, since at least some of the effect will now be captured by these variables.

If we refer back to equation 6.6,

$$6.6)\quad y - y^* = \acute{\alpha}(k - k^*) + \acute{\alpha}(c - c^*) + \beta\gamma(l - l^*) - \beta\gamma(u - u^*) + \beta\delta(h - h^*) + (\tau - \tau^*)$$

we can now see that $\beta\gamma$ in $\beta\gamma(u - u^*)$ is the link between output and unemployment. If we were to assume that goods are produced with a production function that exhibited

[63] Okun, A. 1970 pp 140.

constant returns to scale, then βγ should be approximately equal to labor's share of total production. That would put its value in the range of 0.6-0.7, meaning that a one percent change in output should be accompanied by a 0.6 change in unemployment, rather than the 2.2 percent that current estimates of Okun's coefficient state, the remainder of the change would be some sort of weighting of the other factors. In order to test for the above, we need an econometric form of equation 6.6, (reproduced below)

$$6.6)\quad y - y^* = \acute{\alpha}(k - k^*) + \acute{\alpha}(c-c^*) + \beta\gamma(l - l^*) + \beta\gamma(u - u^*) + \beta\delta(h-h^*) + (\tau - \tau^*)$$

That form is given below in equation 9,

$$6.9)\quad (y - y^*) = \beta_1(k - k^*) + \beta_2(c - c^*) + \beta_3(l - l^*) - \beta_4(u - u^*) + \beta_5(h - h^*) + \varepsilon_t$$

where subscripts for t have all been omitted, again for simplicity.

The above form allows us to characterize Okun's Coefficient with five estimates, all of which have intuitive economic meaning. It also allows for various restrictions to be placed on the tests, to test for significance. It is likely that several of the gap variables calculated above will be non-stationary, so an alternate formulation would be to first difference the above into

$$6.10)\quad \Delta(y - y^*) = \beta_1\Delta(k - k^*) + \beta_2\Delta(c - c^*) + \beta_3\Delta(l - l^*) - \beta_4\Delta(u - u^*) + \beta_5\Delta(h - h^*) + \varepsilon_t$$

which will be the long form of calculating Okun's coefficient.

6.1 Data considerations for the long form estimate of Okun's coefficient.

The main difficulty with all of the previous is how to estimate it. Taking the variables in order, output is readily available, the SIC reports total output for each state, and I can simply use the data was used for previous tests in this paper. Rather than transform it using the Baxter-King or HP filters, I instead simply created the gap variable, and then took its natural log. I followed this procedure for all other variables as well. I address each of the other variables in order.

Capital was measured as each state's total manufacturing and mining output, divided by the states total output[64]. In effect, this means I am assuming that all output in the Manufacturing and Mining sector comes from capital, and output from all other sectors of the economy is due to labor. Obviously this is a huge simplification, and any results obtained will need to bear this in mind. On the other hand, since I am testing against multiple states, this assumption does allow for comparisons. Some states are clearly more industrialized than others, and this assumption allows comparisons between them.

Capital Utilization data does not exist at the state level, so far as I could find. The Federal Reserve does however measure and report this for mining and manufacturing at the national level. One possibility would be to use a weighted value of this (based on manufacturing), but this would simply be re-measuring capital in a different form. If instead we assume that capital stock never declines, than our measure for capital really is

[64] In his tests, Prachowney used Mining, Manufacturing and Utilities. He did so because he was calculating capacity utilization for these three based on Citibank forecasting data. I only used Mining and Manufacturing, because I had capacity utilization rates for them ready made by the Federal Reserve, even though I ended up dropping the variable Capital Utilization.

a measure of capacity, since any short run variation in capital has to be due to changes in utilization. As such, I omitted capital utilization from my long form equation.

Total labor supply was the one variable that Prachowny found to never be significant at the national level. This is not surprising, since the total labor force probably does not vary that much in the course of a normal downturn. However, because he was using national data, any movements in labor from one state to another would be captured in his estimate, since workers who left one state would appear in some other one. Since I am explicitly modeling states, some estimate of this variable is necessary. Fortunately, this data can easily be obtained at the state level, BLS calculates it from the CPS, and all the results are readily available on Economagic. This gap is calculated as the natural log of the Civilian Labor Force less the mean value for this variable, the same estimation method used by Prachowny in his national test.

Hours worked was calculated by Prachowny based on reported average hours worked per week. Until recently, this data was not available at the state level. BLS did not begin systematically collecting this data for all states until after the 2000 census (some earlier data does seem to be available for some states), which would allow this variable to be used with the 1997-2008 NAICS data, but it is not available for the 1977-1997 SIC data I am using. Prachowny did find this variable significant, but data unavailability forced me to omit it.

6.10) $\Delta(y - y^*) = ß_1\Delta(k - k^*) + ß_2\Delta(c - c^*) + ß_3\Delta(l - l^*) - ß_4\Delta(u - u^*) + ß_5\Delta(h - h^*) + \varepsilon_t$

Thus reduces to

$$6.11)\quad \Delta(y - y^*) = ß_1\Delta(k - k^*) + ß_3\Delta(l - l^*) - ß_4\Delta(u - u^*) + \varepsilon_t$$

Table 6.1 gives the results of this estimation for the ten largest states, including the estimate for just $\Delta(y - y^*) = ß_4\Delta(u - u^*) + \varepsilon_t$

Table 6.1: Long Form estímates of Okun's Coefficient for Ten States

	ß1 (Capital)	ß3 (Labor Force)	ß4 (Unemployment)	Overall R^2	Base form Estimate (R^2)
California	.71	.012	1.13*	.562	1.54 (.678)*
New York	.32*	-.03	1.01*	.670	1.129(.668)*
Texas	.11	.13	2.22*	.253	3.57 (.363)*
Florida	.48	-.3*	.980*	.580	1.117 (.692)*
Penn.	.31*	.001	.880*	.567	1.028 (.476)*
Illinois	.41*	-.001	1.32*	.621	1.508 (.591)*
Ohio	.45*	-.14*	1.11*	.630	1.578 (.620)*
Michigan	1.1	-.18*	.870*	.655	1.920 (.705)*
New Jersey	.43	-.03	1.04*	.508	1.050 (.633)*
N. Carolina	-.02	.02	1.34*	.566	1.587 (.707)*

All coefficients give the effect of a one percent difference between the long run trend and the observed variable. $ß_4$ (Unemployment) and $ß_1$ (Capital) are weighted towards their total share of the economy, where any change in manufacturing is assumed to be due to capital changes, and any changes in other sectors of the economy are assumed to be due to changes in labor, the weights assigned were the average of those values over the entire 21 years. Any result that was significant at the 90% or greater level was indicated with a *. The last column gives the results of our original test, where we are only using the unemployment rate (as reported earlier, in table 3.2, or appendix 1), and are included for comparative purposes, all of those results were significant. It should be noted that some of the R^2s reported for the longer form of the estimate are actually lower than for just the test on unemployment, this is due to the fact that unemployment is weighted towards labor's estimated share of output, it is not precisely the same variable as was used in our original test.

The results of this test were fairly disappointing. While capital generally had a higher value than its share of the economy, in only four cases were the results significant at the 90% level. Prachowny's national tests of this variable, using the same methodology, found the national value to be about 1.2, and his results were much more robust. In three large industrialized states, Pennsylvania, Illinois and Ohio, the resulting overall R^2 I obtained was higher than was the case in the original test, all three of these states had significant results for capital. In the other seven cases overall R^2 was lower, the new estimates were less predictive than the older one. The additional variables only added noise to the estimate, they did not improve it.

The results for changes in the size of the labor force were also disappointing. Prachowny never found this to be significant, in three of the ten states tested I found significance at the 90% level. But for other states, the sign of the coefficient changed, and for most states it was of no explanatory value at all. That the coefficient was of different signs for different states implies that labor migration at times can overwhelm local entry and exit into the labor market, but the results were not robust enough to say this with any degree of certainty.

All ten states still had a significant relationship between unemployment and output. Unemployment was less important (as would be expected), but it never approached the .67 value that Prachowny found. Much of the appeal of this test was the idea that an extended form of the coefficient would give results where declines in overall output matched that factors total share of the economy, approximately .33 for capital and .67 for labor. The results above do not approach that, and seem to add very little explanatory power to our simpler tests.

Two explanations for this suggest themselves. One is that the data limitations at the state level make this sort of test impossible. 21 observations, conducted at yearly intervals, is a fairly small dataset, especially when the methodology of gathering the data changed somewhat midway through the period. And our values for capital and labor require some fairly large assumptions, that may not be justified.

Another explanation though, is that Okun's coefficient in its present form does a remarkably good job of capturing disparate effects. There is little question but that many macro-economic variables vary in tandem. Almost certainly, the five variables that I attempted to use for this test, capital and its rate of utilization, the size of the labor force, hours worked per worker, and the unemployment rate, all move in the same direction. It is doubtful that they all increase and decrease by the same amount, at precisely the same rate, during each and every business cycle. But they are all responding (at the time) to the same business cycle. Okun's coefficient seems to do a very good job of capturing that the underlying dynamics that is pushing the whole system.

Chapter 7: Conclusions

Arthur Okun's insights into the relationship between the demand for labor and the supply of output, what is now known as Okun's Coefficient (or Okun's Law), are as important as the Phillups curve is, in understanding the aggregate supply function of the economy. Economists, policymakers, and many reasonably informed laymen are all aware of the fact that output changes lead to changes in employment, even if they can't always describe the coefficient, or process, itself. Rather than attempting to generate yet another parameter test of Okun's coefficient using U.S. quarterly data, this paper attempts to advance the state of knowledge in two ways, by testing Okun's coefficient on a previously neglected state data set, and by looking at variables other than output and unemployment to see if they may be predictive as well.

Using U.S. state data from 1977 to 1997, (and to a limited extent, 1997 to 2007), this paper found that Okun's coefficient does indeed exist at the state level. A majority of U.S. state economies were found to have the relationship, but in almost all cases the relationship was found to be smaller than the estimate for the nation as a whole, a majority of states had coefficients between 1.3 and 1.7, compared to national estimates that are usually around 2.3. That Okun's coefficient is lower at the state level than the national is in line with most other current sub-national studies, including ones for Greece, Canada and Spain, but it contradicts earlier U.S. state studies.

Using pooled data, significant evidence was found to support the recent view that Okun's coefficient is asymmetric. Unemployment seems to go up more (or more quickly) during downturns than it goes down during recoveries. Furthermore, evidence was found to suggest that the state tests were being driven in large part by downturns, in the sense that the more negative years of growth a state had, the more likely it was to have significant results and thus be included in the pooled data. States that had fewer years of negative growth were more likely to be omitted, since they often did not have significant Okun's coefficients to begin with. The finding that the coefficient was smaller, and more significant during downturns mirrors recent work on the coefficient at national levels, both for Europe and the U.S.

Furthermore, several measureable variables seem to impact the size of the coefficient at the state level. A state's population and the make-up of the population, are important, young and female workers are both more likely to leave or enter/re-enter the workforce due to changing labor demand. A large manufacturing sector leads to a higher coefficient, as do some government policies; differing tax rates most importantly. While the coefficients are difficult to quantitatively interpret, and given that population flows between states are confusing the issue, none-the-less looking at how differences between states impacts the coefficient gives insights into how the coefficient will change over time in the U.S.

A formal test of a geographic component to Okun's coefficient provided very little evidence that there is one. Some evidence that the long run trend of population shifting from the Northeast and Midwest towards the South and Southwest was impacting the coefficient was found, but nothing that was statistically significant could be determined. Other tests found more evidence that interstate movements of labor were important, but while these results were significant, they were again difficult to quantify.

Finally, an extended form of the coefficient was tested, one that attempted to directly include variables that most production functions of the economy would include, such as capital, utilization rates, population and hours worked, as well as total output and unemployment. While these tests generally did not give very good results, they did point towards interstate migration as an important factor in some states – to an extent at least state labor markets are integrated.

By necessity, this study was somewhat constrained by the limited extent of historic data sources at the state level. The U.S. data set used, the BEA's Gross State Product Series, 1977-1997 (based on the SIC), is no longer being updated by the BEA, it has been replaced by the NAICS data set, which give a much more accurate and useful picture of state output. As time goes forward, I would hope that this new dataset allows for new and more useful estimates than my study was able to.

Appendix 1: Differencing Tests of Okun's Coefficient (SIC, Alphabetical)

Differencing Tests of Okun's coefficient, Differencing Method (1970 – 1986) and SIC (1976-1997); alphabetical by State. Note the column labeled Blackley is taken from his work.

State	Blackley (70-86)		1976 to 1997			
	Okun's Coef	R^2	Okun's Cooef	R^2	Signif	
Alabama	2.137	0.69	0.49	0.04	0.35	
Alaska			4.082	0.071	0.241	
Arizona			1.46	0.27	0.27	
Arkansas			0.836	0.02	0.45	
California	2.353	0.75	1.77	0.24	0.023	**
Colorado			0.888	0.047	0.34	
Connecticut	3.04	0.56	1.85	0.26	0.018	**
DC			0.467	0.015		
Delaware			0.809	0.081	0.21	
Florida	3.623	0.42	1.55	0.143	0.09	*
Georgia	3.425	0.72	1.46	0.142	0.092	*
Hawaii			3.72	0.45	0.001	***
Idaho			2.03	0.138	0.096	*
Illinois	2.611	0.77	1.27	0.333	0.002	***
Indiana	3.205	0.76	1.71	0.389	0.002	***
Iowa			1.071	0.037	0.4	
Kansas			0.98	0.046	0.347	
Kentucky	2.626	0.73	1.28	0.202	0.041	**
Louisiana	6.803	0.29	0.944	0.021	0.528	
Maine			1.96	0.302	0.01	***
Maryland	3.333	0.67	1.89	0.233	0.027	**
Massachusetts	3.012	0.53	0.944	0.021	0.528	
Michigan	2.933	0.8	1.81	0.549	0	***
Minnesota	3.984	0.56	1.97	0.275	0.015	**
Mississippi			0.841	115	0.132	
Missouri	3.185	0.65	1.789	0.357	0.004	***
Montana			0.061	0.001	0.975	
Nebraska			2.49	0.164	0.068	*
Nevada			1.94	0.299	0.01	***
New Hampshire			2.16	0.297	0.011	***

New Jersey	2.899	0.6	1.61	0.267	0.016	**
New Mexico			0.875	0.016	0.577	
New York	3.322	0.42	1.61	0.263	0.017	**
North Carolina	2.307	0.73	1.56	0.353	0.004	***
North Dakota			3.47	0.042	0.369	
Ohio	2.404	0.9	1.397	0.358	0.004	***
Oklahoma	2.793	0.47	1.742	0.071	0.241	
Oregon			1.61	0.241	0.024	**
Pennsylvania	2.457	0.7	1	0.233	0.026	**
Rhode Island			1.264	0.206	0.039	**
South Carolina	2.294	0.8	1.531	0.313	0.008	***
South Dakota			4.13	0.162	0.07	*
Tennessee	2.915	0.7	0.82	0.089	0.187	
Texas	2.994	0.71	2.332	0.127	0.113	*
Utah			0.784	0.038	0.396	
Vermont			1.8	0.177	0.057	**
Virginia	3.436	0.56	1.12	0.079	0.215	
Washington	3.164	0.65	0.755	0.056	0.301	
West Virginia			0.417	0.055	0.304	
Wisconsin	2.358	0.78	1.024		0.027	**
Wyoming			2.31	0.056	0.299	

Appendix 2: Differencing Tests of Okun’s Coefficient (SIC, by Population)

Differencing Tests of Okun’s coefficient, Blackley (1970 – 86) and SIC (1976-97): Population (1990)

State	Population	Blackley (70-86)		1976 to 1997			
		Okun's Coef	R2	Okun's Cooef	R2	Signif	
California	29,760,021	2.353	0.75	1.77	0.24	0.023	**
New York	17,990,455	3.322	0.42	1.61	0.263	0.017	**
Texas	16,986,510	2.994	0.71	2.332	0.127	0.113	*
Florida	12,937,926	3.623	0.42	1.55	0.143	0.09	*
Pennsylvania	11,881,643	2.457	0.7	1	0.233	0.026	**
Illinois	11,430,602	2.611	0.77	1.27	0.333	0.002	***
Ohio	10,847,115	2.404	0.9	1.397	0.358	0.004	***
Michigan	9,295,297	2.933	0.8	1.81	0.549	0	***
New Jersey	7,730,188	2.899	0.6	1.61	0.267	0.016	**
North Carolina	6,628,637	2.307	0.73	1.56	0.353	0.004	***
Georgia	6,478,216	3.425	0.72	1.46	0.142	0.092	*
Virginia	6,187,358	3.436	0.56	1.12	0.079	0.215	
Massachusetts	6,016,425	3.012	0.53	0.944	0.021	0.528	
Indiana	5,544,159	3.205	0.76	1.71	0.389	0.002	***
Missouri	5,117,073	3.185	0.65	1.789	0.357	0.004	***
Wisconsin	4,891,769	2.358	0.78	1.024		0.027	**
Tennessee	4,877,185	2.915	0.7	0.82	0.089	0.187	
Washington	4,866,692	3.164	0.65	0.755	0.056	0.301	
Maryland	4,781,468	3.333	0.67	1.89	0.233	0.027	**
Minnesota	4,375,099	3.984	0.56	1.97	0.275	0.015	**
Louisiana	4,219,973	6.803	0.29	0.944	0.021	0.528	
Alabama	4,040,587	2.137	0.69	0.49	0.04	0.35	
Kentucky	3,685,296	2.626	0.73	1.28	0.202	0.041	**
Arizona	3,665,228			1.46	0.27	0.27	
South Carolina	3,486,703	2.294	0.8	1.531	0.313	0.008	***
Colorado	3,294,394			0.888	0.047	0.34	
Connecticut	3,287,116	3.04	0.56	1.85	0.26	0.018	**
Oklahoma	3,145,585	2.793	0.47	1.742	0.071	0.241	
Oregon	2,842,321			1.61	0.241	0.024	**
Iowa	2,776,755			1.071	0.037	0.4	
Mississippi	2,573,216			0.841	115	0.132	
Kansas	2,477,574			0.98	0.046	0.347	
Arkansas	2,350,725			0.836	0.02	0.45	

West Virginia	1,793,477	0.417	0.055	0.304	
Utah	1,722,850	0.784	0.038	0.396	
Nebraska	1,578,385	2.49	0.164	0.068	*
New Mexico	1,515,069	0.875	0.016	0.577	
Maine	1,227,928	1.96	0.302	0.01	***
Nevada	1,201,833	1.94	0.299	0.01	***
New Hampshire	1,109,252	2.16	0.297	0.011	***
Hawaii	1,108,229	3.72	0.45	0.001	***
Idaho	1,006,749	2.03	0.138	0.096	*
Rhode Island	1,003,464	1.264	0.206	0.039	**
Montana	799,065	0.061	0.001	0.975	
South Dakota	696,004	4.13	0.162	0.07	*
Delaware	666,168	0.809	0.081	0.21	
North Dakota	638,800	3.47	0.042	0.369	
DC	606,900	0.467	0.015		
Vermont	562,758	1.8	0.177	0.057	**
Alaska	550,043	4.082	0.071	0.241	
Wyoming	453,588	2.31	0.056	0.299	

Appendix 3: Differencing Tests of Okun's coefficient (NAIS)

Differencing Tests of Okun's coefficient, SIC 1976-86, SIC 1986-97, NAIS 1997-2007

	1976 to 1986				1987 to 1997				1997-2007			
	Cooef	R2	Signif		Cooef	R2	Signif		Cooef	R2	Signif	
California	1.455	0.38	0.053	**	1.67	0.35	0.055	*	3.21	0.69	0.003	***
New York	1.091	0.276	0.118		1.15	0.282	0.092	*	2.16	0.579	0.011	***
Texas	3.9	0.315	0.091	*	2.082	0.171	0.206		2.603	0.656	0.004	***
Florida	1.38	0.249	0.142		0.705	0.104	0.333		2.36	0.597	0.009	***
Pennsylvania	1.12	0.391	0.053	**	0.742	0.159	0.224		0.629	0.222	0.169	
Illinois	1.52	0.561	0.013	**	1.42	0.395	0.297		1.18	0.639	0.006	***
Ohio	1.71	0.645	0.005	***	0.832	0.138	0.26		0.295	0.014	0.74	
Michigan	1.931	0.789	0.001	***	1.85	0.35	0.055	*	1.064	0.129	0.308	
New Jersey	1.17	0.355	0.04	**	0.935	0.133	0.27		0.604	0.247	0.143	
North Carolina	1.74	0.707	0.002	***	1.14	0.249	0.118		1.32	0.3	0.101	*
Georgia	2.073	0.616	0.007	***	-0.124	0.003	0.871		2.34	0.303	0.099	*
Virginia	1.16	0.346	0.073	*	1.141	0.2	0.168		1.456	0.295	0.295	
Massachusetts	2.634	0.075	0.441		2.065	0.287	0.089	*	0.87	0.05	0.531	
Indiana	1.9	0.518	0.019	**	1.19	0.119	0.297		1.19	0.129	0.307	
Missouri	1.84	0.572	0.011	**	2.6	0.488	0.017	**	-0.071	0.004	0.848	
Wisconsin	1.227	0.389	0.054	**	1.251	0.354	0.054	**	1.085	0.494	0.023	**
Tennessee	1.046	0.222	0.169		1.32	0.154	0.231		0.44	0.026	0.651	
Washington	0.848	0.086	0.409		1.1	0.149	0.241		2.11	0.325	0.085	*
Maryland	1.383	0.424	0.041	**	1.81	0.243	0.123		-0.652	0.064	0.48	
Minnesota	2.15	0.452	0.033	**	2.25	0.27	0.101	*	0.901	0.09	0.4	
Louisiana	2.634	0.075	0.441		2.065	0.287	0.089	*	0.87	0.05	0.531	
Alabama	0.9	0.23	0.15		1.1	0.13	0.26					
Kentucky	2	0.405	0.048	**	1.01	0.226	0.139		-0.243	0.004	0.851	
Arizona	1.71	0.714	0.003	***	-0.65	0.04	0.53		1.98	0.24	0.14	
South Carolina	1.571	0.535	0.016	**	1.6	0.523	0.012	**	0.247	0.043	0.565	
Colorado	1.75	0.203	0.191		0.335	0.01	0.75		2.031	0.41	0.046	**
Connecticut	0.751	0.22	0.17		1.53	0.18	0.183		1.87	0.544	0.015	**
Oklahoma	3.14	0.226	0.164		-0.586	0.016	0.71		1.845	0.291	0.108	*
Oregon	2.42	0.48	0.026	**	-0.197	0.005	0.833		2.41	0.392	0.052	**
Iowa	1.268	0.046	0.527		1.454	0.063	0.453		-1.248	0.053	0.534	
Mississippi	1.85	0.44	0.036	**	2.83	0.118	0.3		1.074	0.307	0.096	*
Kansas	1.46	0.128	0.309		0.85	0.042	0.544		1.47	0.436	0.038	**

Arkansas	2.22	0.17	-1.6		-0.24	0.06	0.81		0.987	0.05	0.499	
West Virginia	0.658	0.127	0.312		0.414	0.085	0.383		0.3	0.004	0.863	
Utah	1.053	0.089	0.4		1.33	0.061	0.461		1.256	0.259	0.132	
Nebraska	3.66	0.331	0.082	*	1.05	0.026	0.635		1.25	0.084	0.427	
New Mexico	1.68	0.06	0.494		-0.123	0.004	0.955		0.512	0.004	0.861	
Maine	0.943	0.392	0.053	**	2.24	0.424	0.03	**	1.17	0.155	0.259	
Nevada	1.814	0.288	0.109	*	2.49	0.518	0.012	**	5.27	0.552	0.014	**
New Hampshire	1.6	0.461	0.031	**	1.72	0.28	0.094	*	1.83	0.194	0.202	
Hawaii	2.35	0.529	0.017	**	3.52	0.31	0.075	*	1.22	0.03	0.63	
Idaho	2.38	0.136	0.294		2.02	0.177	0.197		4.9	0.475	0.027	**
Rhode Island	0.728	0.228	0.162		1.014	0.138	0.188		-1.043	0.033	0.612	
Montana	1.1	0.0003	0.755		0.1	0.003	0.962		1.46	0.03	0.629	
South Dakota	6.55	0.402	0.049	**	-7.01	0.287	0.089	*	-0.24	0.009	0.936	
Delaware	0.266	0.032	0.621		1.12	0.128	0.28		-0.253	0.008	0.803	
North Dakota	9.53	0.212	0.18		-1.47	0.01	0.765		-0.427	0.002	0.897	
DC	0.428	0.022			-0.504	0.019			-0.024	0		
Vermont	1.084	0.098	0.377		1.93	0.214	0.152		0.689	0.166	0.242	
Alaska	9.18	0.2	0.194		3.301	0.164	0.216		-4.64	0.146	0.275	
Wyoming	4.97	0.208	0.184		0.748	0.016	0.697		3.01	0.092	0.394	

Appendix 4: Gap Estimates of Okun's Coefficient

Gap Estimation of Okun's coefficient, SIC 1976-1997, HP Filter and BK Filter: by State Population

		Baxter king filter………..				HP filter			
State	Population	Coef	r2	conf		Coef	r2	conf	
California	29,760,021	1.19	0.429	0.006	***	1.46	0.481	0.003	***
New York	17,990,455	0.90	0.261	0.043	**	1.33	0.415	0.007	***
Texas	16,986,510	2.12	0.232	0.058	*	1.64	0.065	0.335	
Florida	12,937,926	0.98	0.342	0.017	**	0.96	0.375	0.012	**
Pennsylvania	11,881,643	1.01	0.552	0.001	***	0.78	0.558	0.001	***
Illinois	11,430,602	1.49	0.704	0.000	***	1.13	0.706	0.000	***
Ohio	10,847,115	1.61	0.690	0.000	***	1.03	0.583	0.001	***
Michigan	9,295,297	2.03	0.805	0.000	***	1.53	0.701	0.000	***
New Jersey	7,730,188	1.22	0.368	0.013	**	1.53	0.435	0.005	***
North Carolina	6,628,637	1.54	0.664	0.000	***	1.49	0.771	0.000	***
Georgia	6,478,216	1.32	0.229	0.060	*	2.09	0.288	0.032	**
Virginia	6,187,358	1.06	0.334	0.019	**	1.78	0.410	0.007	***
Massachusetts	6,016,425	1.37	0.528	0.001	***	1.78	0.504	0.002	***
Indiana	5,544,159	2.13	0.642	0.000	***	1.01	0.356	0.015	**
Missouri	5,117,073	1.81	0.672	0.000	***	1.62	0.645	0.000	***
Wisconsin	4,891,769	1.31	0.666	0.000	***	0.64	0.245	0.051	*
Tennessee	4,877,185	1.19	0.360	0.014	**	0.77	0.278	0.036	**
Washington	4,866,692	0.52	0.124	0.180		0.22	0.014	0.653	
Maryland	4,781,468	1.57	0.481	0.003	***	2.27	0.531	0.001	***
Minnesota	4,375,099	2.59	0.705	0.000	***	1.77	0.575	0.001	***
Louisiana	4,219,973	2.39	0.213	0.071	*	0.70	0.017	0.626	
Alabama	4,040,587	0.96	0.496	0.002	***	0.61	0.446	0.005	***
Kentucky	3,685,296	1.87	0.578	0.001	***	0.79	0.185	0.092	*
Arizona	3,665,228	1.22	0.396	0.009	***	1.57	0.327	0.021	**
South Carolina	3,486,703	1.42	0.694	0.000	***	1.38	0.817	0.000	***
Colorado	3,294,394	0.82	0.194	0.088	*	0.36	0.006	0.760	
Connecticut	3,287,116	1.00	0.170	0.112		1.84	0.356	0.015	**
Oklahoma	3,145,585	1.90	0.152	0.135		0.20	0.001	0.908	
Oregon	2,842,321	1.90	0.428	0.006	***	1.14	0.189	0.092	*
Iowa	2,776,755	1.49	0.075	0.302		0.51	0.018	0.618	
Mississippi	2,573,216	1.17	0.473	0.003	***	0.39	0.054	0.383	
Kansas	2,477,574	1.43	0.327	0.021	**	0.09	0.001	0.889	
Arkansas	2,350,725	1.43	0.186	0.095	*	0.45	0.024	0.566	

West Virginia	1,793,477	0.78	0.323	0.021	**	-0.01	0.000	0.976	
Utah	1,722,850	1.62	0.279	0.035	**	-0.67	0.031	0.514	
Nebraska	1,578,385	2.80	0.295	0.030	**	0.64	0.026	0.548	
New Mexico	1,515,069	0.85	0.028	0.586		-2.16	0.059	0.365	
Maine	1,227,928	1.90	0.583	0.001	***	2.40	0.557	0.001	***
Nevada	1,201,833	1.20	0.268	0.040	**	0.95	0.099	0.236	
New Hampshire	1,109,252	1.63	0.368	0.013	**	2.43	0.626	0.000	***
Hawaii	1,108,229	1.56	0.157	0.129		2.86	0.302	0.027	**
Idaho	1,006,749	0.69	0.239	0.054	*	0.08	0.002	0.954	
Rhode Island	1,003,464	1.08	0.407	0.008	***	1.24	0.508	0.002	***
Montana	799,065	0.50	0.008	0.728		-2.18	0.100	0.231	
South Dakota	696,004	5.77	0.488	0.003	***	2.07	0.072	0.317	
Delaware	666,168	-0.40	0.019	0.604		0.48	0.056	0.377	
North Dakota	638,800	3.21	0.056	0.374		-4.64	0.073	0.313	
DC	606,900	0.29	0.055	0.402		0.43	0.082	0.281	
Vermont	562,758	1.51	0.382	0.011	***	1.38	0.214	0.071	*
Alaska	550,043	5.84	0.176	0.105	*	3.10	0.038	0.465	
Wyoming	453,588	3.09	0.197	0.085	*	2.12	0.052	0.398	

Appendix 5: Selected Statistics

State	1976 to 2007 Av. Un. Rate	st. dev	Min	Max	1976 to 1997 Average Growth Rate	st. dev	Min	Max	1997 to 2006 Average Growth Rate	st. dev	Min	Max
Alabama	6.48	2.44	3.49	13.18	6.8%	2.9%	3.4%	14.9%	2.6%	1.6%	0.1%	5.1%
Alaska	8.04	1.48	6.13	11.03	6.9%	14.9%	-	43.1%	0.9%	4.9%	-	8.8%
Arizona	5.95	1.56	3.84	9.98	9.6%	4.2%	2.7%	19.0%	5.7%	2.6%	2.1%	8.8%
Arkansas	6.42	1.53	4.20	9.75	6.8%	3.4%	2.6%	16.2%	2.7%	2.0%	-	6.0%
California	6.97	1.50	4.89	10.03	8.0%	3.6%	2.0%	14.9%	4.4%	2.9%	-	7.9%
Colorado	5.27	1.29	2.74	7.75	8.6%	3.7%	1.5%	16.6%	4.3%	3.0%	0.4%	7.8%
Connecticut	5.02	1.48	2.26	9.12	7.7%	3.3%	1.5%	13.4%	2.3%	2.3%	-	4.7%
Delaware	4.98	1.72	2.92	8.13	8.2%	2.9%	3.3%	12.1%	2.8%	1.9%	-	5.2%
D.C.	7.48	1.45	5.07	11.00	6.1%	2.6%	0.2%	10.0%	3.2%	2.0%	0.6%	5.9%
Florida	5.98	1.51	3.38	9.25	9.0%	3.5%	4.5%	16.7%	4.6%	1.8%	2.6%	7.8%
Georgia	5.47	1.12	3.48	8.08	9.0%	2.7%	4.8%	15.6%	3.4%	2.3%	0.4%	6.3%
Hawaii	4.64	1.58	2.38	9.27	6.8%	4.1%	0.7%	13.9%	1.9%	2.4%	-	5.0%
Idaho	5.80	1.45	3.03	9.00	7.5%	3.9%	-0.3%	18.3%	5.4%	3.6%	0.7%	10.1%
Illinois	6.69	1.80	4.45	11.68	6.3%	2.4%	2.3%	11.9%	2.0%	1.2%	0.2%	3.5%
Indiana	5.82	2.20	2.87	11.92	6.3%	3.2%	-0.5%	14.0%	2.4%	2.1%	-	4.7%
Iowa	4.69	1.56	2.63	8.32	5.6%	4.0%	-3.0%	14.6%	2.2%	1.7%	-	4.4%
Kansas	4.56	0.76	3.12	6.50	6.5%	3.2%	2.0%	15.8%	2.5%	1.2%	1.3%	4.4%
Kentucky	6.63	1.78	4.25	11.27	6.4%	2.8%	2.5%	13.2%	1.4%	2.1%	-	3.0%
Louisiana	7.24	2.35	3.83	12.48	5.9%	7.7%	-	22.8%	0.6%	3.0%	-	4.5%
Maine	5.68	1.48	3.29	8.48	7.1%	3.4%	0.6%	13.1%	2.2%	1.5%	0.0%	4.7%
Maryland	5.08	1.22	3.52	8.24	7.5%	3.1%	2.3%	12.8%	3.6%	0.6%	2.8%	4.7%
Massachusetts	5.47	1.79	2.75	9.83	7.9%	3.5%	0.5%	14.4%	3.6%	2.9%	-	7.7%
Michigan	7.92	2.87	3.72	15.54	5.9%	3.6%	-1.3%	12.8%	1.0%	2.1%	-	3.1%
Minnesota	4.81	1.23	2.74	8.06	7.4%	3.1%	3.1%	15.4%	3.2%	1.6%	0.7%	5.0%
Mississippi	7.72	2.01	5.25	12.62	6.5%	3.1%	2.5%	12.8%	1.6%	1.6%	-	3.6%
Missouri	5.70	1.42	3.15	9.83	6.6%	3.0%	2.1%	14.4%	1.7%	0.7%	0.6%	2.6%
Montana	5.75	1.35	3.28	8.54	5.6%	4.3%	-0.3%	17.8%	3.0%	1.5%	1.4%	5.4%
Nebraska	3.45	0.92	2.32	5.71	6.4%	3.8%	1.2%	14.7%	2.0%	1.5%	0.6%	5.5%
Nevada	5.98	1.53	4.27	9.94	10.6%	3.7%	4.5%	21.5%	5.2%	2.4%	1.9%	8.2%
New	4.31	1.46	2.28	7.58	9.2%	4.5%	-0.9%	17.9%	4.2%	2.6%	0.2%	8.0%
New Jersey	6.04	1.72	3.67	10.47	7.7%	3.1%	3.4%	13.0%	2.5%	0.8%	0.8%	3.2%
New Mexico	6.79	1.53	3.51	9.49	7.6%	5.8%	-4.0%	19.1%	3.5%	2.9%	0.4%	8.2%
New York	6.49	1.51	4.28	10.20	6.8%	2.8%	0.5%	11.8%	3.3%	2.1%	-	5.5%

N. Carolina	5.37	1.43	3.26	9.51	8.4%	2.9%	3.8%	14.5%	3.2%	1.7%	1.5%	6.4%
North Dakota	4.10	0.96	2.78	5.99	5.9%	8.3%	-8.7%	30.4%	2.6%	2.6%	-	5.8%
Ohio	6.63	2.08	4.03	12.65	6.0%	2.8%	1.0%	13.1%	1.5%	1.6%	-	3.5%
Oklahoma	5.23	1.47	3.11	8.62	6.2%	6.6%	-8.3%	20.9%	2.5%	0.7%	1.2%	3.3%
Oregon	6.97	1.75	4.91	11.60	7.6%	3.4%	-0.5%	16.1%	4.6%	3.6%	-	9.6%
Pennsylvania	6.42	1.87	4.17	11.63	6.3%	2.2%	2.6%	11.6%	2.2%	0.7%	1.4%	3.7%
Rhode Island	5.96	1.68	3.02	9.38	7.3%	3.5%	0.6%	13.4%	3.0%	1.7%	1.5%	6.3%
S. Carolina	6.08	1.50	3.57	10.71	7.8%	3.3%	3.4%	15.5%	2.3%	1.2%	0.7%	3.7%
South Dakota	3.71	0.74	2.68	5.48	6.9%	4.1%	0.6%	17.0%	4.1%	2.3%	1.1%	8.4%
Tennessee	6.33	1.87	4.00	11.69	7.6%	2.9%	2.9%	14.2%	2.8%	1.6%	0.7%	5.3%
Texas	6.06	1.20	4.36	8.94	8.0%	5.6%	-5.1%	20.8%	3.8%	1.7%	1.4%	6.2%
Utah	4.95	1.45	2.69	8.83	8.6%	3.5%	1.5%	16.2%	3.5%	1.8%	1.1%	5.8%
Vermont	4.76	1.42	2.70	8.50	7.7%	4.1%	0.0%	18.3%	3.9%	1.0%	2.0%	4.9%
Virginia	4.51	1.17	2.29	7.36	8.1%	2.8%	3.9%	13.5%	4.2%	1.7%	0.6%	5.8%
Washington	6.88	1.78	4.54	11.83	8.2%	3.1%	3.4%	16.8%	3.1%	3.3%	-	8.4%
West Virginia	8.44	3.31	4.27	17.44	4.8%	3.0%	-1.8%	10.9%	1.5%	1.6%	-	3.3%
Wisconsin	5.29	1.74	3.07	10.27	6.5%	2.2%	3.1%	11.9%	2.5%	1.0%	1.0%	4.2%
Wyoming	4.95	1.60	2.58	8.88	5.9%	9.9%	-	29.5%	3.3%	1.7%	0.6%	5.6%

Appendix 6: BEA and BLS Data, and Calculated Okun's Coefficients

BLS and BEA regional definitions for the Unites States, and Estimates of Okun's Coefficient for Annual Data for U.S. Regions, 1977-1997, using the Baxter-King filter

BLS Div	STATES	STATES	BEA Div.
New England	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont	New England
Middle Atlantic	New Jersey, New York, Pennsylvania	**Delaware, Washington D.C., Maryland**, New Jersey, New York, Pennsylvania;	Middle East (states)
South Atlantic	**Delaware**, **District of Columbia,** Florida, Georgia, **Maryland**, North Carolina, South Carolina, Virginia, West Virginia	Alabama, **Arkansas**, Florida, Georgia, Kentucky, **Louisiana**, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, West Virginia,	South East
East South Central	Alabama, Kentucky, Mississippi, Tennessee		
West South Central	**Arkansas, Louisiana**, Oklahoma, Texas	**Arizona, New Mexico**, Oklahoma, Texas	South West
East North Central	Illinois, Indiana, Michigan, Ohio, Wisconsin	Illinois, Indiana, Michigan, Ohio, Wisconsin	Great Lakes
West North Central	Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota	Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota	Plains
Mountain	**Arizona**, Colorado, Idaho, Montana, **Nevada**, **New Mexico**, Utah, Wyoming	Colorado, Idaho, Montana, Utah, Wyoming	Rocky Mountain
Pacific	Alaska, California, Hawaii, Oregon, Washington	Alaska, California, Hawaii, Oregon, Washington, **Nevada**	Far West

Source: BEA and BLS

Appendix 7: Yearly tests of Okun's Coefficient

Differencing Tests of Okun's Coefficient, by Year

	Ten Largest States				All States				25 Largest			
Year	Coeff	R2	Signif		Coeff	R2	Signif		Coeff	R2	Signif	
1978	0.71	0.034	0.609		-2.78	0.169	0.003	***	0.2	0.006	0.71	
1979	1.72	0.262	0.13		1.4	0.079	0.045	**	1.56	0.282	0.006	***
1980	1.86	0.672	0.004	***	2.53	0.206	0.001	***	2.36	0.469	0	***
1981	-1.36	0.0168	0.721		0.416	0.003	0.703		0.318	0.004	0.765	
1982	0.92	0.056	0.51		-1.2	0.0232	0.268		0.553	0.014	0.567	
1983	5.88	0.74	0.001	***	3.1	0.414	0.001	***	3.23	0.497	0	***
1984	-0.2	0.002	0.892		0.138	0.001	0.827		0.275	0.004	0.744	
1985	-0.54	0.075	0.443		0.582	0.0242	0.275		0.205	0.005	0.72	
1986	3.3	0.888	0.001	***	4.9	0.384	0.001	***	3.75	0.567	0	***
1987	-1.18	0.031	0.627		1.12	0.0041	0.657		1.42	0.029	0.413	
1988	5.93	0.501	0.022	**	1.69	0.0291	0.231		3.15	0.334	0.002	***
1989	2.04	0.288	0.109	*	2.09	0.1266	0.01	***	0.537	0.055	0.257	
1990	2.18	0.256	0.135		1.99	0.395	0.001	***	1.85	0.463	0	***
1991	0.017	0	0.991		-0.069	0.001	0.933		0.788	0.033	0.381	
1992	1.4	0.4152	0.044	**	-0.106	0.0004	0.89		0.25	0.004	0.744	
1993	0.187	0.004	0.856		-0.42	0.005	0.613		0.183	0.001	0.878	
1994	4.61	0.628	0.006	***	0.845	0.023	0.287		1.07	0.045	0.304	
1995	-2.42	0.061	0.493		1.12	0.013	0.358		0.306	0.002	0.813	
1996	2.3	0.103	0.364		-1.54	0.041	0.152		1.16	0.046	0.303	
1997	0.596	0.019	0.704		1.8	0.033	0.199		0.155	0.001	0.838	
1998												
1999												
2000	3.56	0.56	0.013	**	0.043	0	0.962		0.898	0.016	0.539	
2001	-1.14	0.048	0.542		0.634	0.009	0.493		0.935	0.019	0.51	
2002	3.83	0.0858	0.412		0.194	0.001	0.85		1.13	0.0293	0.413	
2003	1.96	0.168	0.239		1.035	0.018	0.339		1.13	0.025	0.445	
2004	2.33	0.263	0.129	*	1.44	0.0513	0.11		1.02	0.075	0.199	
2005	0.79	0.019	0.697		0.029	0	0.969		0.005	0.001	0.995	
2006	0.883	0.0347	0.607		-0.269	0.003	0.686		0.825	0.095	0.144	
2007	0.76	0.031	0.626		-0.257	0.0014	0.793		0.004	0.001	0.997	

2008

Gap Equation Tests (using the BK Filter to detrend data) of Okun's Coefficient, by Year

	Ten largest states				25 largest states				All States			
Year	Coeff	R2	Signif		Coeff	R2	Signif		Coeff	R2	Signif	
1979	0.716	1.5	0.002	***	1.04	0.271	0.008	***	1.12	0.081	0.043	**
1980	0.177	2.34	0.33		1.19	0.031	0.393		3.04	0.132	0.009	***
1981	0.658	2.9	0.004	***	2.31	0.433	0.001	***	3.25	0.475	0.001	***
1982	0.252	0.848	0.139		0.323	0.02	0.497		0.504	0.056	0.087	*
1983	0.596	1.73	0.009	***	0.295	0.017	0.533		0.394	0.017	0.349	
1984	0.551	5.04	0.014	**	-0.06	0.001	0.959		0.987	0.014	0.393	
1985	0.545	1.73	0.015	**	2.28	0.454	0.001	***	3.25	0.287	0.001	***
1986	0.91	3.81	0	***	3.36	0.638	0.001	***	2.42	0.338	0.001	***
1987	0.566	3.65	0.012	**	1.38	0.247	0.011	**	2.76	0.261	0.001	***
1988	0.176	1.33	0.227		1.59	0.197	0.026		2.97	0.373	0.001	***
1989	0.668	5.44	0.004	***	2.66	0.43	0.001	***	2.16	0.16	0.004	***
1990	0.503	2.16	0.022	**	0.767	0.079	0.172		0.911	0.119	0.013	**
1991	0.002	-0.137	0.895		0.457	0.016	0.538		0.54	0.03	0.224	
1992	0.084	0.551	0.414		0.336	0.008	0.667		0.434	0.012	0.482	
1993	0.368	3.58	0.063		1.61	0.164	0.044	**	1.18	0.139	..093	*

Appendix 8: Regional Tests of Okun's Coefficient

Region	Okun's Coeff.	Significance
New England	2.52	.003
Mideast	1.95	.005
Great Lakes	2.71	.002
Plains	2.23	.004
Southeast	1.87	.006
Southwest	1.54	.008
Rocky Mountain	2.08	.010
Far West	1.98	.006

Appendix 9: Data Variables Used

Data Descriptions

Variable	Description
YEAR	Year
STATE	U.S. State, District of Columbia
REGION	BEA Region
U	Unemployment Rate
HPU1	Unemployment Data, 1977-1997, de-trended with HP Filter
HPU2	Unemployment Data, 1997-2007, de-trended with HP Filter
BKU1	Unemployment Data, 1977-1997, de-trended with BK Filter
BKU2	Unemployment Data, 1997-2007, de-trended with BK Filter
Y1	Gross State Product, 1977-1997
Y2	Gross State Product, 1997-2007
HPY1	Gross State Product, 1977-1997, de-trended with HP Filter
HPY2	Gross State Product, 1997-2007, de-trended with HP Filter
BKY1	Gross State Product, 1977-1997, de-trended with BK Filter
BKY2	Gross State Product, 1997-2007, de-trended with BK Filter
MANU	Percent of output from Manufacturing
MINING	Percent of output from Mining
MANMINE	Percent of output from Manufacturing and Mining
AVU	Average Unemployment
LFEMALE	Percent of Labor force made up of women

LYOUTH	Percent of Labor force made up of Youth
LUNION	Percent of Labor force that is Unionized
LGROWTH	Percent Growth of the Labor Force
UNINS	Unemployment benefits, compared to an index of 100
TAXIN	Income tax collected per $1,000 of income
TAXSALES	Sales taxes collected per $1,000 of income
GOV80	State Governors Party affiliation, 1980
GOV90	State Governors Party affiliation, 1990
ATT48	Distance Between State Capitals (from TSP Module)
ATT8	Distance Between Regional Economic Centers

Appendix 10: The Moran I Statistic

Moran's I is a measure of spatial autocorrelation used to see if observations show correlation across distance rather than time. Spatial autocorrelation is about proximity in (two-dimensional) space.

Moran's I is defined as

$$I = \frac{N}{\sum_i \sum_j w_{ij}} \frac{\sum_i \sum_j w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_i (x_i - \bar{x})^2}$$

where N is the number of spatial units indexed by i and j; X is the variable of interest; $\bar{X}$ is the mean of X; and w_{ij} is a matrix of spatial weights.

The expected value of Moran's I is

$$E(I) = \frac{-1}{N-1}$$

With a variance of

$$Var(I) = \frac{NS_4 - S_3 S_5}{(N-1)(N-2)(N-3)(\sum_i \sum_j w_{ij})^2}$$

Where

$$S_1 = \frac{1}{2} \sum_i \sum_j (w_{ij} + w_{ji})^2$$

$$S_2 = \frac{\sum_i (\sum_j w_{ij} + \sum_j w_{ji})^2}{1}$$

$$S_3 = \frac{N^{-1} \sum_i (x_i - \bar{x})^4}{(N^{-1} \sum_i (x_i - \bar{x})^2)^2}$$

$$S_4 = \frac{(N^{-2} - 3N + 3)S_1 - NS_2 + 3(\sum_i \sum_j w_{ij})^2}{1}$$

$$S_5 = S_1 - 2NS_1 = \frac{6(\sum_i \sum_j w_{ij})^2}{1}$$

Negative (positive) values indicate negative (positive) spatial autocorrelation. Values range from −1 (indicating perfect dispersion) to +1 (perfect correlation). A zero values indicates a random spatial pattern. Moran's I values can be transformed to Z-scores in which values less than or greater than 2 indicate spatial autocorrelation that is significant at the 5% level.

Stata has two downloadable functions, spatwmat and spatgsa, which can be used to generate a Z statistic for Moran I testing. The commands require a matrix of distances, a 48 by 48 matrix of distances between state capitals was downloaded from the University of Texas, deleting out the necessary columns/rows gave an 8 by 8 matrix of the largest state capitals for the eight BEA regions.

Appendix 11: The Hodrick-Prescott Filter

The Hodrick-Prescott cyclical component v_j^{HP} is defined as the difference between the original signal u_j and a smooth growth component g_j. The latter is the solution of the optimization problem

$$\min_{\{g_j\}} \sum_{j=0}^{N-1} [(u_j - g_j)^2 + \lambda(g_{j+1} - 2g_j + g_{j-1})^2$$

which minimizes the sum of the norm of the cyclical component $\|v_j^{HP}\| = \|u_j - g_j\|$ and the weighted norm of the rate of the growth component $\|(1-L)(1-L^{-1})g_j\|$, where L is the lag operator $Lx_j \equiv x_{j-1}$.

The smoothing parameter λ penalizes variations in the growth rate with respect to the differences between filtered and unfiltered series and is usually set to 6.25 for annual data. For large values of λ, the growth component g_j tends to the OLS line calculated from the data.

The solution for $N \to \infty$ can be found explicitly in the frequency domain and leads to the following expression for the frequency response function

$$H^{HP}(v) = \frac{4\lambda(1-\cos(2\pi v \Delta t))^2}{1+4\lambda(1-\cos(2\pi v \Delta t))^2}$$

$$= \frac{16\lambda \sin^4(\pi v \Delta t)}{1+16\lambda \sin^4(\pi v \Delta t)}$$

where $G(v)$ is the Fourier transform of the series growth component g_j .

The HP filter is in fact a highpass filter, the frequency response rising monotonically from zero at $v = 0$ to nearly one at the highest frequency. The transition is rather smooth and occurs at a cutoff frequency — defined as the frequency for which the response is equal to 0.5 — given by

$$v_c = (\pi \Delta t)^{-1} \arcsin(\frac{\pi^{-1/4}}{2})$$

Hence the HP filter, in the configuration suggested for annual data, selects periodicities shorter than approximately 10 years. The frequency response goes as $\lambda(2\pi v \Delta t)^4$ at low frequencies; hence it behaves as a fourth-difference filter, up to an $I(4)$ process can be rendered stationary

Two practical methods of calculating the HP filter were available. One way was to use a downloadable module for STATA, created by Christopher F. Baum at Boston College, available from http://ideas.repec.org/c/boc/bocode/s447001.html.

A second method, and the one ultimately adopted, was an Excel add-on developed by Kurt Annen and available at http://www.web-reg.de/index.html. This was the utility actually used to implement the HP filter, because it more easily allowed an excel record of the variable to be saved with the other data files, and important consideration when running the same test 59 (50 states, D.C., 8 regions) times.

Appendix 12: The Baxter-King Filter

The Baxter and King filter relies on the use of a symmetric finite odd-order $M = 2K + 1$ moving average so that

$$v_j = \sum_{n=-K}^{K} h_n u_{j-n}$$

$$= h_o u_j + \sum_{n=1}^{K} h_n (u_{j-n} + u_{j+n})$$

The set of M coefficients $\{h_j^{BK}\}$ is obtained by truncating the ideal filter coefficients at M under the constraint of the correct amplitude at $v = 0$, that is, $H(0) = 0$ for bandpass and highpass filters and $H(0) = 1$ for lowpass filters. The BK filter coefficients thus have to solve the following optimization problem:

$$\min_{\{h_n^{BK}\}_{n=-K,\ldots\ldots,K}} \int_{-(2\Delta t)^{-1}}^{(2\Delta t)^{-1}} dv \left| \sum_{n=-K}^{K} (h_n^{BK} - h_n^{ideal}) e^{-i2\pi n v \Delta t} \right|^2$$

Subject to

$$\sum_{n=-K}^{K} h_n^{BK} = \frac{H(0)}{\Delta t}$$

The solution of the constrained problem simply shifts all ideal coefficients by the same constant quantity

$$h_n^{BK} = h_j^{ideal} + \frac{H(0) - \Delta t \sum_{n=-K}^{K} h_n^{ideal}}{M \Delta t}$$

As a practical matter, three parameters need to be selected for the filter, the phi and pho, representing the short and long term trends, and K, which is the number of observations on either end of the data set used to create the average. Standard practice for annual data is a phi and pho of 2 and 8, and a K of 3, these were the values I used.

As with the HP filter, two practical methods of calculating the BK filter were available. One way was to use a downloadable module for STATA, created by Christopher F. Baum at Boston College, available from http://ideas.repec.org/c/boc/bocode/s447001.html.

A second method, and the one ultimately adopted, was an Excel add-on developed by Kurt Annen and available at http://www.web-reg.de/index.html. This was the utility actually used to implement the BK filter, because it more easily allowed an excel record of the variable to be saved with the other data files.

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CURRICULUM VITAE

Brian P. Kennedy was born and raised in and around New York City, before moving out to Wyoming in the early 1980s. In 1988, he graduated from the University of Wyoming with a Bachelors of Science in International Relations (Russian Studies), with minors in History and Economics. He was then employed for eight years at the Unites States Agency for International Development, before leaving the Agency in 1997. After helping to open two Thai restaurants in the D.C. area, he moved to Bangkok. Since 2004, he has been a lecturer at Thammasat University, in Thailand, teaching both in the Economics and Liberal Arts Departments.