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Abstract

This paper reconsiders the question of regional convergence across the US States over the long-run. The analysis is carried out over the period 1929-2005. Our analysis advocates and implements an Error-Correction-Model (ECM) approach to deal with this issue. The aforementioned model is applied in order to assess the possibilities of *intra*regional convergence towards steady-state equilibrium, approximated in terms of the State with highest per-capita income in each broad region. Empirical analysis suggests a pattern of convergence in accordance with the ECM supporting its validity. Further inspection of the results provides an indirect indication of the agglomerative effects in shaping the patterns of convergence.

Key Words: Income Convergence, Error-Correction-Model, US States

JEL Classification: C22, R10

1. Introduction

The publication of the ground breaking work of Baumol (1986) was the spark that ignited an enormous interest to the issue of convergence across national economies. This issue can also be tackled with respect to different areas within a country, that is to say, *regions*. In the context of *regional convergence*, the term ‘region’ refers either to areas determined according to similarities in geographical characteristics or areas corresponding to administrative divisions, which may be arbitrary. As perhaps anticipated, recent years have witnessed a growing number of attempts to assess regional convergence using extensive datasets, such as the regions of the European Union (e.g. Button and Pentecost, 1995; Neven and Gouyette, 1995; Sala-i-Martin, 1996; Fingleton and McCombie, 1998; Álvarez-Garcia *et al*., 2004; Ezcurra *et al*., 2005) or the regions of individual countries (e.g. Peeters, 2008) and the States of the USA (e.g. Christopoulos and Tsionas, 2007; Rey and Montouri, 1999; Bernard, 2001; Tsionas, 2000; 2001). Within this literature, convergence is expressed either in terms of per-capita income or some other observational variable, such as levels of employment or unemployment. In empirical studies, an approach used extensively involves deployment of cross-section data. However, the notion of regional convergence is characterised by transformations and adjustments, properties that are difficult to be examined in such context. This has led to the development of alternative methodologies using time-series, generating a considerable empirical literature (e.g. Bernard and Jones, 1996; Carlino and Mills, 1993).

The main econometric apparatus in stochastic convergence derives from the theory of *cointegration* analysis. Nevertheless, a test for cointegration does not reveal tendencies over the long-run and it is silent to the issue of the adjustment towards steady-state equilibrium. In other words, the critical question 'convergence to what?' remains unanswered. These problems are tackled in a more efficient way employing an Error-Correction-Model (hereafter ECM). As a result, there is a plethora of studies implementing this model in examining long-run convergence of regional employment and unemployment levels towards the respective national levels (e.g. Baddeley *et al.*, 1998; 2000; Martin and Tyler, 2000; Muscatelli and Tirelli, 2001; Gray, 2004). While the ECM offers a thorough perspective to the aforementioned issue, the question of long-run *income* convergence has remained, to our knowledge, a rather unexplored area. This is perhaps not so surprising if one takes into account that a definition of long-run steady-state equilibrium is easy in the case of variables such as employment or unemployment in which the national level is considered (e.g. Martin, 1997; Keil, 1997; Gray, 2005). Such a definition is not so clear when income convergence is the main objective of the analysis.

Notwithstanding the fact that average per-capita income at national level seems to be a good candidate for approaching steady-state equilibrium, nevertheless not always such a proxy reflects the implied social preferences. A convergence perspective taken by society does not coincide necessarily with movement towards an average whereas a *relatively high level* of per-capita income might reflect those preferences in a more realistic manner. Seen in this light, a geographical unit with the highest level of per-capita income, within a given set of areas with close proximity, might constitute an appropriate proxy for the steady-state equilibrium.

This idea constitutes the point of departure in the present paper. Using the ECM we examine empirically the question of whether the US States move towards alternative steady-state equilibria, expressed in terms of the State with the highest per-capita income in the Region (hereafter *HISR*). Additionally, a detailed analysis of the adjustment process towards long-run equilibrium is carried out.

Divided into four sections, the rest of this paper is structured in the following manner. Section 2 sets the appropriate framework which the empirical analysis will be conducted upon. The econometric application takes place in section 3, in conjunction with a detailed presentation of the obtained results. Finally, section 4 assesses the implications of the results for the debate concerning regional convergence and suggests possible avenues for future research.

2. The Empirical Setting

Traditionally, the econometric methodologies for regional convergence can be classified into two approaches; viz. cross-section and time-series. The nature of the cross-section approach to convergence is restricted to only two points in time, the initial and the terminal year[1]. Obviously, choosing different initial and terminal years could lead to different conclusions. Furthermore, data relating to the *interim* period are not utilised, thus excluding a considerable amount of useful information. Such information has the potential to reveal further interesting aspects of the patterns of convergence; a phenomenon that varies through time. Such variations are not easily detected by an approach utilising cross-section data.

[1] The cross-section approach is encapsulated in the notion of β-convergence, which requires that 'poor' regions grow faster than 'rich' ones. However, several criticisms have been raised against the conclusions, which this notion has yielded because of the problem know as 'regression towards the mean' ('Galton's fallacy'). This can lead to a considerable bias to the estimates of the obtained rate of convergence (see Bliss, 2000; Cannon and Duck, 2000, among others). This bias casts doubts on the econometric estimates of β-convergence regressions, as forcefully argued by Fingleton and McCombie (1998). Time-series tests do not suffer from such bias, yielding thus robust estimates of the underlying tendencies of convergence within a set of economies. This consideration is the motive for using time-series in the examination of the convergence hypothesis.

Those problems can be overcome by an alternative approach, based on the concept of *stochastic* convergence using time-series data[2]. Advocates of this approach (e.g. Bernard and Jones, 1996; Bernard and Durlauf, 1995) claim that convergence is, by definition, a *dynamic* concept that cannot be captured by cross-sectional studies[3].

The associated convergence tests are based on whether the dispersion in per-capita income between two (or more) regions has narrowed during a given time period, and all observations from that time period are used (Durlauf and Quah, 1998). Thus, convergence is identified, not as a property of the relationship between initial per-capita income and growth over a fixed sample period, as cross-section studies claim, but instead is defined by the relationship between long-run forecasts of the time-series in per-capita income. It follows, then, that this approach takes into account all the relevant information available throughout the given time period, although it might be argued that the issue of choice of time period remains. By definition, the impacts of random shocks to national and regional economies are taken into account, in predicting long-run trends.

The primary concern of this paper is to provide a detailed examination of the stable steady-state equilibrium in the long-run in conjunction with the short-run adjustment procedure towards it. While the theory of time-series econometrics provides a wide range of methodological tools, the present analysis is based exclusively on the ECM, which is discussed next.

The premise upon which time-series convergence is built involves the issue of *stationarity*. A time series, let $\{X_t; t = 1,2,...\}$, is said to be stationary if fulfils the

[2] Of course, there is an alternative set of tests that lie in between cross-section and time-series tests; this approach implements panel-data. Examples of this line of research can be found in the empirical studies of Badinger *et al.*, (2004), Esposti and Bussoletti (2008), Byrne *et al.*, (2009), inter alias. Nevertheless, using of panel-data, while useful in certain contexts, might be criticised as being ‘aggregative’, in a similar way with the cross-section data. Furthermore, panel-data are sensitive to the choice of time intervals and, consequently, their ability to detect a long-run tendency is limited.

[3] There has been an interest in testing for stochastic convergence across the regions of individual countries. Such regional studies concentrate to a large extent on the US (e.g. Carlino and Mills, 1993; Tsionas, 2000). Empirical studies for stochastic convergence have also been conducted for the regions of the UK (e.g. McGuinness and Sheehan, 1998), Austria (Hofer and Wörgötter, 1997), Italy (Proietti, 2005), Greece (Alexiadis and Tomkins, 2004).

conditions of constant mean and variance over time, i.e. if $E(X_t) = \mu, Var(X_t) = \sigma^2 < \infty$, and the (auto) covariances between two different points in time, let t and s, depend only on the absolute difference between them ($|t-s|$), i.e. when $Cov(X_t, X_s) = \sigma_{|t-s|}\ (t \neq s)$. If one of the above conditions does not hold, then the time-series in question is non-stationary. Of course, non-stationary series can become stationary by differencing them up to the point where the three conditions are hold. The number of times that non-stationary series are required to be differenced, as to become stationary, defines the order of integration. In most cases, economic time-series have been found to be integrated of order one, i.e. $I(1)$. The order of integration can be determined though the Augmented Dickey-Fuller (ADF) test for unit-roots.[4]

Economic theory investigates equilibrium relationships between variables without offering a view of the dynamic adjustments necessary to achieve equilibrium. As a result, several models have been developed that contain a long-run (or equilibrium) solution and capture adjustments in the short-run.

Despite the fact that several time series can be characterized as non-stationary, it is possible that certain combinations among these series to exhibit a common behaviour over time. In other words, a (linear) combination of non-stationary series might be integrated of a lower order than the individual series themselves, leading to what is known as cointegration, as described by Engle and Granger (1987).

The analytical aspect of this process can be described with the aid of the following example. Let X_t and Y_t, denote two time-series of $I(1)$, with the following long-run equilibrium relationship between them:

$$Y_t = \beta_0 + \beta_1 X_t \tag{1}$$

and the respected deviations from it calculated as

$$u_t = Y_t - \beta_0 - \beta_1 X_t \tag{2}$$

[4] See Dickey and Fuller (1981).

If the two time-series in question are cointegrated, then it is necessary that the deviations should be integrated of a lower order than the individual series, i.e. $I(0)$.

Following Engle and Granger (1987), the test for cointegration involves three steps. First, through an ADF test the order of integration between the two time-series is determined. Second, the residuals ($\hat{u}_t$) from regressing equation (1), the cointegrating regression, are estimated[5]. Third, the ADF test[6] is applied to specify the order of integration of $\hat{u}_t$.

Having determined the cointegration property, the short-run adjustment process can be examined in terms of an ECM, which takes the following form:

$$\Delta Y_t = \gamma\hat{u}_{t-1} + a_0 + a_1\Delta X_t + \varepsilon_t \qquad (3)$$

where Δ denotes the first difference (e.g. $\Delta Y_t = Y_t - Y_{t-1}$) and ε_t is a random residual series.

In equation (3) $\hat{u}_{t-1}$ is the error correction term which captures the adjustment towards the long run equilibrium (steady state relationship) between Y_t and X_t. Of critical importance is the parameter γ, which provides an estimate of the *speed* of this adjustment. More specifically, this parameter indicates the proportion of the disequilibrium between Y_t and X_t that is corrected in the next period. Typically, one would expect that parameter $\gamma < 0$. The argument runs as follows. Assuming that Y_t was below its equilibrium level in period $t-1$ (so that $\hat{u}_{t-1} < 0$), then Y_t needs to be increased $(\Delta Y_t > 0)$ in an attempt to achieve equilibrium, implying that the value of the parameter γ should be negative.

5 The vector $[\hat{\beta}_0 \quad \hat{\beta}_1]$ is known as the 'cointegrating vector'.

6 Given that the obtained residuals are estimates, i.e. have not been derived from the original time-series, the critical values given by Dickey and Fuller (1981) are inappropriate. Instead the relevant critical values for this test can be found in the work of MacKinnon (1996).

Having outlined the empirical setting, the next section proceeds by examining the data used in the econometric analysis, followed by a presentation and a detailed explanation of the results.

3. Income Convergence across the US States

The discussion in Section 2 made clear that the ECM is an appropriate tool for examining long-run relationships between time-series, with the additional advantage of providing an estimate for the rate at which the adjustment process takes place. It follows, therefore, that the ECM is an effective approach in the study of long-run patterns in regional convergence.

As mentioned in introductory section, the ECM has implemented extensively in analysing regional disparities in terms of unemployment in which the national rate approximated steady-state. Such an approach inevitably leads to different patterns in the convergence behaviour of regions. This is not, perhaps, surprising since unemployment rates differ between regions due to differences in regional endowments (e.g. population, resources). Furthermore, it is reasonable to assume that those differences affect not only unemployment, but also, and perhaps to a greater extent, income differences, providing thus ample justification for using the ECM.

An important issue in this context is defining an appropriate proxy for steady-state equilibrium. While the level of per-capita income at national level seems to be a good candidate, nevertheless, does not take into account the local spillovers generated by geographical proximity. The national level of per-capita income is, essentially, a weighted average of all the local economies in a country. Such a measure ignores the fact that spillovers diffuse relatively faster towards neighbouring areas rather than to the nation as a whole. With this consideration in mind, it is reasonable to assume that the process of income convergence implied by the ECM would be more pronounced within a set of localities with close geographical proximity (physically contiguous localities). Consequently, the locality with the highest income in this set is chosen to approximate steady-state equilibrium. In this case the adjustment process would be faster since it is enhanced by geographical proximity[7], avoiding thus any downward biases imposed by the national level proxy.

This paper addresses the issue of long-run regional convergence in terms of per-capita income across the US States over the period 1929-2005. The regional groupings used are those delineated by the Bureau of Economic Analysis (BEA). In doing so, we implement an ECM in which the State with highest per-capita income in each BEA Region approximates steady-state equilibrium.

For each state, an ECM is estimated, which appears in the following form:

$$\Delta y_{it} = a_{i0} + a_{i1}\Delta y_{HISR_t} + \theta_i [y_{i_{t-1}} - (\beta_{i0} + \beta_{i1} y_{HISR_{t-1}})] + \varepsilon_{it} \quad (4)$$

where i denotes a given state in a given BEA Region, y is the natural logarithm of per-capita income and the subscript $HISR$ stands for the state with the highest per-capita income in each BEA Region. Following the discussion in Section 2, the parameter θ measures the adjustment rate or to which extend the gap between a state's per-capita income and per-capita income in *HISR* in one period is corrected in the next period.

Equation (4) does not take into account the effects of structural breaks. In relevant empirical studies across the BEA Regions of the US, the application was enhanced by the introduction of structural breaks (e.g. Tsionas 2001). While the absence of them might constitute a criticism to our approach, since it is possible to introduce such consideration in an ECM, nevertheless the primary question to be tackled with is *intra*regional convergence (amongst the states within a broad region) and not *inter*regional convergence, as it was the case in previous studies.

Before estimating the ECM in equation (4), the available time-series are tested for cointegration using the methodology proposed by Engle and Granger (1987). According to the ADF and Philips-Perron (1988) (PP) tests[8], all the states are $I(1)$ for

[7] Such, spatial, effects can be approximated in various ways. For example Quah (1996) examining spatial clusters across Europe, normalises per-capita income in a region by the average of all the physically surrounding regions. While this is an innovative approach in capturing spatial effects in a time-series context, it is difficult to be applied in an ECM.

[8] See Table A in the Appendix.

1% level of significance, with the exemption of the state of Idaho, where only the ADF test fails to accept the hypothesis of stationarity of the first difference. Following this process, an ADF test is conducted for unit-root in the estimated residuals obtained from the cointegrated equation:

$$y_{it} = \beta_{i0} + \beta_{i1} y_{HISR_t} \tag{5}$$

The relevant results for every state in each BEA Region are set out on Table 1 together with the estimated coefficients from equation (5) and the coefficient of the error-correction term (θ_i). Table 1 reports also the short-run relation between a state's per-capita income and *HIRS* (a_{i1})[9].

[Table 1 around here]

According to the results of the ADF tests, 11 states do not appear to cointegrate with their relevant *HISR*. Obviously, the property of convergence does not characterise these states (22% of the total) and the ECM does not apply in such cases. Nevertheless, the results are reported for the sake of convenience and to provide some indications of the underlying process of convergence. A striking fact from the results on Table 1 is that in the Mideast, no state is able to converge with the *HISR* (District of Columbia). In the case of New York, the next state with the highest income in the region of Mideast, the ADF test is statistically significant only marginally (at 10% level), however, the error-correction term turns to be statistically insignificant. Bearing this in mind, it might be argued that District of Columbia is, in fact, an outlier and therefore not representative of the underlying tendencies. To verify this further, we conduct a similar analysis where each *HISR* is tested for convergence with the District of Columbia (Table 2).

[Table 2 around here]

As it becomes apparent from the obtained results, the ADF test do not confirm the hypothesis of cointegration in most of the examined cases; only two cases yield marginally significant test values. Yet, the estimated error-correction terms appear to

[9] We also conduct the usual Ramsey RESET test (Ramsey, 1969) for the null hypothesis of non misspecification errors. A misspecification may arise due to omitted variables, incorrect functional form and correlation between the residuals and the dependent variable. The null hypothesis is not rejected for level 1%, 5% and 10% level of significance if the associated p-values are greater than 0.01, 0.05 and 0.1, respectively. The p-values for this test are given in Table B in the Appendix.

be statistically insignificant in all cases, enhancing therefore the argument that the District of Columbia is an outlier.

In this case a choice for an alternative *HISR* in the region of Mideast must be made. Choosing the state with the second highest per-capita income, namely New York, produces the results in Table 3.

[Table 3 around here]

As it might expected the states in Mideast exhibit tendencies towards convergence with New York. Thus, the particular state cannot be considered as an outlier and, consequently, is an appropriate proxy for steady-state equilibrium in the region of Mideast. This is established further by testing for convergence between the state of New York and the remaining *HISR*s (Table 4); a process yielding better results compared to those using the state of District of Columbia.

[Table 4 around here]

Nevertheless, the property of convergence is not apparent amongst all *HIRS*s. As the results indicate the cointegration ADF test is statistically significant at 10% level for California, Wyoming and Florida while Connecticut appears to produce the most robust results. It is worth noting that the aforementioned state exhibits the higher rate of adjustment among all the *HISR*s.

Insofar, the analysis has shown the classification of the US states according to their convergence behaviour, namely converging and non-converging towards a *HISR*. The underlying structure of the ECM implies that convergence occurs towards different steady-state equilibria, approximated in terms of the *HISR*s. This brings into consideration the hypothesis of ‘club-convergence’. However, the fact that convergence is apparent amongst most *HISR*s suggests that the US states as a whole are in a process towards long-run *overall* convergence.

Figure 1 shows the geographical location of the converging and non-converging states identified using the ECM[10]. As it might be expected most converging states share a common border with a *HISR* suggesting, thus, the existence of a strong geographical component in the process of convergence. Striking exemptions of this pattern are the

[10] See Table C in the Appendix for the abbreviations used in Figures 1 and 2.

non-converging states of Vermont and Pennsylvania which fail to converge with their respective *HISR*s. It is beyond argument that neighbouring to a relatively prosperous state might cause beneficial effects. In the case of the two aforementioned states, such effects do not seem to have an impact on their convergence behaviour towards steady-state equilibrium, irrespective of their physical proximity to a *HISR*, viz. New York. Absence of impacts due to geographical proximity to a *HISR* is also identified for the states of Alabama and Georgia; two non-converging states located close to Florida, the state with the highest per-capita income in the region of South-East. Similarly, the convergence pattern of Oregon and New Mexico seems to be 'indifferent' to the proximity to California and Arizona, respectively. Finally, in the case of Kentucky, proximity to two *HISR*s (Illinois and Missouri) is a factor unrelated to the shape of the convergence behaviour of that particular state.

[Figure 1 around here]

A factor that appears to be common in most cases mentioned above is that the *HISR*s in question contain big *agglomerations* (e.g. New York City, Los Angeles, etc). It is almost an article of faith in economic geography that agglomerations cause negative, as well as, positive effects in the area where located. However, the *exceptional* cases discussed here, imply that close proximity to a state containing an agglomerative centre might cause adverse effects to the convergence paths of the surrounding states.

Nevertheless, that there will be exceptions does not invalidate our ECM approach, or make it inapplicable. As can be seen from Figure 1, an ECM is in a position to describe adequately the convergence path for the vast majority of the US states.

A further advantage of the ECM is that it allows for a distinction of the converging states based on the rate at which cover the distance between long-run equilibrium. For each converging state the calculation of the years (n) to adjust is made for the 95% of the disequilibrium according to the following formula:

$$n = -\frac{\ln(0.05)}{|\theta_i|} \tag{6}$$

[Table 5 around here]

Table 5 shows the adjustment parameters together with the years required for deviations from steady-state equilibrium to almost dissipate. Following that the structure of ECM in this paper implies different steady-state equilibria, a variation in the adjustment rate is somehow anticipated. Based on the estimated rates, it might be argued that the majority of converging states follows a relatively slow adjustment process. In particular, 43% of the US states converge towards their steady-state equilibria at a rate in the range between 10% and 30%. Fewer states (12%) exhibit faster rates of adjustment (in the range between 40% and 60%).

The geographical distribution of the converging states according to their speed of adjustment is illustrated by Figure 2.

[Figure 2 around here]

The picture that appears is considerably more complicated to that revealed by Figure 1. This is to be expected, since in the convergence-classification exercise a new dimension is added. States are now ordered by their adjustment rates, which show a high degree of diversity causing difficulties in detecting an underlying pattern. Nevertheless, at a glance, it is suffice to state that a kind of 'clustering' is evident for four states located in the north part of the country (North Dakota, South Dakota, Minnesota and Wisconsin).

4. Conclusions

For more than twenty years the question of income convergence has caused one of the most remarkable debates in economics. Different empirical studies using various econometric techniques in diverse contexts were conducted. For the US states and regions, especially, the issue of income convergence has generated, and continues to do so, a vast literature. Our paper, however, does not simply add to the list of successful tests of income convergence across the US states. Most importantly, by implementing an ECM, our study provides an alternative econometric technique that allows a more thorough and detailed perspective in this topic. The ECM is extensively used in analysing convergence in terms of employment/unemployment. To our knowledge, such a model has not been deployed in assessing convergence possibilities regarding per-capita income. By testing this hypothesis across the US states, utilising an ECM, this paper extends the applicability of this model.

Following the econometric estimations, reported in Section 3 of the present paper, the hypothesis that the US states move towards different steady-state equilibria appears to be confirmed. This comes as a natural outcome of the ECM proposed in this paper. Steady-state equilibrium is now expressed in a more elaborated way compared to a simple measure of average per-capita income. To be more concrete, the state with the highest per-capita income in a region is applied in an attempt to depict the long-run equilibrium. Such a proxy also allows for the effects stemming from geographical proximity to be taken into account in a time-series framework, leading to one of the major findings in this paper. The empirical application has made us suspicious regarding the positive effects of agglomerations in promoting the process of income convergence in surrounding states. Hence, it might be argued that the relative convergence effects of agglomerations are examined in a more effective manner within the ambit of an ECM, providing thus a 'nexus' between time-series and spatial analysis. We are aware that more factors are required in order to obtain a more clear view of such issues. However, the framework introduced in this paper is flexible enough as to allow for more extensions. What is then the purpose of such a paper? Perhaps our main intention is to provoke further interest in the applicability of models based on the structure of error-correction mechanisms in examining the morphology of income convergence across spatial units.

Table 1: ECM, US States, 1929-2005

Region 1(Far West)	ADF test	β_{i0}	β_{i1}	θ_i	a_{i1}
HISR: California					
Nevada	-0.505***	0.093**	0.988***	-0.532***	1.125***
	[0]	(0.043)	(0.005)	(0.159)†	(0.168)
Oregon	-2.460	-0.534***	1.040***	-0.151**	1.166***
	[1]	(0.052)	(0.006)	(0.063)†	(0.062)
Washington	-2.774*	-0.569***	1.053***	-0.147**	1.165***
	[1]	(0.045)	(0.005)	(0.062)†	(0.056)

Region 2 (Great Lakes)	ADF test	β_{i0}	β_{i1}	θ_i	a_{i1}
HISR: Illinois					
Indiana	-3.384***	-0.519***	1.038***	-0.275***	1.206***
	[0]	(0.043)	(0.005)	(0.055) ‡	(0.055)
Michigan	-4.823***	-0.153***	1.001***	-0.463***	1.244***
	[1]	(0.035)	(0.004)	(0.092)†	(0.058)
Ohio	-5.400***	-0.155***	1.004***	-0.395***	1.105***
	[2]	(0.023)	(0.003)	(0.075) ‡	(0.035)
Wisconsin	-2.849*	-0.541***	1.044***	-0.343***	1.029***
	[10]	(0.024)	(0.030)	(0.125)†	(0.070)

Region 3 (Mideast)	ADF test	β_{i0}	β_{i1}	θ_i	a_{i1}
HISR: District of Columbia					
Delaware	-1.595	-0.15	-0.983***	-0. 091	1.051***
	[0]	(0.096)	(0.011)	(0.065)†	(0.228)
Maryland	-1.997	-0.903***	1.078***	-0.025	0.966***
	[1]	(0.102)	(0.012)	(0.043)	(0.113)
New Jersey	-2.218	-0.649***	1.059***	-0.032	0.991***
	[1]	(0.100)	(0.011)	(0.046) ‡	(0.188)
New York	-2.707*	-0.224***	1.010***	-0.061	0.941***
	[2]	(0.079)	(0.009)	(0.052) ‡	(0.237)
Pennsylvania	-2.210	-0.784***	1.053***	-0.047	1.067***
	[2]	(0.109)	(0.012)	(0.059) ‡	(0.236)

Region 4 (New England)	ADF test	β_{i0}	β_{i1}	θ_i	a_{i1}
HISR: Connecticut					
Maine	-3.286**	-0.539***	1.012***	-0.235**	0.929***
	[1]	(0.037)	(0.004)	(0.101)†	(0.072)
Massachusetts	-3.482**	-0.199***	1.007***	-0.234***	0.764***
	[1]	(0.031)	(0.003)	(0.054)†	(0.029)
New Hampshire	-3.678***	-0.682***	1.046***	-0.169**	0.843***
	[1]	(0.034)	(0.004)	(0.066) ‡	(0.078)
Vermont	-2.155	-0.744***	1.037***	-0.105**	0.922***
	[0]	(0.041)	(0.005)	(0.053)	(0.043)
Rhode Island	-2.530	0.078***	0.964***	-0.139**	0.813***
	[0]	(0.029)	(0.003)	(0.066)†	(0.030)

Region 5 (Plaines)	ADF test	β_{i0}	β_{i1}	θ_i	a_{i1}
HISR: Missouri					
Kansas	-2.667* [0]	-0.373*** (0.051)	1.043*** (0.006)	-0.257*** (0.053) ‡	1.349*** (0.075)
Minnesota	-4.212*** [0]	-0.266*** (0.022)	1.038*** (0.002)	-0.388*** (0.101) ‡	1.028*** (0.046)
Iowa	-2.744* [1]	-0.145*** (0.049)	1.015*** (0.006)	-0.553*** (0.127) ‡	1.410*** (0.067)
Nebraska	-4.630*** [0]	-0.289*** (0.046)	1.033*** (0.005)	-0.467*** (0.135) ‡	1.251*** (0.066)
North Dakota	-3.040** [0]	-0.930*** (0.122)	1.092*** (0.015)	-0.316*** (0.063) ‡	1.671*** (0.173)
South Dakota	-3.557*** [0]	-0.876*** (0.097)	1.085*** (0.012)	-0.379*** (0.093) ‡	1.729*** (0.123)

Region 6 (Rocky Mountains)	ADF test	β_{i0}	β_{i1}	θ_i	a_{i1}
HISR: Wyoming					
Idaho	-3.881*** [4]	-0.285*** (0.055)	1.012*** (0.007)	-0.580** (0.242) ‡	1.076*** (0.154)
Montana	-2.870* [1]	0.074* (0.039)	0.977*** (0.005)	-0.411*** (0.118) ‡	1.001*** (0.040)
Utah	-3.130** [0]	-0.192*** (0.046)	1.000*** (0.005)	-0.245** (0.095) †	0.924*** (0.107)
Colorado	-2.891* [0]	-0.404*** (0.042)	1.048*** (0.005)	-0.282*** (0.070)	0.838*** (0.055)

Region 7 (South East)	ADF test	β_{i0}	β_{i1}	θ_i	a_{i1}
HISR: Florida					
Arkansas	-2.882* [0]	1.068*** (0.051)	1.086*** (0.006)	-0.206** (0.090) ‡	1.103*** (0.099)
Alabama	-2.437 [3]	-0.996*** (0.049)	1.084*** (0.006)	-0.128* (0.076) †	1.134*** (0.099)
Georgia	-2.140 [0]	-0.802*** (0.041)	1.075*** (0.005)	-0.095* (0.055) †	1.001*** (0.068)
Kentucky	-2.587 [0]	-0.592*** (0.044)	1.043*** (0.005)	-0.165*** (0.053) ‡	1.017*** (0.103)
Louisiana	-2.838* [1]	-0.331*** (0.040)	1.015*** (0.005)	-0.173** (0.071)	0.963*** (0.060)
Mississippi	-3.265** [0]	-1.321*** (0.055)	1.104*** (0.007)	-0.293*** (0.104) †	1.310*** (0.139)
North Carolina	-3.067** [0]	-0.798*** (0.040)	1.072*** (0.005)	-0.179* (0.105) †	0.981*** (0.111)
South Carolina	-3.143** [0]	-0.994*** (0.048)	1.084*** (0.006)	-0.153* (0.083) †	1.006*** (0.104)
Tennessee	-2.639* [3]	-0.719*** (0.031)	1.062*** (0.004)	-0.226** (0.103) †	1.057*** (0.101)
Virginia	-4.171*** [1]	-0.402*** (0.032)	1.047*** (0.004)	-0.252** (0.105) †	0.835*** (0.125)
West Virginia	-3.798*** [2]	-0.047 (0.033)	0.979*** (0.004)	-0.283*** (0.081) †	0.902*** (0.105)

Region 8 (South West)	ADF test	β_{i0}	β_{i1}	θ_i	a_{i1}
HISR: Arizona					
New Mexico	-2.300	-0.570***	1.049***	-0.085	0.938*** (0.079)
	[0]	(0.050)	(0.006)	(0.058) †	
Oklahoma	-2.843*	-0.690***	1.069***	-0.148**	0.994*** (0.055)
	[1]	(0.048)	(0.006)	(0.063)	
Texas	-3.804***	-0.512***	1.059***	-0.247**	0.887*** (0.063)
	[0]	(0.033)	(0.004)	(0.124) ‡	

Notes: Figures in parentheses are standard errors, ***, **, * denote significance at 1%, 5% and 10%, respectively. In the ADF test equation only constant is included. The maximum lag length in ADF test is determined using the Schwarz information criterion. The number of lag lengths is in brackets. † and ‡ denote that the estimated standard errors are corrected using the heteroscedasticity consistent covariance matrix estimator proposed by White (1980) and heteroscedasticity autocorrelation consistent covariance matrix estimator, proposed by Newey and West (1987a,b), respectively.

Table 2: District of Columbia – outlier

HISR: District of Columbia					
	ADF test	β_{i0}	β_{i1}	θ_i	a_{i1}
California	-2.281	-0.167	1.001***	-0.041	0.995*** (0.224)
	[1]	(0.113)	(0.013)	(0.052) ‡	
Illinois	-0.992	-0.468***	1.029***	-0.049	1.121*** (0.287)
	[0]	(0.128)	(0.015)	(0.055) ‡	
Connecticut	-2.754*	-0.541***	1.055***	-0.074	0.987*** (0.215)
	[1]	(0.093)	(0.011)	(0.052) ‡	
Missouri	-2.161	-1.102***	1.078***	-0.018	1.016*** (0.236)
	[2]	(0.143)	(0.016)	(0.046) ‡	
Wyoming	-1.357	-0.793***	1.052***	-0.048	1.068*** (0.190)
	[0]	(0.152)	(0.017)	(0.047) ‡	
Florida	-2.843*	-1.488***	1.121***	-0.017	1.017*** (0.230)
	[2]	(0.152)	(0.017)	(0.057) ‡	
Arizona	-2.174	-1.075***	1.070***	-0.047	1.121*** (0.269)
	[1]	(0.153)	(0.017)	(0.059) ‡	

Notes: Figures in parentheses are standard errors, ***, **, * denote significance at 1%, 5% and 10%, respectively. In the ADF test equation only constant is included. The maximum lag length in ADF test is determined using the Schwarz information criterion. The number of lag lengths is in brackets. ‡ denotes that the estimated standard errors are corrected using heteroscedasticity autocorrelation consistent covariance matrix estimator, proposed by Newey and West (1987a, b), respectively.

Table 3: New York as an Alternative HISR for Mideast

Region 3 (Mideast)	ADF test	β_{i0}	β_{i1}	θ_i	a_{i1}
HISR: New York					
Delaware	-4.188***	0.200***	0.974***	-0.275***	1.117***
	[1]	(0.048)	(0.005)	(0.075)	(0.077)
Maryland	-4.683***	-0.669***	1.067***	-0.173**	1.019***
	[1]	(0.044)	(0.005)	(0.069) ‡	(0.083)
New Jersey	-3.913***	-0.422***	1.049***	-0.206***	1.065***
	[1]	(0.031)	(0.004)	(0.064) ‡	(0.056)
Pennsylvania	-2.587	-0.563***	1.044***	-0.177***	1.160***
	[1]	(0.041)	(0.005)	(0.059) ‡	(0.050)

Notes: Figures in parentheses are standard errors, ***, **, * denote significance at 1%, 5% and 10%, respectively. In the ADF test equation only constant is included. The maximum lag length in ADF test is determined using the Schwarz information criterion. The number of lag lengths is in brackets. ‡ denotes that the estimated standard errors are corrected using heteroscedasticity autocorrelation consistent covariance matrix estimator, proposed by Newey and West (1987a, b), respectively.

Table 4: Convergence between *HISRs*

HISR: New York					
	ADF test	β_{i0}	β_{i1}	θ_i	a_{i1}
California	-2.764 *	0.038	0.993***	-0.156**	1.113*** (0.068)
	[2]	(0.049)	(0.006)	(0.065) ‡	
Illinois	-1.476	-0.265***	1.022***	-0.103***	1.200*** (0.048)
	[0]	(0.060)	(0.007)	(0.038)	
Connecticut	-5.215***	-0.308***	1.044***	-0.251***	1.119*** (0.055)
	[1]	(0.038)	(0.004)	(0.079) ‡	
Missouri	-2.241	-0.893***	1.071***	-0.069**	1.085*** (0.049)
	[0]	(0.071)	(0.008)	(0.032)	
Wyoming	-2.761 *	-0.582***	1.044***	-0.084*	1.107*** (0.101)
	[1]	(0.100)	(0.012)	(0.053) ‡	
Florida	-2.892 *	-1.270***	1.114***	-0.108**	1.174*** (0.108)
	[1]	(0.081)	(0.009)	(0.050) †	
Arizona	-2.140	-0.870***	1.064***	-0.140**	1.255*** (0.109)
	[0]	(0.086)	(0.010)	(0.062) ‡	

Notes: Figures in parentheses are standard errors, ***, **, * denote significance at 1%, 5% and 10%, respectively. In the ADF test equation only constant is included. The maximum lag length in ADF test is determined using the Schwarz information criterion. The number of lag lengths is in brackets. † and ‡ denote that the estimated standard errors are corrected using the heteroscedasticity consistent covariance matrix estimator proposed by White (1980) and heteroscedasticity autocorrelation consistent covariance matrix estimator, proposed by Newey and West (1987a,b), respectively.

Table 5: Adjustment Process

State	Speed of Adjustment	Years to Adjust (n)
Idaho	0.58	5
Iowa	0.553	5
Nevada	0.532	6
Nebraska	0.467	6
Michigan	0.463	6
Montana	0.411	7
Ohio	0.395	8
Minnesota	0.388	8
South Dakota	0.379	8
Wisconsin	0.343	9
North Dakota	0.316	9
Mississippi	0.293	10
West Virginia	0.283	11
Colorado	0.282	11
Delaware	0.275	11
Indiana	0.275	11
Kansas	0.257	12
Virginia	0.252	12
Texas	0.247	12
Utah	0.245	12
Maine	0.235	13
Massachusetts	0.234	13
Tennessee	0.226	13
New Jersey	0.206	15
Arkansas	0.206	15
North Carolina	0.179	17
Maryland	0.173	17
Louisiana	0.173	17
New Hampshire	0.169	18
South Carolina	0.153	20
Oklahoma	0.148	20
Washington	0.147	20

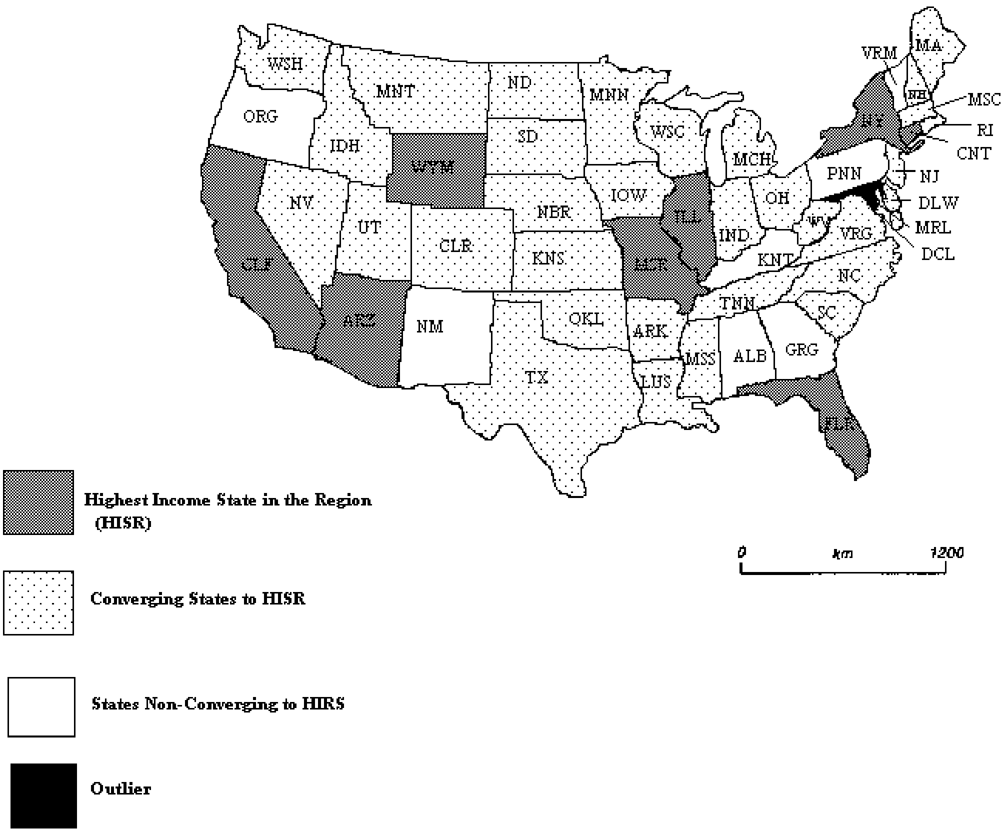

Figure 1: Converging States, US, 1929-2005

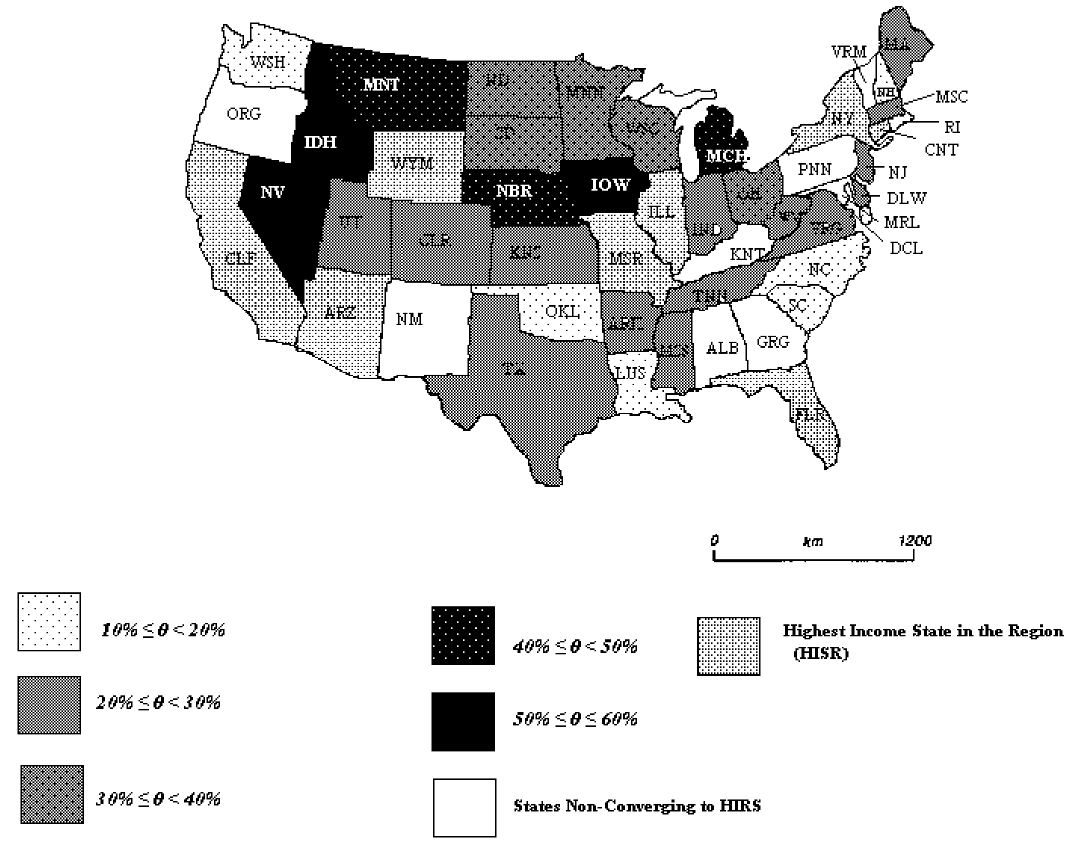

Figure 2: Adjustment Rates

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Appendix

Table A: Phillips-Perron test for Levels

State	Prob.	Bandwidth	Obs
ALABAMA	0.9577	3.0	76
ARIZONA	0.9719	2.0	76
ARKANSAS	0.9570	4.0	76
CALIFORNIA	0.9832	3.0	76
COLORADO	0.9789	2.0	76
CONNECTICUT	0.9912	2.0	76
DELAWARE	0.9887	3.0	76
DISTRICT_OF_COLUMBIA	0.9996	4.0	76
FLORIDA	0.9641	3.0	76
GEORGIA	0.9496	3.0	76
IDAHO	0.9575	7.0	76
ILLINOIS	0.9809	3.0	76
INDIANA	0.9640	2.0	76
IOWA	0.9705	0.0	76
KANSAS	0.9584	1.0	76
KENTUCKY	0.9658	3.0	76
LOUISIANA	0.9449	3.0	76
MAINE	0.9863	2.0	76
MARYLAND	0.9885	3.0	76
MASSACHUSETTS	0.9959	4.0	76
MICHIGAN	0.9731	1.0	76
MINNESOTA	0.9804	2.0	76
MISSISSIPPI	0.9589	3.0	76
MISSOURI	0.9761	4.0	76
MONTANA	0.9681	2.0	76
NEBRASKA	0.9681	2.0	76
NEVADA	0.9744	1.0	76
NEW_HAMPSHIRE	0.9904	4.0	76
NEW_JERSEY	0.9881	4.0	76
NEW_MEXICO	0.9545	3.0	76
NEW_YORK	0.9928	4.0	76
NORTH_CAROLINA	0.9509	3.0	76
NORTH_DAKOTA	0.9314	2.0	76
OHIO	0.9766	2.0	76
OKLAHOMA	0.9577	3.0	76
OREGON	0.9661	2.0	76
PENNSYLVANIA	0.9853	3.0	76
RHODE_ISLAND	0.9952	3.0	76
SOUTH_CAROLINA	0.9360	3.0	76
SOUTH_DAKOTA	0.9467	2.0	76
TENNESSEE	0.9644	3.0	76
TEXAS	0.9609	3.0	76
UTAH	0.9720	1.0	76
VERMONT	0.9898	3.0	76
VIRGINIA	0.9730	4.0	76
WASHINGTON	0.9694	2.0	76

WEST_VIRGINIA	0.9787	2.0	76
WISCONSIN	0.9780	2.0	76
WYOMING	0.9796	3.0	76

Note: In the test equation only constant is included.

Phillips-Perron test for first difference

State	Prob.	Bandwidth	Obs
D(ALABAMA)	0.0001	4.0	75
D(ARIZONA)	0.0006	12.0	75
D(ARKANSAS)	0.0000	0.0	75
D(CALIFORNIA)	0.0051	21.0	75
D(COLORADO)	0.0014	11.0	75
D(CONNECTICUT)	0.0007	14.0	75
D(DELAWARE)	0.0000	4.0	75
D(DISTRICT_OF_COLUMBIA)	0.0006	6.0	75
D(FLORIDA)	0.0026	6.0	75
D(GEORGIA)	0.0020	7.0	75
D(IDAHO)	0.0000	16.0	75
D(ILLINOIS)	0.0001	10.0	75
D(INDIANA)	0.0000	10.0	75
D(IOWA)	0.0000	5.0	75
D(KANSAS)	0.0006	19.0	75
D(KENTUCKY)	0.0000	9.0	75
D(LOUISIANA)	0.0020	11.0	75
D(MAINE)	0.0009	8.0	75
D(MARYLAND)	0.0024	11.0	75
D(MASSACHUSETTS)	0.0009	8.0	75
D(MICHIGAN)	0.0000	14.0	75
D(MINNESOTA)	0.0001	10.0	75
D(MISSISSIPPI)	0.0000	3.0	75
D(MISSOURI)	0.0015	12.0	75
D(MONTANA)	0.0000	9.0	75
D(NEBRASKA)	0.0000	5.0	75
D(NEVADA)	0.0000	5.0	75
D(NEW_HAMPSHIRE)	0.0011	8.0	75
D(NEW_JERSEY)	0.0051	9.0	75
D(NEW_MEXICO)	0.0002	9.0	75
D(NEW_YORK)	0.0059	9.0	75
D(NORTH_CAROLINA)	0.0001	5.0	75
D(NORTH_DAKOTA)	0.0000	1.0	75
D(OHIO)	0.0001	11.0	75
D(OKLAHOMA)	0.0001	12.0	75
D(OREGON)	0.0012	13.0	75
D(PENNSYLVANIA)	0.0015	8.0	75
D(RHODE_ISLAND)	0.0001	9.0	75
D(SOUTH_CAROLINA)	0.0001	5.0	75
D(SOUTH_DAKOTA)	0.0000	1.0	75
D(TENNESSEE)	0.0003	4.0	75
D(TEXAS)	0.0030	13.0	75
D(UTAH)	0.0012	11.0	75

D(VERMONT)	0.0017	12.0	75
D(VIRGINIA)	0.0000	3.0	75
D(WASHINGTON)	0.0085	21.0	75
D(WEST_VIRGINIA)	0.0001	8.0	75
D(WISCONSIN)	0.0006	32.0	75
D(WYOMING)	0.0000	36.0	75

Note: In the test equation only constant is included.

ADF test for levels

State	Prob.	No of Lags	Max Lag	Obs
ALABAMA	0.8272	1	11	75
ARIZONA	0.8642	2	11	74
ARKANSAS	0.8080	1	11	75
CALIFORNIA	0.9071	2	11	74
COLORADO	0.8871	2	11	74
CONNECTICUT	0.9516	2	11	74
DELAWARE	0.9461	1	11	75
DISTRICT_OF_COLUMBIA	0.9951	2	11	74
FLORIDA	0.7963	2	11	74
GEORGIA	0.8039	1	11	75
IDAHO	0.9325	1	11	75
ILLINOIS	0.9104	1	11	75
INDIANA	0.8791	1	11	75
IOWA	0.9705	0	11	76
KANSAS	0.8611	1	11	75
KENTUCKY	0.8616	1	11	75
LOUISIANA	0.7381	2	11	74
MAINE	0.9400	2	11	74
MARYLAND	0.8881	11	11	65
MASSACHUSETTS	0.9707	1	11	75
MICHIGAN	0.8798	1	11	75
MINNESOTA	0.9343	1	11	75
MISSISSIPPI	0.8186	1	11	75
MISSOURI	0.9011	1	11	75
MONTANA	0.9798	0	11	76
NEBRASKA	0.9797	0	11	76
NEVADA	0.9805	0	11	76
NEW_HAMPSHIRE	0.9576	1	11	75
NEW_JERSEY	0.9298	1	11	75
NEW_MEXICO	0.6691	9	11	67
NEW_YORK	0.9383	1	11	75
NORTH_CAROLINA	0.8454	1	11	75
NORTH_DAKOTA	0.9374	0	11	76
OHIO	0.9046	1	11	75
OKLAHOMA	0.8088	1	11	75
OREGON	0.8464	2	11	74
PENNSYLVANIA	0.9351	1	11	75
RHODE_ISLAND	0.9696	1	11	75
SOUTH_CAROLINA	0.8212	1	11	75

SOUTH_DAKOTA	0.9520	0	11	76
TENNESSEE	0.2792	3	11	73
TEXAS	0.8040	2	11	74
UTAH	0.7720	2	11	74
VERMONT	0.9429	1	11	75
VIRGINIA	0.9089	1	11	75
WASHINGTON	0.8323	2	11	74
WEST_VIRGINIA	0.9186	1	11	75
WISCONSIN	0.8607	1	11	75
WYOMING	0.8925	1	11	75

Note: In the test equation only constant is included. The number of lags for the ADF test was chosen according to the Schwarz information criterion.

ADF test for first difference

States	**Prob.**	**No of Lags**	**Max Lag**	**Obs**
D(ALABAMA)	0.0000	0	11	75
D(ARIZONA)	0.0061	4	11	71
D(ARKANSAS)	0.0000	0	11	75
D(CALIFORNIA)	0.0014	0	11	75
D(COLORADO)	0.0003	0	11	75
D(CONNECTICUT)	0.0000	1	11	74
D(DELAWARE)	0.0000	0	11	75
D(DISTRICT_OF_COLUMBIA)	0.0014	1	11	74
D(FLORIDA)	0.0000	1	11	74
D(GEORGIA)	0.0005	0	11	75
D(IDAHO)	0.1824	7	11	68
D(ILLINOIS)	0.0001	0	11	75
D(INDIANA)	0.0000	0	11	75
D(IOWA)	0.0001	11	11	64
D(KANSAS)	0.0001	0	11	75
D(KENTUCKY)	0.0000	0	11	75
D(LOUISIANA)	0.0001	1	11	74
D(MAINE)	0.0000	1	11	74
D(MARYLAND)	0.0000	1	11	74
D(MASSACHUSETTS)	0.0003	0	11	75
D(MICHIGAN)	0.0000	0	11	75
D(MINNESOTA)	0.0000	0	11	75
D(MISSISSIPPI)	0.0000	0	11	75
D(MISSOURI)	0.0003	0	11	75
D(MONTANA)	0.0000	0	11	75
D(NEBRASKA)	0.0000	0	11	75
D(NEVADA)	0.0000	0	11	75
D(NEW_HAMPSHIRE)	0.0003	0	11	75
D(NEW_JERSEY)	0.0014	0	11	75
D(NEW_MEXICO)	0.0000	3	11	72
D(NEW_YORK)	0.0019	0	11	75
D(NORTH_CAROLINA)	0.0000	0	11	75
D(NORTH_DAKOTA)	0.0000	0	11	75
D(OHIO)	0.0000	0	11	75

D(OKLAHOMA)	0.0019	11	11	64
D(OREGON)	0.0000	1	11	74
D(PENNSYLVANIA)	0.0003	0	11	75
D(RHODE_ISLAND)	0.0000	0	11	75
D(SOUTH_CAROLINA)	0.0000	0	11	75
D(SOUTH_DAKOTA)	0.0000	0	11	75
D(TENNESSEE)	0.0001	0	11	75
D(TEXAS)	0.0000	1	11	74
D(UTAH)	0.0002	0	11	75
D(VERMONT)	0.0004	0	11	75
D(VIRGINIA)	0.0000	0	11	75
D(WASHINGTON)	0.0000	1	11	74
D(WEST_VIRGINIA)	0.0000	0	11	75
D(WISCONSIN)	0.0009	0	11	75
D(WYOMING)	0.0003	0	11	75

Note: In the test equation only constant is included. The number of lags for the ADF test was chosen according to the Schwarz information criterion.

Table B: Ramsey RESET Test	**p-value**
Region 1(Far West)	
California	
Nevada	0.048
Oregon	0.164
Washington	0.371
Region 2 (Great Lakes)	
Illinois	
Indiana	0.057
Michigan	0.014
Ohio	0.138
Wisconsin	0.039
Region 4 (New England)	
Connecticut	
Maine	0.534
Massachusetts	0.060
New Hampshire	0.001
Vermont	0.019
Rhode Island	0.760
Region 5 (Plaines)	
Missouri	
Kansas	0.498
Minnesota	0.178
Iowa	0.312
Nebraska	0.108
North Dakota	0.121
South Dakota	0.116
Region 6 (Rocky Mountains)	
Wyoming	
Idaho	0.628
Montana	0.684
Utah	0.776
Colorado	0.119
Region 7 (South East)	
Florida	
Arkansas	0.057
Alabama	0.128
Georgia	0.309
Kentucky	0.061
Louisiana	0.611
Mississippi	0.224
North Carolina	0.069
South Carolina	0.160
Tennessee	0.003
Virginia	0.101
West Virginia	0.001
Region 8 (South West)	
Arizona	
New Mexico	0.000
Oklahoma	0.006
Texas	0.013

	p-value
New York	
California	0.020
Illinois	0.061
Connecticut	0.189
Missouri	0.760
Wyoming	0.713
Florida	0.000
Arizona	0.414

	p-value
New York	
Delaware	0.146
Maryland	0.025
New Jersey	0.002
Pennsylvania	0.757

Table C: The States used in the empirical analysis
Alabama (ALB)
Arizona (ARZ)
Arkansas (ARK)
California (CLF)
Colorado (CLR)
Connecticut (CNT)
Delaware (DLW)
District of Columbia (DCL)
Florida (FLR)
Georgia (GRG)
Idaho (IDH)
Illinois (ILL)
Indiana (IND)
Iowa (IOW)
Kansas (KNS)
Kentucky (KNT)
Louisiana (LUS)
Maine (MA)
Maryland (MRL)
Massachusetts (MSC)
Michigan (MCH)
Minnesota (MNN)
Mississippi (MSS)
Missouri (MSR)
Montana (MNT)
Nebraska (NBR)
Nevada (NV)
New Hampshire (NH)
New Jersey (NJ)
New Mexico (NM)
New York (NY)
North Carolina (NC)
North Dakota (ND)
Ohio (OH)
Oklahoma (OKL)
Oregon (ORG)
Pennsylvania (PNN)
Rhode Island (RI)
South Carolina (SC)
South Dakota (SD)
Tennessee (TNN)
Texas (TX)
Utah (UT)
Vermont (VRM)
Virginia (VRG)
Washington (WSH)
West Virginia (WV)
Wisconsin (WSC)
Wyoming (WYM)