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(Abstract)

Lucas (1987, 2003) calculates the potential welfare gains to stabilization of business cycles to be surprisingly small. Welfare gain is measured by a compensation parameter which makes a household indifferent between a deterministic lifetime stream and a compensated, risky lifetime stream of consumption. Using a constant relative risk aversion utility function and a coefficient of risk aversion of one, Lucas calculates that the welfare gain in real per capita consumption is in the order of one-twentieth of 1 percent. This is equivalent to an increase of about $18.33 in real per capita consumption per year for 1947 – 2001, stated in 2016 dollars.

The main focus of this paper is to examine the welfare cost of business cycles for the 50 states using the same preference function as Lucas (1987, 2003). To our knowledge, this is the first paper that examines the welfare cost of business cycles at the state level. Our results support the findings of Lucas (1987, 2003) and Otrok (2001) that further welfare gain from stabilization of business cycles are very small, ranging from one-eighth of 1 percent for Wyoming to one-forty-fifth of 1 percent for Iowa. Further results from additional analysis also suggest that welfare cost of business cycles varies considerably across regions of the country.

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I. Introduction

In a provocation essay in 1987 and again in 2003, Robert Lucas, using a general quantitative public finance framework, calculates that the potential welfare gain from further improvements in short-run stabilization policy to be surprisingly small. Welfare gain is measured as the potential percentage gain in consumption per capita when all consumption variability around the trend is eliminated. Lucas calculates this percentage to be in the order of one-twentieth of one percent using U.S. real per capita consumption data spanning 1947 – 2001. This is equivalent to between $18.32 and $36.64 increase in real per capita consumption per year in 2016 dollars, depending on the consumer's risk aversion. Yellen and Akerlof (2006) point out that this may be because if rational consumers are smoothing their consumption following the lift-cycle hypothesis, then short-run stabilization policy might not result in much additional consumption smoothing.

Not surprisingly, Lucas's finding has generated an extensive follow-up literature. Both Lucas (2003) and Otrok (2001) provide a good review and summary of this follow-up research. Since Lucas's result is dependent on the assumed preference function and the exogenous process generating consumption, much of the subsequent research has focused on replacing Lucas's constant-relative-risk-aversion (CRRA) preference function and the process generating consumption, with other functional forms and consumption processes commonly used in the macroeconomic literature. For example, Dolmas (1998), using alternative specifications of individuals' risk preferences and alternative stochastic processes of per capita consumption that are found in the equity premium puzzle literature, concludes that the cost of business cycles is between 0.1% and 23% of real annual per capita consumption. Yellen and Akerlof (2006), on the other hand, question key assumptions underlying Lucas's conclusion. They focus on his implicit assumption that the Phillips curve is linear in unemployment, and secondly on what Lucas considers to be plausible values for the rate of relative risk aversion, effectively allowing only near linear welfare loss functions. They provide evidence to refute these implicit assumptions, and conclude that stabilization policy can produce gain in welfare that is non-negligible.

But, Otrok (2001), using a time-non-separable preference function in a real business cycle model, obtains the welfare cost of business cycles close to Lucas's estimate. Krusell and Smith[1] (1999) examine the welfare cost of stabilization policy in a dynamic general equilibrium model with heterogeneous agents. Agents differ in wealth,

[1] Lucas (2003) provides a rather thorough discussion of this paper.

preferences, and employment prospects. They find that the welfare gain from stabilization policy, about 0.1% of average consumption, although higher than Lucas's calculation, is nevertheless extremely small for almost all consumers, and even negative for some during transitions to steady state. They find two exceptions, however. Very poor unemployed consumers facing borrowing constraint[2] and very wealthy consumers[3] can benefit substantially from stabilization policy, up to 2% gain in average consumption.

However, after addressing many of the criticisms of his original finding, Lucas (2003) concludes that this original finding is rather robust. Yellen and Akerlof (2006), their criticism of Lucas's result not withstanding, also state that "Lucas's argument rests on assumptions concerning the determinants of social welfare and the characteristics of the Phillips curve that are broadly endorsed by professional macroeconomists and incorporated in most macroeconomics textbooks. Given the strong grounding of Lucas's conclusion in standard theory, our objective has been to reconsider the economic logic of stabilization policy." (Yellen and Akerlof, 2006, p. 19). Thus, Yellen and Akerlof (2006) are more critical of Lucas's policy recommendation based on his result than of Lucas's modeling framework. Otrok (2001) is also critical of research which uses alternative preference functions and consumption generating processes, arguing that this line of research imposes little discipline on the choices of the preference functions. Thus, it is possible to make the welfare cost of business cycles arbitrarily large by choosing an appropriate form of the preference function. Otrok (2001) argues that it is necessary to impose the discipline that the preference function should be able to replicate the observed consumption process and other aggregate variables in a model of business cycles.

This paper has three objectives. First, we update Lucas's result to 2016. This period includes the Great Recession with increased variability and uncertainty of real GDP. Thus, it is interesting to examine whether or not the Great Recession may have affected the welfare cost of business cycles. Second, we are aware of no other paper that examines the welfare cost of business cycles at the state level. Several researchers, for example, Ahking (2016) finds that state business cycles can differ considerably from the national business cycles, Owyang, Rapach, and Wall (2009) find there is considerable heterogeneities in state business cycles, and Carlino and DeFina (2004) find different business cycle co-movement in employment across states and regions. Yet, we know very little about

[2] Poor consumers are those close to zero consumption level according to Krusell and Smith (1999).
[3] Krusell and Smith (1999) conjecture that wealthy consumers benefit from stabilization policy because interest income is a large part of their total income and thus benefit from the elimination of interest rate fluctuations.

whether or not welfare cost of business cycles at the state level also differs considerably from that at the national level, and also from each other. This is an especially interesting question since states have no ability to engage in counter-cyclical monetary policy, and forty-nine states, except Vermont, have balanced budget requirements,[4] which potentially could aggravate state business cycles. Moreover, states are also subjected to region-specific and state-specific shocks, and also sectoral shocks, in addition to national shocks. Finally, policy stimulus at the national level may cause state economies that are not in recession to overheat, and a lack of stimulus at the national level may deepen the downturn in states that are in recession. In other words, given the very limited ability of state governments to engage in stabilization policy at the state level, and given that state business cycles are not always of the same frequency, duration, timing, and magnitude as the national cycles, what is the potential welfare gain to the states from national stabilization policy? Third, since we do expect the welfare cost of business cycles to differ across states, we explore some possible factors which could explain this variation.

In this paper, we take Otrok's (2001, p. 88) position that it is doubtful "… that empirically plausible modifications to preferences alone could lead to large costs of consumption volatility." Furthermore, for reasons discussed above, we use Lucas's CRRA preference function and consumption process to examine the welfare cost of business cycles at the state level. We do not specify a complete real business cycle (RBC) model[5] because different models can result in different welfare cost estimates, and to model and calibrate models for 50 states is impractical and beyond the scope of this paper. We want to focus on investigating how and why welfare gain varies across states. We provide a brief sketch of the theory and model in Section II. Our calculation and discussion of the welfare cost for the 50 states are in Section III. Section IV presents regression results on the possible determinants of welfare gain across states, and finally, Section V contains our summary and conclusions.

II. Theory and model

In a simple quantitative public finance framework, the objective is to calculate the welfare gain from alternative policies. We assume that in each state there is a representative consumer whose welfare is $U(c_t^A)$, where $U(\bullet)$ denotes instantaneous utility, and c_t^A represents consumption stream at time *t* under policy *A*.[6] Similarly, the

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[4] This is obtained from a report from the National Conference of State Legislatures, 2010.
[5] This is the same approach used by Dolmas (1998), Pallage and Robe (2003), and Houssa (2013).
[6] There are 50 representative agents, one in each state. Each representative agent has different risk aversion and faces different income shocks.

representative consumer's welfare under policy *B* is $U(c_t^B)$. Suppose further that the representative consumer prefers c_t^B, so that

$$U(c_t^A) < U(c_t^B).$$

To be able to quantify the welfare gain in moving from policy *A* to *B*, Lucas (2003) calculates $\lambda > 0$ such that

$$U((1+\lambda)c_t^A) = U(c_t^B). \tag{1}$$

The parameter λ is also called the compensation parameter, and is measured in units of percentage of consumption goods. This parameter is the quantitative measure of the welfare gain in moving from policy *A* to *B*, or equivalently, the welfare cost of not moving from policy *A* to *B*. Alternatively, equation (1) can also be interpreted as showing the compensation, in units of percentage of consumption goods, given by the parameter λ, that would make the representative consumer indifferent between c_t^A and c_t^B, since the welfare under either policy would be the same.

To implement this calculation, an infinite-lived, risk-averse, representative consumer is assumed to maximize an expected discounted lifetime utility:

$$E\sum_{t=0}^{\infty}\beta^t U(c_t), \tag{2}$$

where $0 < \beta = \dfrac{1}{1+\rho} < 1$ is the discount factor, and ρ is a subjective discount rate. Further assume that the instantaneous utility is of the constant relative risk aversion (CRRA) form, i.e., $U(c_t) = \dfrac{c_t^{1-\gamma}}{1-\gamma}$, equation (2) becomes

$$E\sum_{t=0}^{\infty}\beta^t \frac{c_t^{1-\gamma}}{1-\gamma}, \tag{3}$$

and γ is the coefficient of risk aversion, which measures a consumer's degree of relative risk aversion. Finally, assume that the representative consumer faces a stochastic consumption stream:

$$c_t = Ae^{\mu t}e^{-(1/2)\sigma^2}\varepsilon_t, \tag{4}$$

where μ is the long-term consumption growth rate, and $\ln\varepsilon_t$ is distributed as $N(0,\sigma^2)$. Given these assumptions, Lucas (2003), and DeJong and Dave (2011) show that

$$E(e^{-(1/2)\sigma^2}\varepsilon_t) = 1, \text{ i.e., } E\varepsilon_t = e^{(1/2)\sigma^2}, \tag{5}$$

therefore,

$$E(c_t) = Ae^{\mu t} . \tag{6}$$

Suppose policy *B* is a policy that is capable of eliminating all consumption variability around the long-term consumption growth path, the risk-averse representative consumer would prefer this policy which produces a deterministic consumption growth path over an alternative policy which produces a stochastic consumption growth path but with the same mean. The improvement in welfare from the preferred policy is found by calculating λ such that equation (1) is true. Or, given our model,

$$E\sum_{t=0}^{\infty}\beta^t \frac{\left[(1+\lambda)c_t\right]^{1-\gamma}}{1-\gamma} = \sum_{t=0}^{\infty}\beta^t \frac{(Ae^{\mu t})^{1-\gamma}}{1-\gamma} . \tag{7}$$

Substituting equations (4) and (5) into equation (7), taking natural logs, canceling terms, and approximating $\ln(1+\lambda) \approx \lambda$, Lucas (2003), and DeJong and Dave (2011) show that

$$\lambda = \frac{1}{2}\sigma^2\gamma . \tag{8}$$

Equation (8) shows that the calculation of welfare gain depends positively on only two parameters: σ^2 and γ . In addition to γ , the parameter σ^2 is the variance of the deviation of per capita consumption from its growth path, and thus is a measure of the uncertainly of the consumption stream. In sum, the greater the degree of risk aversion, and/or the greater the uncertainty of the consumption stream, the greater is the potential for welfare gain. In the next section, we show our calculation of λ for each of the 50 states and the U.S.

III. Calibration and calculation

Equation (8) shows that quantitatively, welfare gain depends on only two parameters, σ^2 , and γ . The parameter, σ^2 , measures consumption variability around the long-run trend. This is estimated as the residual variance of a regression of ln c_t on a constant and a linear trend. For c_t, we use the annual real per capita personal consumption expenditures (per capita RPCE) from 1997 to 2016 for the U.S. and the 50 states.[7] Unfortunately, per capita personal consumption expenditures for the 50 states are available only in current dollars. We deflate the 50

[7] Appendix A lists the data sources and the construction of the variables used in this paper. Note that state GDP data are incompatible pre- and post-1997 because of a change in the calculation methodology.

states per capita personal consumption expenditures using a constructed implicit personal consumption expenditures deflator for the 50 states to obtain the per capita RPCE for the 50 states.[8]

Although σ^2 can be estimated from the data, γ is an unknown parameter, i.e., it is not calibrated from the data, and welfare gain can be made arbitrarily large by the appropriate choice of γ . However, it can be shown that with a CRRA utility function, the optimal consumption path over time is[9]

$$\mu = \frac{1}{\gamma}(r - \rho), \tag{9}$$

where *r* is the after-tax rate of return on physical capital. Given that $\rho \geq 0$, μ can be calculated from the data, and *r* averages about 0.05 estimated from postwar U.S. data as suggested by Lucas (2003), the upper bound value for γ , i.e., $\rho = 0,$ can be calculated using equation (9).[10]

We'll start the discussion of our results with Table 1 which compares our result for the U.S. with Lucas's (2003) result. Lucas (2003) estimates his σ^2 with data from 1947 to 2001. As mentioned earlier, our data period is annual, 1997 – 2016, which includes the Great Recession which starts in the fourth quarter of 2007 and ends in the second quarter of 2009.[11] We obtain σ^2 = 0.001042, which is remarkably close to Lucas's σ^2 = 0.001024. For γ = 1, which is used by Lucas, we obtain λ = 0.000521, or the equivalent of $18.65 extra per capita RPCE per year in 2016 dollars. This is almost identical to Lucas's original estimate of λ = 0.000512, or the equivalent of $18.33 extra in 2016 dollars of per capita RPCE per year! Thus, the welfare gain parameter for the U.S. has remained remarkably stable for a long period of time. What is even more remarkable is that our estimate of σ^2 is obtained from the sample period which includes the Great Recession, which does not appear to have affected the potential welfare gain from stabilization policy. Using an upper bound of γ = 2.2[12] for Lucas's result, we obtain λ = 0.001126, or $40.33

[8] The construction of this personal consumption expenditures deflator for the 50 states is discussed in Appendix A. Alternatively, we have also constructed the per capita RPCE expenditures for the 50 states by deflating the nominal per capita personal consumption expenditures for the 50 states with the U.S. implicit personal consumption expenditures deflator. This assumes that all the states have the same implicit personal consumption expenditures deflator as the U.S. which is not true, of course. States such as California, Hawaii, and New York have higher costs of living than the U.S. However, the results from using the two versions of the per capita RPEC for the 50 states are almost identical, and thus we do not report the results using per capita RPCE constructed with using the U.S. implicit personal consumption expenditures deflator.

[9] This is demonstrated in Appendix C.

[10] Lucas (2003) also appeals to this equation to argue why the value of γ is generally low, between 1 and 4.

[11] Business cycle dates are NBER's business cycle reference dates.

[12] This is suggested by DeJong and Dave (2011).

extra in per capita RPCE per year in 2016 dollars. We calculate our corresponding upper bound of γ to be 2.99 using equation (9), and λ = 0.001558, or the equivalent of an extra $55.78 RPCE per capita per year in 2016 dollars. Thus, the upper bound for γ turns out to be relatively low in both cases, and the corresponding potential welfare gain, as expected is larger than when γ = 1, is nevertheless rather small. Finally, Table 1 also includes result from DeJong and Dave (2011) which updates Lucas's result with data through 2009. Their result again confirms what we have found, that Lucas's result is remarkably robust even when the sample period includes the Great Recession. DeJong and Dave (2011) obtain an estimate of λ = 0.000448 with γ = 1, which is slightly smaller that Lucas's and our estimates, and λ = 0.000987 when the implied upper bound of γ = 2.2 is used.

Table 2 reports our estimates of σ^2 for the 50 states.[13] There is clearly great variability among the states. Iowa has the lowest σ^2, while Wyoming has the highest σ^2, which is about five times that of Iowa's σ^2. Table 3 shows our calculation of welfare gain for each state, and the associated gain per capita RPCE per year in 2016 dollars, using γ =1, which is frequently used as a benchmark. Note that when γ =1, $U(c_t) = \ln(c_t)$, and λ is simply $\frac{1}{2}\sigma^2$.

At the state level, the value of the potential welfare gain appears to be uniformly relatively small. Wyoming has the most to gain with a λ = 0.001257, or about one-eighth of one percent, and 2.41 times that of the U.S.'s λ. This is equivalent to about an additional $45.76 per capita of RPCE per year in 2016 dollars for Wyoming. On the other end, Iowa has the least to gain with a λ = 0.000251, or about one-fortieth of one percent, and 0.48 times that of the U.S.'s λ. This is equivalent to $8.37 additional RPCE per capita per year in 2016 dollars for Iowa. Finally, 26 states have larger λs, while 22 states have lower λs, than the U.S.'s λ. Two states have about the same λs as the U.S.'s λ. In summary, while there is considerable variation among the states in the λ values, for example, Wyoming's λ value is about five times that of Iowa's λ value, the potential welfare gain is nevertheless uniformly small among all the states.

Table 4 reports the results of our welfare gain calculations for the states, and the associated gain in per capita RPCE per year in 2016 dollars, using the upper bound value of γ implied by equation (9). Since there is no data on *r* for the states, the same *r* = 0.05 is used for all states. Nevada, in this instance, has the most to gain with an implied upper bound of γ = 4.01, and λ = 0.004263, or an additional $139.23 in RPCE per capita per year in 2016 dollars.

[13] The result for the U.S. is also included in Tables 2 – 4 for comparison purpose.

North Dakota has the least to gain with an implied upper bound of γ = 1.73, and λ= 0.000446, or an additional $19.40 in RPCE per capita per year in 2016 dollars.

In summary, the potential gain at the state level from further improvements in short-term stabilization policy at the national level appear to be very small. This result is consistent with what Lucas has found at the national level. The potential welfare gain varies from a low of $8.37 (Iowa) to a high of $45.76 (Wyoming) in RPCE per capita per year in 2016 dollars, when γ = 1. Or, using the implied upper bound value for γ, the potential gain varies from a low of $19.40 (North Dakota) to a high of $139.23 (Nevada) in RPCE per capita per year in 2016 dollars.

Although the potential percentage welfare gain and the equivalent dollar amount are small, in relative terms, however, it could be quite large. For example, the ratio of Wyoming's λ to Iowa's λ is 5 (γ = 1), or Nevada's λ is 9.56 times that of North Dakota's λ, using the implied upper bound for γ. In the next section, we explore some possible reasons that could explain the variations of the λs across the states.

IV. What can explain the variation of λs across the states?

We explore several possible reasons why there is such a great variation of λs across the states in this section. One possibility has been suggested by the research of Krusell and Smith (1999). They find that low income, unemployed consumers facing borrowing constraint can benefit substantially from stabilization policy. This suggests that per capita state income potentially may explain the variation in welfare gain among the states. For example, a recession may impact states with low income more severely than states with higher income. If so, the lower income states may potentially benefit more from stabilization policy than higher income states, all else equal, giving rise to a negative correlation between λ and per capita real state income. On the other hand, Krusell and Smith (1999) also show that very wealthy consumers benefit substantially from stabilization policy. Thus, to the extent that wealth is positively correlated with real income, it is also possible that λ and real per capita income are positively correlated, all else equal. Krusell and Smith (1999) also find that the average consumers do not benefit much from stabilization policy. Thus, the research of Krusell and Smith (1999) suggests that there is a possible relationship between welfare gain from stabilization policy and real income. We study a representative consumer and not subgroups of consumers in this paper, however, using the real per capita GDP of each state. A priori then, we cannot predict the relationship between state real per capita GDP and λ.

Figure 1(a) shows a plot of the λs against the average 1997 – 2016 annual real GDP per capita for the 50 states for γ = 1. A linear regression line, which also includes a constant, of the two variables is also included. Figure 1(b) is a plot of the same two variables including the regression line, for the case when the upper bound value of γ is used for each state.

Figures 1(a) and 1(b) both clearly show a positive correlation between γ and real GDP per capita, suggesting that states with higher real GDP per capita benefit more from stabilization policy than states with lower real GDP per capita. Although the results are consistent with the findings of Krusell and Smith (1999) that wealthy, and hence high income individuals benefit more from stabilization policy, but we caution that our results should be interpreted with care since we study a representative consumer and not subgroups of consumers.

Another possible link between real income and potential gain from stabilization policy is suggested by the research on the relationship between real income growth rate and its volatility. Kormendi and Meguire (1985), and Grier and Tullock (1989) find that real income growth rate and its volatility, measured by the standard deviations of real income growth rates, are positively correlated. Ramey and Ramey (1995), and Lin and Kim (2014), however, find a negative correlation. Following this line of research, we examine whether or not there is a statistical relationship between the growth rate of real per capita GDP and λ. If the correlation between real per capita growth rate of income and its volatility is positive, short run stabilization policy which dampens this volatility, can improve welfare.[14] Thus, we expect a positive correlation between real per capita income growth and potential welfare gain. On the other hand, if the growth rate of real per capita income and its volatility are negatively correlated, we would then expect a negative correlation between real income growth rate and λ, as states with low real per capita income growth rate are likely to benefit more from short-run stabilization policy.

Figure 2(a) and 2(b) show the plots of real per capita income growth rate against λ and the associated regression line for γ = 1, and for the upper bound value of γ, respectively, for the 50 states.[15] Both figures show a negative correlation between λ and the per capita growth rate of real GDP, suggesting the possibility that states with low growth rate of per capita real GDP can benefit more from short-run stabilization policy.

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[14] Lin and Kim (2014) also make this same point and further note that in this case, there is a tradeoff between short-term stability and long-run economic growth. Lucas (2003) also notes that there is a relationship between growth rate of output and its volatility.

[15] Income growth rate for each state is the growth rate of real GDP from 1997 – 2016, computed as $\left(\frac{y_i}{y_j}\right)^{\frac{1}{19}} - 1$,

where y_i and y_j are real GDP per capita of 2016, and 1997, respectively.

A final possibility is that states that are more generous in providing transfers and other forms of assistance to their residents may provide them with a better cushion against uncertainty in income, especially during recessions. This is related to the literature on precautionary savings, which is also discussed by Lucas (2003). Precautionary savings are self-insurance against future income uncertainty. Thus, individuals with precautionary savings can experience less consumption variability and the associated welfare loss. This suggests a negative relationship between precautionary savings and potential welfare gain from short-short stabilization policy. Unfortunately, data on savings in general are not available at the state level. However, state public assistance may be a suitable substitute since, like precautionary savings, it provides a cushion against income shocks. Moreover, residents receiving transfers and other form of welfare payments are also more likely to face a borrowing constraint. Thus, transfers and welfare payments allow them to better smooth their consumption. As a result, we conjecture that states with more generous transfers and welfare payments may benefit less from stabilization policy, all else equal. Therefore, we expect a negative correlation between λ and state transfer payments.

We show in Figure 3(a) and 3(b) the plots of state transfers and subsidies as a percent of state GDP[16] against λ and the associated regression line, for $\gamma = 1$, and for the upper bound value of γ, respectively, for the 50 states. We see a weak negative correlation between λ and state transfers and subsidies as a percentage of the state's GDP. The results are consistent with our expectations that, because states with more generous transfer payments provide a larger buffer against unforeseen income shocks, these states are likely to benefit less from stabilization policy.

We also present regression results where we estimate the following linear regression:

$$\lambda_j = \alpha + \beta y_j + \sum_{i=1}^{7} \delta_i D_{i,j} + v_j \qquad (10)$$

where

λ_j = the value of λ for the jth state;

y_j = average per capita real GDP, or the growth rate of per capita real GDP, or state transfers and subsidies as a percentage of the state's GDP, for the jth state;

$D_{i,j}$ = regional dummy variables indicating the BEA regional classification of the state; and

v_j = is a normally distributed, zero mean, and constant variance error term.

[16] See Appendix A for the source of the data on state transfer payments.

There are eight Bureau of Economic Analysis (BEA) regions: New England, Mideast, Great Lakes, Plains, Southeast, Southwest, Rocky Mountain, and Far West. The Far West region is the omitted region in the regressions.[17] We also estimate a variant of equation (10):

$$\lambda_j = \alpha + \beta y_j + \theta z_j + \sum_{i=1}^{7} \delta_i D_{i,j} + v_j \qquad (11)$$

where

y_j = average per capita real GDP, or the growth rate of per capita real GDP, for the jth state;

z_j = state transfers and subsidies as a percentage of the state's GDP, for the jth state.

Tables 5 and 6 report the results of estimating equation (10), with and without the regional dummies. Table 5 reports the results assuming $\gamma = 1$, while Table 6 reports the results using the upper bound values of γ. Table 7 reports the results from estimating equation (11), again with and without the regional dummies. Columns (1) – (4) of Table 7 report the results using $\gamma = 1$, and columns (5) – (8) are the results using the upper bound values of γ.

To begin with, transfers and subsidies as a percentage of state GDP has the expected negative sign in all the regressions, but in all but one case, it is not a statistically significant variable determining λs. The results with real GDP per capita are mixed. It has the expected positive sign in all regressions, but it is statistically significant mostly in regressions when $\gamma = 1$ is assumed. The results with the growth rate of real GDP per capita are also rather mixed. It has the expected negative sign in all regressions, but it is mostly statistically significant in regressions when the upper bound of γ is used.

There are clearly differences among the regions in terms of the potential benefits from short-term stabilization policy. States in the Far West region, in New England, the Northeast, the Mideast, the Southeast, the Southwest, and the Rocky Mountain regions appear to benefit more from short-term stabilization policy than states in the Great Lakes and the Plains regions. To see this, note that the regional dummy variable for the Far West region is the region omitted from the regressions, and its relationship to welfare gain is therefore given by the constant term in the regressions. In all cases, the constant term is positive and statistically significant in the regressions where regional dummies are included. The regional dummy coefficients for the New England, the Northeast, the Mideast, the Southeast, the Southwest, and the Rocky Mountain regions are mostly not statistically significant. Thus, the welfare

[17] States in each region are reported in Appendix A. Note that the Mideast region includes the District of Columbia, which is not included in our sample.

gain to these regions are the same as the welfare gain to the Far West region. On the other hand, the coefficients of the regional dummies for the Great Lakes and the Plains states are negative and statistically significant. The welfare gain to these two regions is the difference between the constant term and the coefficient of the respective regional dummy, which is positive in all cases. Therefore, states in these two regions have smaller welfare gain than the states in the other regions of the country. Additionally, the regional dummy variables may reflect several related factors. For example, variations among states and regions in industrial mix, e.g., manufacturing industry vs. service industry, capital mix, e.g., physical capital vs. human capital, can affect how a region react to an income shock, and the potential welfare gain from stabilization policy. Yet another possibility is that the regional dummy variables are capturing region-specific shocks, which when combined with national and sectoral or state-specific shocks, may again affect a region's potential gain from national stabilization policy. Finally, the regional dummy variables may also reflect the differential impacts of stabilization policy on regions and states, and thus their potential welfare gain.[18]

The last row of Table 7 reports the F-test for the joint significance of the two right-hand-side variables that are not the constant or the seven regional dummies. Of the four F-tests, the only F-test that can be rejected at the 5% and the 1% levels is the F-test that the growth rate of real GDP per capita and transfers and subsidies with upper bound γ (column 8) are jointly statistically insignificant.

V. Summary and conclusion

Lucas (1987, 2003) finds surprisingly small welfare gain to further improvement in stabilization policy in the U.S. We first update Lucas's study for the U.S. using data from 1997 to 2006, which include the Great Recession. We obtain $\lambda = 0.000521$, which is remarkably close to Lucas's (2003) $\lambda = 0.000512$, calculated from annual data from 1947 to 2001. At the state level, we also find relatively small potential welfare gain to further short-term stabilization policy. However, we find considerable variations in potential welfare gain across the 50 states, ranging from $\lambda = 0.001257$ in Wyoming to $\lambda = 0.000251$ in Iowa, assuming $\gamma = 1$. In terms of order of magnitude, these potential gains are extremely small. For example, for Wyoming, it is the equivalent of an additional \$45.76 of RPCE per capita per year in 2016 dollars. When the implied upper bound values of γ are used instead, the range is from the lowest welfare gain in North Dakota of \$19.40 ($\lambda = 0.000446$) to the highest of \$139.23 ($\lambda = 0.004263$) in Nevada, of RPCE per capita per year in 2016 dollars.

[18] See a recent paper by Bremmer (2010) for a discussion of differential state impacts of monetary policy.

The considerable variations in λs across the 50 states allow us to explore the factors which may determine a state's potential gain from national stabilization policy. We explore three potential determinants; real GDP per capita as suggested by the research of Krusell and Smith (1999); the growth rate of real GDP per capita, as suggested by the research on real income growth and its volatility, for example, Ramey and Ramey (1995). A third potential determinant we explore is motivated by the literature on precautionary savings and consumption variability. However, because of a lack of data on precautionary savings, we use instead a state's transfers and subsidies as a percent of its GDP. We find that a state's transfers and subsides as a percent of its GDP is mostly not statistically significant, although it has the expected sign. We obtain mixed results with real GDP per capita and the growth rate of real GDP per capita. Real GDP per capita is mostly statistically significant in regressions when $\gamma = 1$ is assumed, while the growth rate of real GDP per capita is mostly statistically significant in regressions where the upper bound of γ is used. There is evidence, however, that potential welfare gain from short-term stabilization policy varies across regions of the country, with states in the Far West, the New England, the Mideast, the Southeast, the Southwest, and the Rocky Mountain regions appear to have more to gain than states in the Great Lakes, and the Plains regions. But again, the potential gain appears to be rather small. Based on our results, we generally agree with Lucas that there is not much to be gained from further improvement in stabilization policy. Rather, policy should be directed at increasing long-run economic growth.

Appendix A

Data sources and methods

1. Sources

Data for state level nominal personal consumption expenditures per capita are downloaded from the website of the Bureau of Economic Analysis (BEA) (https://www.bea.gov). Date of download: January 6, 2018.

Data for the implicit price deflator for U.S. personal consumption expenditures, index 2009 = 100 are downloaded from the FRED data base of the Federal Reserve Bank of St. Louis (https://fred.stlouisfed.org). Date of download: January 6, 2018.

Data for state real GDP per capita, chained 2009 dollars, are downloaded from the website of the Bureau of Economic Analysis (BEA) (https://www.bea.gov). Date of download: December 20, 2017.

Data for U.S. real personal consumption expenditures per capita, chained 2009 dollars, quarterly, seasonally adjusted annual rate are downloaded from the FRED data base of the Federal Reserve Bank of St. Louis (https://fred.stlouisfed.org). Date of download: December 20, 2017.

Data for regional price parities by state are downloaded from the website of the Bureau of Economic Analysis (BEA) (https://www.bea.gov). Date of download: April 10, 2018.

Transfers and subsidies as a percentage of income is component 1B of the Economic Freedom of North America Index. Data are downloaded from https://www.fraserinstitute.org/studies/economic-freedom-of-north-america-2016, on May 11, 2018.

BEA Regions

New England: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont
Mideast: Delaware, District of Columbia, Maryland, New Jersey, New York, Pennsylvania
Great Lakes: Illinois, Indiana, Michigan, Ohio, Wisconsin
Plains: Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota
Southeast: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, West Virginia
Southwest: Arizona, New Mexico, Oklahoma, Texas
Far West: California, Nevada, Oregon, Washington

2. Methods

Data are annual except for U.S. real personal consumption expenditures per capita, which are available quarterly. The annual data used in the paper are quarterly averages. Real state GDP per capita used in regressions (10) and (11) is an average of real state GDP per capita for 1997 – 2016. State transfers and subsidies as a percentage of state GDP is constructed by averaging state transfer and subsidies as a percentage of state GDP for 1997 – 2015.

The Bureau of Economic Analysis (BEA) reports state GDP and accounts based on state GDP computed based on the North American Industry Classification System (NAICS) after 1997. Before 1997, these accounts are calculated based on the Standard Industrial Classification (SIC). The two sets of data are therefore incompatible. For this reason, our data set is for 1997 to 2016.

2.a Construction of an alternative PCE deflator for each state

The Bureau of Economic analysis publishes a time series called Regional Price Parities by state for the U.S., the 50 states and the District of Columbia, available from 2008 to 2015, which are the latest figures available when this research begins. These are indexes of the average prices paid by consumers for the mix of goods and services consumed in each state relative to the U.S. for 2008 – 2015. Take New York as an example. In 2015, the index of regional price parity for New York is 115.3 (U.S. = 100), this means that the prices in New York in 2015 are 15.3% higher than the national U.S. prices on the average.

To construct the alternative per capita RPCE deflator for each state, we start by averaging the regional price parity index for each state over 2008 to 2015. Hawaii has the highest average regional price parity index of 117.81, while Mississippi has the lowest at 86.49. A new PCE deflator for each state from 1997 to 2016 is constructed by adjusting the U.S. implicit price deflator for personal consumption expenditures by the average regional price parity index for each state, i.e., multiplying the average regional price parity index for each state by the U.S. implicit price deflator for personal consumption expenditures.

Appendix B

Derivation of the optimal consumption path

This appendix shows the derivation of the optimal consumption path, which is equation (9) in the text. The derivation is a standard one and can be found in many advanced macroeconomics texts, thus we provide only a brief sketch here. We follow the derivation in Bagliano and Bertola (2004), where the interested readers can find more detailed information.

An infinitely-lived representative consumer is assumed to maximize an expected lifetime utility function

$$E\sum_{t=0}^{\infty}\beta^{t}U(c_t)\,, \qquad \text{(B.1)}$$

subject to a budget constraint

$$A_{t+1}=(1+r)A_t+y_t-c_t\,,\ (t=1,2,...\infty)\,, \qquad \text{(B.2)}$$

and the transversality condition

$$\lim_{t\to\infty}\left(\frac{1}{1+r}\right)^{t}A_t=0,$$

where $0<\beta=\frac{1}{1+\rho}<1$ is the discount factor, and ρ is a subjective discount rate, r is a real rate of return on asset A_t, y_t, and c_t are real income and consumption, respectively.

Substituting equation B.2 into equation B.1, we obtain

$$E\sum_{t=0}^{\infty}\beta^{t}U((1+r)A_t-A_{t+1}+c_{t+1})\,. \qquad \text{(B.3)}$$

The first-order necessary and sufficient conditions for optimality is

$$U'(c_t)=\frac{1+r}{1+\rho}EU'(c_{t+1})\,, \qquad \text{(B.4)}$$

for $U'(c)>0$, $U''(c)<0$, and $EU'(c_t)=U'(c_t)$, since $U'(c_t)$ is known at time t.

For a (CRRA) utility function, $U(c_t)=\frac{c_t^{1-\gamma}}{1-\gamma}$, $U'(c_t)=c_t^{-\gamma}$, and $U'(c_{t+1})=c_{t+1}^{-\gamma}$ Substituting into equation B.4, which is also called the Euler equation, taking natural logs on both sides, solving the resulting expression under certainty, and noting the approximation that $\ln(1+r)\approx r$, and $\ln(1+\rho)\approx\rho$, we obtain equation (9) in the text

$$\left(\ln\frac{c_{t+1}}{c_t}\right)\equiv\mu=\frac{1}{\gamma}(r-\rho).$$

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Figure 1(a): Plot of lamda and the average real GDP per capita, γ = 1

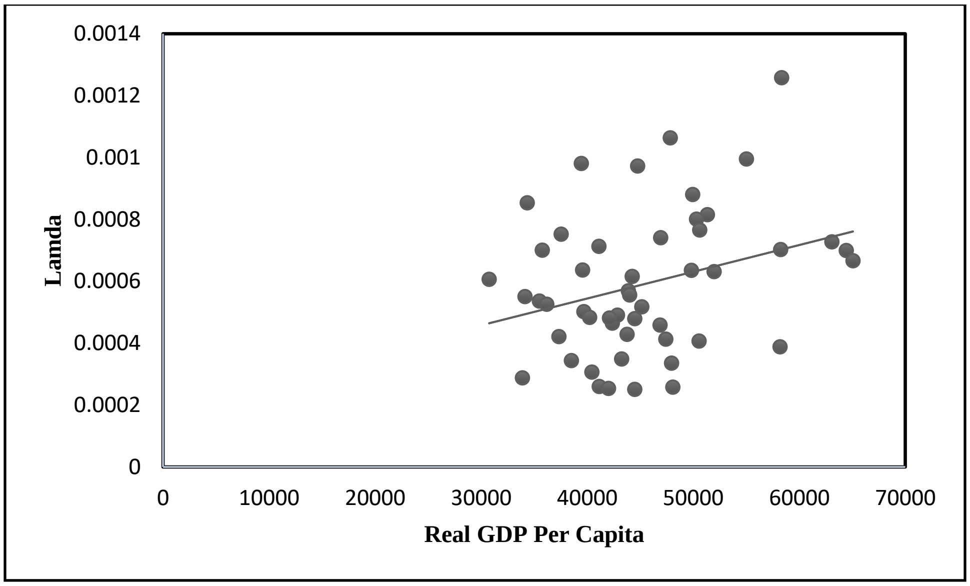

Figure 1(b): Plot of lamda and the average real GDP per capita, upper bound γ

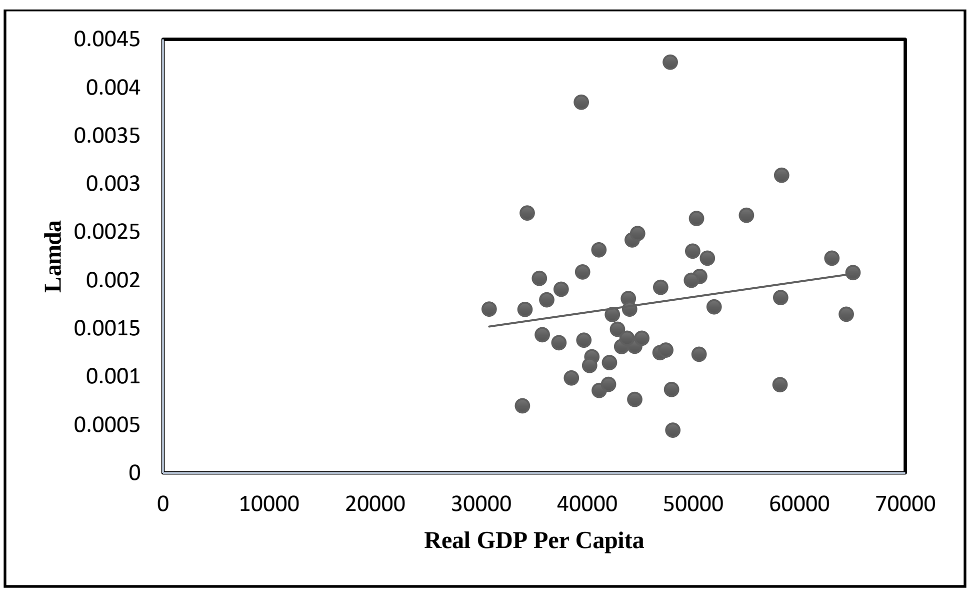

Figure 2(a): Plot of lamda and the growth rate of real GDP per capita, γ = 1

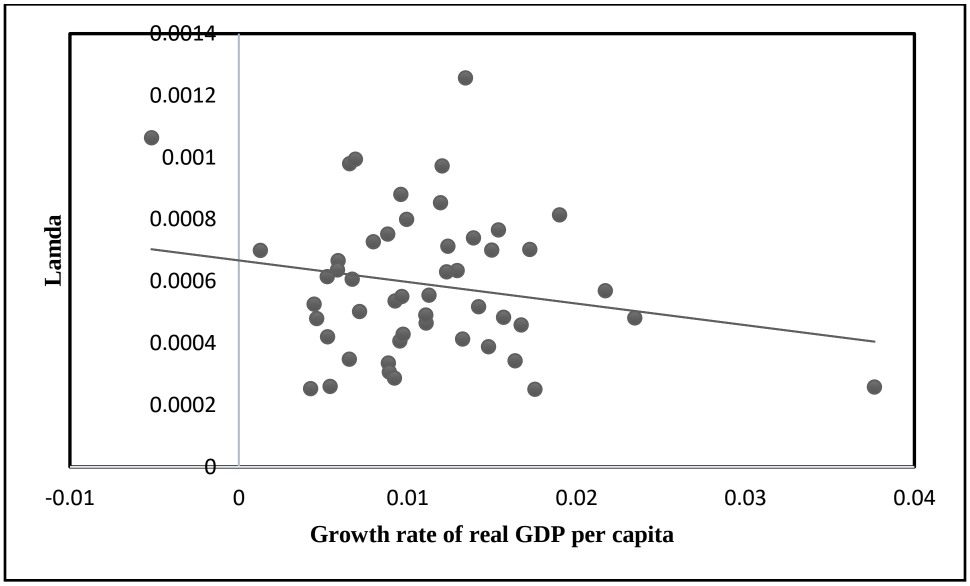

Figure 2(b): Plot of lamda and the growth rate of real GDP per capita, upper bound γ

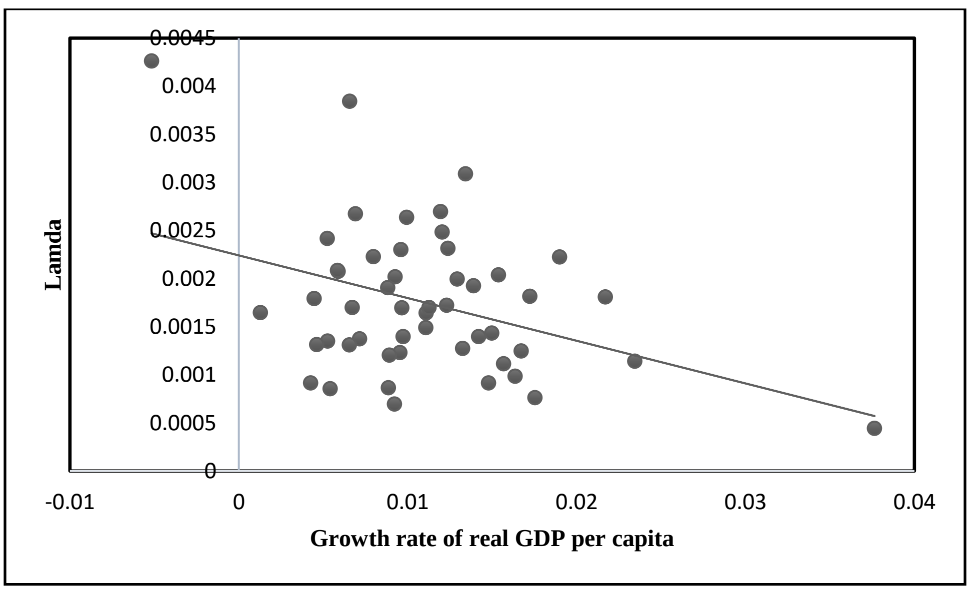

Figure 3(a): Plot of lamda and transfers and subsidies, γ = 1

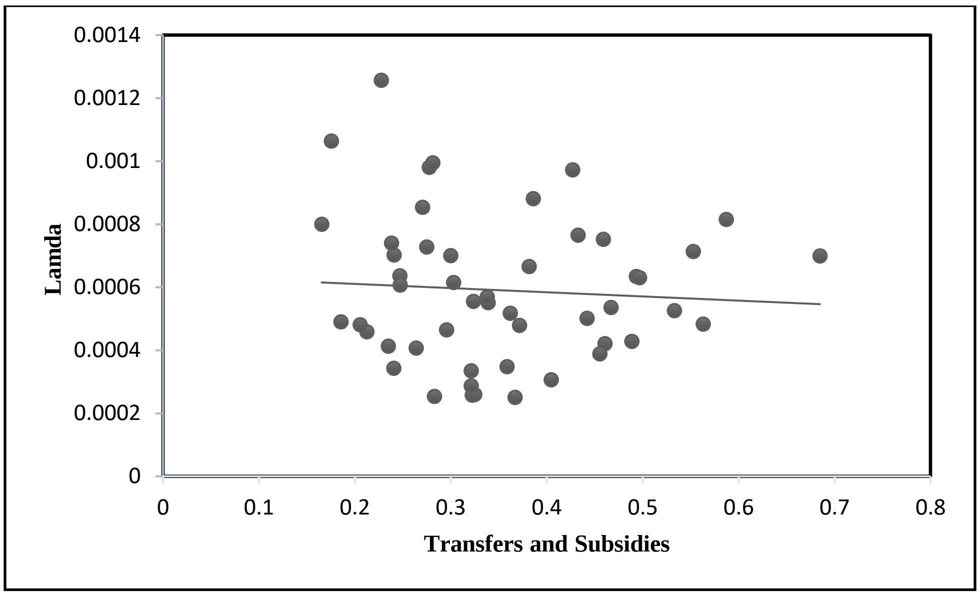

Figure 3(b): Plot of lamda and transfers and subsidies, upper bound γ

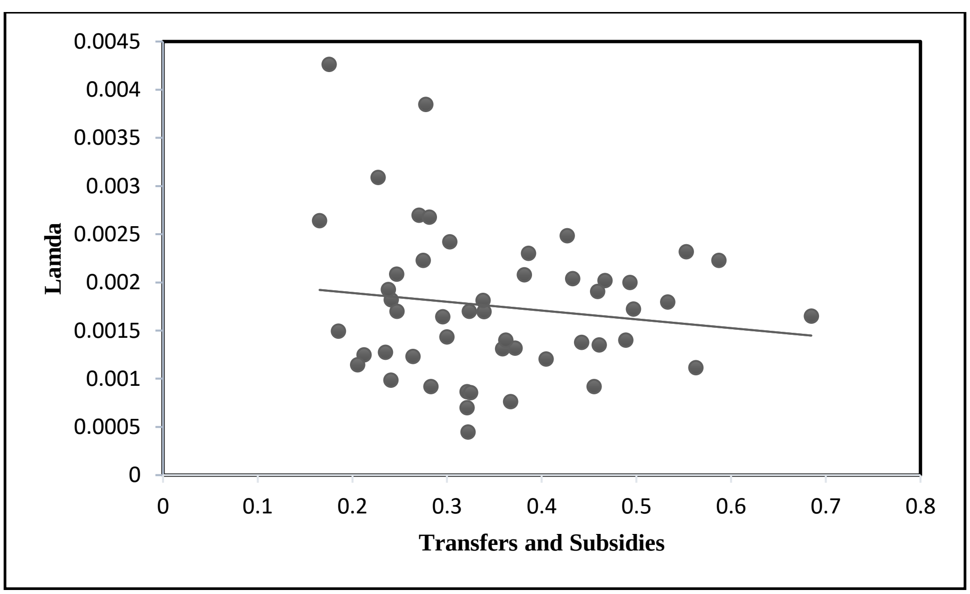

Table 1: Update of Lucas's original results

	Time Period	σ^2	γ	λ	2016$
Lucas (2003)	1947 - 2001	0.001024	1	0.000512	$18.33*
			2.2+	0.001126*	$40.33*
Author's calculation	1997 - 2016	0.001042	1	0.000521	$18.65
			2.99+	0.001558	$55.78
DeJong and Dave (2011)	1947 - 2009	0.000898	1	0.000449	$16.08*
			2.2+	0.000988*	$35.36*

Notes: * author's calculations.

+ Upper bound value of γ, Lucas's (2003) and DeJong and Dave's (2011) upper bound value is from DeJong and Dave (2011).

2016$ = potential welfare gain in per capita RPCE per year in 2016 dollars.

Table 2: Estimates of σ^2 for the 50 states

	σ^2		σ^2
U.S.	0.001042		
Alabama	0.001071	Montana	0.001400
Alaska	0.001398	Nebraska	0.000916
Arizona	0.001960	Nevada	0.002127
Arkansas	0.001101	New Hampshire	0.001480
California	0.001629	New Jersey	0.001989
Colorado	0.001600	New Mexico	0.001003
Connecticut	0.001455	New York	0.000776
Delaware	0.001332	North Carolina	0.000696
Florida	0.001272	North Dakota	0.000515
Georgia	0.001230	Ohio	0.000857
Hawaii	0.000067	Oklahoma	0.000686
Idaho	0.001706	Oregon	0.001138
Illinois	0.000813	Pennsylvania	0.001034
Indiana	0.000929	Rhode Island	0.001945
Iowa	0.000501	South Carolina	0.001051
Kansas	0.000980	South Dakota	0.000962
Kentucky	0.000841	Tennessee	0.000612
Louisiana	0.000958	Texas	0.000825
Maine	0.001504	Utah	0.001426
Maryland	0.001530	Vermont	0.000966
Massachusetts	0.001404	Virginia	0.001761
Michigan	0.000519	Washington	0.001261
Minnesota	0.001269	West Virginia	0.000574
Mississippi	0.001213	Wisconsin	0.001110
Missouri	0.000506	Wyoming	0.002514

Table 3: Welfare Gain for the 50 states with $\gamma = 1$

	λ	2016$		λ	2016$
U.S.	0.000521	$18.65			
Alabama	0.000535	$15.15	Montana	0.000700	$26.04
Alaska	0.000699	$31.26	Nebraska	0.000458	$16.11
Arizona	0.000980	$30.59	Nevada	0.001064	$34.73
Arkansas	0.000550	$15.46	New Hampshire	0.000740	$32.60
California	0.000815	$30.75	New Jersey	0.000995	$43.96
Colorado	0.000800	$30.80	New Mexico	0.000502	$16.16
Connecticut	0.000728	$31.85	New York	0.000388	$16.43
Delaware	0.000666	$25.77	North Carolina	0.000348	$10.61
Florida	0.000636	$22.19	North Dakota	0.000258	$11.21
Georgia	0.000615	$19.24	Ohio	0.000429	$14.48
Hawaii	0.000335	$13.64	Oklahoma	0.000343	$10.21
Idaho	0.000853	$25.91	Oregon	0.000569	$20.41
Illinois	0.000407	$15.33	Pennsylvania	0.000517	$19.08
Indiana	0.000465	$14.94	Rhode Island	0.000973	$37.27
Iowa	0.000251	$8.37	South Carolina	0.000526	$15.78
Kansas	0.000490	$15.92	South Dakota	0.000481	$17.14
Kentucky	0.000421	$12.64	Tennessee	0.000306	$9.45
Louisiana	0.000479	$14.78	Texas	0.000413	$13.60
Maine	0.000752	$29.20	Utah	0.000713	$22.60
Maryland	0.000765	$30.90	Vermont	0.000483	$20.77
Massachusetts	0.000702	$32.94	Virginia	0.000881	$33.09
Michigan	0.000259	$9.21	Washington	0.000631	$24.43
Minnesota	0.000635	$25.16	West Virginia	0.000287	$8.92
Mississippi	0.000607	$16.53	Wisconsin	0.000555	$19.43
Missouri	0.000253	$8.57	Wyoming	0.001257	$45.76

Note: 2016$ = potential welfare gain in per capita RPCE per year in 2016 dollars.

Table 4: Welfare Gain for the 50 states, upper bound γ

	Upper bound γ	λ	2016$		Upper bound γ	λ	2016$
U.S.	2.99	0.001558	$55.78				
Alabama	3.77	0.002020	$57.15	Montana	2.05	0.000700	$53.36
Alaska	2.36	0.001649	$73.73	Nebraska	2.73	0.001248	$43.90
Arizona	3.93	0.003847	$120.09	Nevada	4.01	0.004263	$139.23
Arkansas	3.08	0.001697	$47.68	New Hampshire	2.60	0.001927	$84.88
California	2.74	0.002228	$84.13	New Jersey	2.69	0.002676	$118.28
Colorado	3.30	0.002640	$101.63	New Mexico	2.75	0.001377	$44.37
Connecticut	3.06	0.002229	$97.59	New York	2.37	0.000918	$38.87
Delaware	3.12	0.002078	$80.42	North Carolina	3.77	0.001311	$39.98
Florida	3.28	0.002086	$72.76	North Dakota	1.73	0.000446	$19.40
Georgia	3.94	0.002420	$75.72	Ohio	3.26	0.001399	$47.29
Hawaii	2.59	0.000867	$35.30	Oklahoma	2.87	0.000986	$29.35
Idaho	3.16	0.002698	$81.95	Oregon	3.18	0.001812	$64.99
Illinois	3.03	0.001232	$46.46	Pennsylvania	2.71	0.001400	$51.67
Indiana	3.54	0.001644	$52.87	Rhode Island	2.56	0.002485	$95.24
Iowa	3.05	0.000763	$25.49	South Carolina	3.42	0.001796	$93.92
Kansas	3.05	0.001493	$48.49	South Dakota	2.38	0.001145	$40.78
Kentucky	3.22	0.001352	$40.63	Tennessee	3.94	0.001205	$37.21
Louisiana	2.75	0.001316	$40.62	Texas	3.09	0.001275	$42.05
Maine	2.54	0.001906	$74.03	Utah	3.25	0.002317	$73.43
Maryland	2.67	0.002040	$82.40	Vermont	2.31	0.001116	$47.98
Massachusetts	2.59	0.001819	$85.36	Virginia	2.62	0.002303	$86.53
Michigan	3.30	0.000856	$30.40	Washington	2.73	0.001724	$66.80
Minnesota	3.15	0.002000	$76.25	West Virginia	2.43	0.000699	$21.70
Mississippi	2.80	0.001700	$46.35	Wisconsin	3.06	0.001700	$59.54
Missouri	3.63	0.000918	$31.10	Wyoming	2.46	0.003090	$112.48

Note: 2016$ = potential welfare gain in per capita RPCE per year in 2016 dollars.

Table 5: Regression Results: Dependent variable = λ, γ= 1

Coefficient of :						
Constant	1.98×10^{-4} (1.19)	3.47×10^{-4} (1.50)**	6.67×10^{-4} (10.37)*	7.70×10^{-4} (7.84)*	6.37×10^{-4} (5.98)*	8.10×10^{-4} (4.94)*
Average real GDP per capita	8.65×10^{-9} (2.33)*	6.60×10^{-9} (1.75)**				
Growth rate of real GDP per capita			-6.97×10^{-3} (1.53)	-8.80×10^{-3} (2.06)*		
Transfers and subsidies					-1.32×10^{-4} (0.52)	-2.87×10^{-4} (1.26)
New England		6.26×10^{-4} (0.56)		7.01×10^{-5} (0.73)		2.57×10^{-5} (0.22)
Mideast		-4.27×10^{-5} (0.33)		-3.64×10^{-6} (0.03)		-3.39×10^{-5} (0.26)
Great Lakes		-2.17×10^{-4} (2.00)*		-2.65×10^{-4} (1.85)**		-2.90×10^{-4} (2.58)*
Plains		-2.42×10^{-4} (2.16)*		-2.11×10^{-4} (1.98)*		-3.22×10^{-4} (2.52)*
Southeast		-8.96×10^{-5} (0.73)		-1.92×10^{-4} (1.98)*		-1.88×10^{-4} (1.73)**
Southwest		-6.02×10^{-5} (0.37)		-1.16×10^{-4} (0.84)		-1.65×10^{-4} (1.01)
Rocky Mountain		2.27×10^{-4} (1.73)**		2.05×10^{-4} (1.69)**		1.42×10^{-4} (1.05)
R^2	0.09	0.43	0.04	0.44	0.00	0.41

Notes: Absolute values of the t-statistic are in parenthesis below the estimates.
*, ** statistically significant at the 5% and 10% levels, respectively.

Table 6: Regression Results: Dependent variable = λ, upper bound value of γ

Coefficient of :						
Constant	1.03×10^{-3} (2.06)*	1.30×10^{-3} (1.60)**	2.24×10^{-3} (8.86)*	2.57×10^{-3} (5.20)*	2.07×10^{-3} (5.40)*	2.73×10^{-3} (3.54)*
Average real GDP per capita	1.60×10^{-8} (1.49)	1.54×10^{-8} (1.37)				
Growth rate of real GDP per capita			-4.43×10^{-2} (2.55)*	-4.92×10^{-2} (2.54)*		
Transfers and subsidies					-9.11×10^{-4} (1.01)	-1.47×10^{-3} (1.48)
New England		-1.34×10^{-4} (0.28)		3.16×10^{-5} (0.08)		2.75×10^{-4} (0.58)
Mideast		-3.23×10^{-4} (0.64)		-1.81×10^{-4} (0.44)		-3.43×10^{-4} (0.69)
Great Lakes		-6.19×10^{-4} (1.27)		-7.37×10^{-4} (1.78)**		-8.63×10^{-4} (1.76)**
Plains		-8.53×10^{-4} (1.71)**		-5.52×10^{-4} (1.44)		-1.15×10^{-3} (2.06)*
Southeast		-2.46×10^{-4} (0.48)		-5.57×10^{-4} (1.32)		-5.26×10^{-4} (1.14)
Southwest		-6.62×10^{-5} (0.09)		-1.62×10^{-4} (0.26)		-4.18×10^{-4} (0.56)
Rocky Mountain		4.57×10^{-4} (0.90)		4.87×10^{-4} (1.18)		1.53×10^{-4} (0.28)
R^2	0.03	0.26	0.15	0.37	0.02	0.29

Notes: Absolute values of the t-statistic are in parenthesis below the estimates.
*, ** statistically significant at the 5% and 10% levels, respectively.

Table 7: Regression Results: Dependent variable = λ

Coefficient of :	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Constant	2.52×10^{-4} (1.52)	4.75×10^{-4} (1.71)**	7.22×10^{-4} (5.59)*	8.77×10^{-4} (6.13)*	1.33×10^{-3} (2.42)*	1.98×10^{-3} (1.74)**	2.62×10^{-3} (5.43)*	3.11×10^{-3} (4.87)*
Average real GDP per capita	8.83×10^{-9} (2.42)*	6.42×10^{-9} (1.71)**			1.70×10^{-8} (1.67)**	1.44×10^{-8} (1.36)		
Growth rate of real GDP per capita			-7.12×10^{-3} (1.56)	-8.42×10^{-3} (2.12)*			-4.53×10^{-2} (2.72)**	-4.73×10^{-2} (2.84)*
Transfers and subsidies	-1.76×10^{-4} (0.76)	-2.74×10^{-4} (1.21)	-1.52×10^{-4} (0.61)	-2.55×10^{-4} (1.35)	-9.95×10^{-4} (1.13)	-1.44×10^{-3} (1.42)	-1.04×10^{-3} (1.24)	-1.29×10^{-3} (1.70)**
New England		4.38×10^{-5} (0.37)		5.20×10^{-5} (0.50)		2.33×10^{-4} (0.48)		-1.23×10^{-4} (0.33)
Mideast		-5.61×10^{-5} (0.44)		-1.74×10^{-5} (0.15)		-3.93×10^{-4} (0.81)		-2.51×10^{-4} (0.62)
Great Lakes		-2.44×10^{-4} (2.06)*		-2.89×10^{-4} (2.79)*		-7.62×10^{-4} (1.44)		-8.58×10^{-4} (2.04)*
Plains		-2.81×10^{-4} (2.13)*		-2.50×10^{-4} (2.01)*		-1.06×10^{-3} (1.79)**		-7.47×10^{-4} (1.65)**
Southeast		-1.09×10^{-4} (0.86)		-2.07×10^{-4} (2.08)*		-3.50×10^{-4} (1.14)		-6.35×10^{-4} (1.57)
Southwest		-9.90×10^{-5} (0.57)		-1.51×10^{-4} (1.04)		-2.70×10^{-4} (0.34)		-3.38×10^{-4} (0.53)
Rocky Mountain		1.90×10^{-4} (1.37)		1.70×10^{-4} (1.38)		2.61×10^{-4} (0.46)		3.12×10^{-4} (0.72)
R^2	0.10	0.44	0.04	0.45	0.05	0.30	0.17	0.41
$F(2, 41)$		1.80		2.24		1.76		5.77*

Notes: Absolute values of the t-statistic are in parenthesis below the estimates.
*, ** statistically significant at the 5% and 10% levels, respectively.
Columns (1) – (4) are results using $\gamma = 1$, and columns (5) – (8) are results using the upper bound value of γ.
The F statistic is for the test of the joint significance of the two right-hand-side variables except the constant and the dummy variables.