



**Investigating Convergence of the U.S. Regions:
A Time-Series Analysis**

Richard Kane

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*The views expressed in this paper are solely those of the author and
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Abstract: *Most economists conclude that the U.S. regions have converged in per capita earnings during a majority of the 20th century, though controversy abounds over the methods employed to test for such convergence. Using time-series techniques, this paper finds evidence that the U.S. regions have conditionally converged in per capita earnings. The findings in this paper differ from cross-sectional studies, which implicitly assume that all regions converge toward the same steady-state and at the same rate. The findings in this paper differ from other time-series studies with its use of recursive parameter estimates¹.*

Introduction

Most economists conclude that per capita incomes among the States and regions² have converged during a majority of the twentieth century, though controversy abounds over the methods employed to test for such convergence. Barro and Sala-i-Martin find convergence occurring among the States and regions for the years 1880 to 1988 (Barro and Sala-i-Martin 1992). Several economists, such as Garnick(1990) and Sherwood(1996), find convergence continuing up until about 1979. Economists generally agree that per capita incomes diverged between the years 1979 to 1988, but they disagree over what knowledge can be ascertained from this apparent change in trend. Sherwood(1996) argues that this period of divergence arose from a positive shock to the Northeast States. Other economists argue that the 1980's divergence stemmed from falling oil prices. The important question is whether the 1980's divergence represents a temporary interruption in convergence due to shocks affecting States and regions differently or whether it signifies the end (or even a reversal) of convergence among the States and regions.

Competing economic growth theories provide limited and conflicting answers as to whether integrated economies, such as the States and regions, will converge over time. Standard neoclassical, Solow-type, growth theory suggests that earnings³ should converge among integrated

¹Recursive estimation involves estimating an equation over successively larger samples, starting from a minimum sub-sample and extending to the full sample. Parameter stability may be tracked by looking at the behavior of the estimated coefficients, as sample size is increased, to see whether they fluctuate significantly or remain stable (Banerjee et al. 1997).

²U.S. regions refer to the eight regions defined by the Bureau of Economic Analysis, U.S. Department of Commerce. See [Figure 1] for a map of these regions.

³Economic growth and convergence theory is more directly applicable to earnings and not income, as commonly used. Earnings is a component of income. Income includes earnings as well as interest, dividends, rent, and transfer payments. Carlino and Mills(1996) also focus on

economies due to decreasing returns. In the presence of decreasing returns, additional factor inputs yield higher returns in regions with lower earnings and lower returns in regions with higher earnings. With technology homogenous across regions, firms employ factors (i.e. labor) where they are cheaper in order to achieve a higher return. In the presence of factor mobility, differences in factor returns diminish over time as labor and capital migrate to regions where the payoff for their services is highest. Neoclassical theory does not reject disparities occurring among economies due to shocks to relative earnings, but it does suggest that decreasing returns and factor mobility will dissipate the effect of such shocks.

Endogenous growth theory suggests that integrated economies may actually diverge in their growth paths, becoming more unequal from one another over time. Endogenous growth theory casts doubt on the notion that decreasing returns holds true for most industries. According to endogenous growth theory, firms' location decisions may create positive externalities for neighboring firms in the region. For instance, firms demanding skilled labor might benefit by locating close to other firms demanding the same skilled labor. In such cases, firms may be choosing not to locate in lower-earnings regions because the returns on labor are higher in the region with the existing pool of skilled labor. A mobile labor force will further increase this clustering of economic activity as skilled workers move to join these labor pools. Firms may also choose to locate in regions with higher earnings if those regions offer a higher demand for their goods and services. This notion has been termed the home-market effect. By locating within (or near) these higher-earnings regions, firms can minimize transport costs. Firms in certain industries, particularly some service-producing industries, may choose to locate in a higher-earnings region in order to gain access to their customers.

Strictly speaking, the above theories apply to economies where goods, labor, and capital flow freely across borders. The States and regions of the United States are a real-world example of closely integrated economies where labor and capital flow freely. As nations reduce their barriers to trade and factor mobility, the implications of these growth models become more and more relevant to other areas of the world. Finding convergence or divergence among the U.S. regions suggests what might occur among national economies that choose to become more integrated with their neighbors-- perhaps through the establishment of regional trade arrangements

earnings.

similar to the European Union or the North American Free Trade Agreement.

Methods of Testing for Convergence

There are several competing methods to test for convergence; and, there are about as many competing definitions of convergence to correspond with the different methods for testing. Two of the more common types of convergence measured are sigma-convergence and beta-convergence. Sigma-convergence occurs when the disparities in per capita earnings among the regions decrease over time. One can test for sigma-convergence by testing whether the standard deviation of per capita earnings among the regions narrows over time. Beta-convergence occurs when per-capita earnings in the lower-earnings, or poorer, regions grow at a faster rate than in the higher-earnings, or richer, regions. Both sigma-convergence and beta-convergence can be either absolute or conditional. Absolute convergence means regions are converging toward an identical, single value of per capita earnings. Conditional convergence means regions are converging up to an extent, or once certain factors are accounted for. More specifically, under conditional convergence each region is converging toward its own, unique steady state and per capita earnings are becoming more similar across regions only to the extent that steady states are similar for each region.⁴

In this paper, I test for conditional beta-convergence because it best fits the type of convergence predicted by the neoclassical, Solow model. Conditional beta-convergence means poorer regions grow at a faster rate than richer ones, but only to the extent that differences in their initial per capita earnings arise from being at different points relative to their own steady state. The Solow model predicts only that regions will converge toward their own steady state. If regions have differing steady states, then the Solow model predicts that disparities in per capita earnings between the regions will persist (Mankiw, Romer, Weil 1992). Thus, absolute beta-convergence becomes a special case of all regions converging toward steady states that are identical.

Two popular methods of testing for conditional beta-convergence are the cross-sectional and time-series approaches. Barro and Sala-i-Martin find convergence using a cross-sectional test

⁴The term “conditional convergence” is used by Mankiw, Romer, and Weil (1992), who argue that the Solow model predicts convergence among countries only after controlling for the determinants of each country’s steady state.

relating the growth rates of State and region economies during the period of analysis to their initial levels of per capita income; an inverse relationship suggests convergence. Equation (1), similar to the one used by Baumol (1986), regresses income growth over a particular period on a constant and on initial income. Again, a negative beta term implies convergence.

$$(1) \ln[(Y/N)_{i,1998}] - \ln[(Y/N)_{i,1929}] = \alpha + \beta \ln[\ln(Y/N)_{i,1929}] + u_i$$

where Y/N = per capita income; β = rate of convergence across all regions

There are three shortcomings to a cross-sectional approach. First, a cross-sectional approach assumes all regions converge at the same rate, which is estimated by the beta term in equation (1). This means that, using this approach, one can't distinguish between a change in the overall rate of convergence and a scenario where some regions reach their steady-state while other regions continue to converge. Second, a cross-sectional approach assumes each region is converging toward an identical steady state. Though variables for steady-state determinants can be included in a cross-sectional equation, model specification may be difficult to achieve since, under the Solow model, steady-state determinants can include anything other than labor and capital that affect per capita earnings. Moreover, using steady-state determinants as variables in a cross-sectional equation necessarily assumes that each region's steady state is affected by each of those determinants in the same manner and magnitude. Simplifications in the Solow Model make the assumption of identical steady states for each region even more problematic. Third, a cross-sectional approach infers dynamic properties on per capita earnings while ignoring problems associated with potential non-stationarities in the data.

Carlino and Mills use a time-series approach to test whether the U.S. regions exhibit conditional beta-convergence. They argue that two conditions are required for convergence: shocks to relative per capita earnings for each region should have transient, or dissipating, effects and regions having relative per capita earnings initially above their compensating differential should exhibit slower growth than those regions having relative per capita earnings initially below their compensating differential. Carlino and Mills test whether relative per capita earnings are converging toward unity with the national average, plus or minus a compensating differential. This compensating differential may differ for each region as a result of that region's unique characteristics.

Following Carlino and Mills, I estimate an equation for relative per capita earnings (RE) for each region (see equation 9) . For this approach, the beta term is the deterministic trend parameter, or the rate of convergence for each region. Like Carlino and Mills, I assume that each region has an equilibrium level of relative per capita earnings.⁵ A region's equilibrium relative per capita earnings is a function of some combination of steady-state determinants (i.e. education, social climate, political institution, etc.), but it's also a function of differences among the regions in terms of labor force characteristics, industry mix, and prices. These last three factors are not among the steady-state determinants referred to in growth theory; however, they must be recognized due to simplifications in the Solow model. For instance, the Solow model assumes the entire population of an economy is composed only of workers, but real-world per capita figures include a region's population of retirees, children, and the unemployed. Also, the Solow model uses a single-industry economy, or simply refers to one aggregate production function. Even if we assume decreasing returns for all industries, variations in the shape of the production functions across industries makes a region's industry mix a factor affecting its steady state, and therefore its equilibrium relative per capita earnings. Because regional price indices are not available to adjust regional earnings, price differences among the regions also affect each region's equilibrium relative per capita earnings.

Extending upon the earlier work done by Carlino and Mills (1996), I first test whether relative per capita earnings for each region are stationary as a necessary, though not sufficient, condition for conditional beta-convergence. Shocks to relative per capita earnings must be transient in order for convergence to occur; that is, the effects of shocks to relative per capita earnings must dissipate over time. This requires that relative per capita earnings for each region be stationary. Unit-root tests are run on relative per capita earnings for each of the regions. If a unit root is found, then shocks to relative per capita earnings lead to permanent deviations in relative per capita earnings and convergence cannot take place for that region. In ignoring the issue of stationarity, a cross-sectional approach is more vulnerable to sample (time interval) selection bias. Continuing to test for conditional beta-convergence, I then test whether regions having relative per capita earnings initially above their equilibrium level exhibit slower growth than those regions having relative per capita earnings initially below their equilibrium level. An

⁵Carlino and Mills refer to this equilibrium relative per capita earnings as a compensating differential.

inverse relationship between the trend (beta) and intercept term implies convergence (see equation 9). The benefits of this time-series approach are that it allows each region to converge at a different rate toward a unique steady state. The findings from this time-series approach are therefore more robust to the influence of regional differences in labor force characteristics, industry mix, and prices, as well as any differences in actual steady states.

Carlino and Mills conclude that the regions are converging if we allow for a trend break in 1946. Carlino and Mills find that the regions are converging up until around 1946. After 1946, they find that the regions are converging at a much slower rate (if at all for some regions). My findings differ from Carlino and Mills for two reasons. First, I use Perron-Phillips unit root tests instead of Dickey-Fuller unit root tests. Unlike Carlino and Mills, I am able to reject a unit root for all regions (except New England perhaps) without having to establish a trend break around 1946. Second, I use recursive least-squares estimation (RLS) for the trend (beta) and intercept term to interpret when or if conditional beta-convergence is achieved for each region. RLS estimation involves estimating an equation over successively larger samples (time interval), starting from a minimum sub-sample and extending to the full sample. Concluding that a region achieved convergence at a particular point in time requires not only that the beta term be significant and inversely related to the intercept term up to this point in time, but also that the beta term becomes (and remains) insignificant after this point in time. I find using an RLS approach preferable to conducting t-tests on beta for a series of exogenously determined change points, or supposed trend breaks. Estimating beta using RLS is a more agnostic method of inquiry into the convergence characteristics of each region.

Using recursive estimates of beta and the intercept term, I find evidence that all eight regions continue to converge significantly after 1946. The Great Lakes, Plains, and Far West Regions continue to converge through 1998 (the latest year of data). The New England and Rocky Mountain Regions reach their relative steady-states in the mid-1950's, while the Midwest and Southeast Regions converge until the late 1970's and late 1980's respectively. The Southwest Region converges into the early 1960's. The apparent divergence of the 1980's is due mainly to positive shocks to the New England Region and due partly to a negative shock to the Great Lakes Region.

Modeling Relative Per Capita Earnings

Conditional Beta-Convergence Hypothesis

The convergence hypothesis most often used in the literature is one of absolute convergence. Absolute convergence states that relative per capita earnings for each region will converge toward unity (or zero when the data used are in logged form). The conditional convergence hypothesis states that relative per capita earnings for each region will not converge toward unity, but towards a stable differential. This ‘compensating differential’, which is assumed to be time-invariant, exists due to unique characteristics in each region. These unique characteristics include steady-state determinants such as a region’s education level, social climate, and political institutions. However, features such as a region’s labor force characteristics, industry mix and prices also affect its compensating differential, or equilibrium level of relative per capita earnings. Labor force characteristics include population traits that affect labor force participation and unemployment.

Borrowing from Carlino and Mills (1996), I employ a simple model of a region’s relative per capita earnings to explain the notion of a conditional convergence equilibrium. The equilibrium nominal wage in each region (i) is a function of prices (P), capital in the region (K), and steady-state determinants in the region (S):

$$(2) \quad W_i = P_i * h(K_i, S_i)$$

where P_i is a regional price index.

Regional Earnings (Y) is a product of nominal wages and number of workers in the region (N).

$$(3) \quad Y_i = W_i * N_i$$

$$(4) \quad N_i = (1-u_i)\lambda_i * POP_i$$

where POP_i is population, u_i is unemployment, and λ_i is the labor force participation rate.

Substituting equation (2) into equation (3) and (4) gives a region’s per capita earnings (y).

$$(5) \quad y_i = Y_i / POP_i = P_i * g(K_i, S_i, u_i, \lambda_i)$$

Therefore, the log of a region’s per capita earnings relative to the nation (in equilibrium) is:

$$(6) \quad RE_i^e = \log(y_i / y_n) = \log[P_i * g(K_i, S_i, u_i, \lambda_i)] - \log[P_n * g(K_n, S_n, u_n, \lambda_n)]$$

where subscript n refers to a national average.

Equation (6) shows that the log of a region’s relative per capita earnings may differ from zero in equilibrium due to differences in prices, capital (includes industry mix), steady-state determinants, unemployment, and labor force participation.

The times-series properties of a region's relative per capita earnings, RE_i , consists of two parts: the equilibrium level, or compensating differential, RE_i^e , and the deviation, or stochastic term, u_t .

$$(7) \quad RE_{it} = RE_i^e + u_t$$

Allowing for conditional convergence, $RE_i^e \neq 0$. The error term is modeled with a deterministic linear trend and a stochastic term:

$$(8) \quad u_t = v_0 + \beta t + v_t$$

Beta-convergence requires an inverse relation between v_0 and β . v_0 is the initial deviation from equilibrium and β is the region's rate of convergence. If a region is initially above its compensating differential, $v_0 > 0$, then it should grow at a slower rate than the national average, $\beta < 0$. Likewise, if a region is initially below its compensating differential, $v_0 < 0$, then it should grow at a faster rate, $\beta > 0$. As Carlino and Mills point out, this time-series approach to β -convergence allows the rate of convergence to differ across regions.

Substituting equation (8) into equation (7) is:

$$(9) \quad RE_{it} = \alpha + \beta t + v_t$$

where $\alpha = RE_i^e + v_0$.

Although estimates of α do not separately identify RE_i^e and v_0 , α and β should still be inversely related under the notion of beta-convergence⁶. Convergence requires that the deviations from relative trend growth, v_t , be transient; that is, v_t must be stationary and have a fixed distribution with a mean of zero.

Data sources

Per capita earnings data for each region is calculated using earnings and population data from the State Personal Income Series: 1929-1998, Bureau of Economic Analysis, U.S.

⁶It is possible for v_0 to be large but opposite in sign from RE_i^e so that α and β are positively related. Carlino and Mills argue that empirical results suggest that this is counterfactual.

Department of Commerce. Per capita employment data for each region is calculated using employment data from the Regional Economic Information System (REIS) CD: 1969-1998, Bureau of Economic Analysis, U.S. Department of Commerce. Population and earnings data on the REIS CD are consistent with population and earnings data for the State personal income series. REIS employment data is not available prior to 1969. The industry similarity index for each region is calculated using earnings-by-industry data from the State personal income series: 1958-1998, Bureau of Economic Analysis, U.S. Department of Commerce. Earnings-by-industry data are not available prior to 1958.

Testing for Stationarity

Conditional beta-convergence requires that a region's relative per capita earnings be stationary. Shocks to a stationary time series are transient in that their effects will dissipate and the series will revert back to its long-run mean or trend. If relative per capita earnings are non-stationary for a particular region, then shocks affecting that region's relative per capita earnings have permanent effects and convergence cannot occur. In order to determine whether a series is stationary, we must test for unit roots in the auto-regressive terms. If a unit root is present, the series is non-stationary.

Testing for unit-roots can be difficult for three reasons. First, it is difficult to distinguish a unit-root process from a near unit-root process. Second, the presence of deterministic variables affects the test results. Third, the presence of structural breaks can bias the test results toward a non-rejection of the unit root. These last two difficulties present a particular challenge in this case since, in testing for beta-convergence, we are trying to figure out when and if there are significant deterministic variables and structural breaks in the data-generating process.

Autocorrelation functions (ACF) and partial autocorrelation functions (PACF) suggest either AR(1) or ARMA(1,1) processes for each of the regions. However, it is difficult to differentiate the ACF and PACF of a near unit-root process from those of a unit-root process. Dickey-Fuller tests⁷ were applied to relative per capita earnings for each region. For the period 1929-1998, a unit-root could not be rejected for any of the regions regardless of whether or not a deterministic trend was included in the regression equation. This suggests that the series are

⁷Augmented Dickey-Fuller tests were used when appropriate for each region.

integrated and the regions are not converging. But, using Phillips-Perron tests⁸, the unit root could be rejected for each of the regions during the time period 1929-1998, though evidence is somewhat less convincing for the New England Region. The Phillips-Perron test has a greater power to reject a false null hypothesis of a unit root by allowing for a weaker set of assumptions regarding the error process; the errors can be weakly dependent and heterogeneously distributed (Perron 1989). The Dickey-Fuller test assumes that the errors are statistically independent and with constant variance. Although the Augmented Dickey-Fuller test can deal with correlated errors, the Phillips-Perron test has greater power so long as the true data-generating process is one of positive moving-average terms (Enders 1995). Recursive Least-Squares estimates for each of the regions during the 1929-1998 period indicate an unstable variance term, suggesting a bias in the Dickey-Fuller tests that would be absent from the Phillips-Perron tests.

Trend breaks in a series also bias unit-root tests toward a non-rejection of the unit root. A series with a structural break will be interpreted as a series having permanently persistent shocks instead of a series that is stationary around a structural break (Enders 1995). In order to test for unit roots around a structural break using Dickey-Fuller tests, a test must be run for each of the subperiods occurring before and after the break. But, if the subperiods are not large enough, low degrees of freedom will bias the results toward the non-rejection of a unit root. Phillips-Perron tests can test for unit roots around structural breaks while maintaining the degrees of freedom afforded by the entire sample period. Thus, in the presence of structural breaks, Phillips-Perron tests have a still greater power to reject a false null hypothesis of a unit root than Dickey-Fuller tests. For all regions, Phillips-Perron tests rejected the unit root before taking account of any structural breaks. Taking account of structural breaks did allow the Dickey-Fuller tests to reject the unit root for some regions.

Using Dickey-Fuller tests, Carlino and Mills could also not reject the unit root for any of the regions during the 1929-1990 period. They resorted to parametric and non-parametric methods to examine the amount of persistence (Carlino and Mills 1996) in relative earnings for each region. If there was a unit-root, then persistence would be unending. A near unit-root might show lasting persistence, but it would not be permanent. Carlino and Mills were only able to rule out substantial persistence after they allowed for a structural break in 1946. Allowing for the trend

⁸All Phillips-Perron tests were run with a constant term and deterministic trend term.

break, Carlino and Mills conclude that the effects of shocks to relative earnings tend to dampen after 5-10 years, supporting the notion that relative earnings are, in fact, stationary.⁹

Testing for Beta-Convergence

Beta-convergence occurs when regions starting out at above-average earnings levels grow slower than regions starting out at below-average earnings levels. Conditional beta-convergence occurs when regions starting out at relative earnings levels above their compensating differential, or equilibrium level, grow slower than regions starting out at relative earnings levels below their compensating differential. Conditional beta-convergence requires a negative relationship between α and β in equation (9) for each region.

For the period 1929-1998, three regions (Great Lakes, Plains, and Far West) show beta-convergence (see Table 1). No significant trend is found for any of the other five regions. However, this does not mean that those five regions are not converging since they may achieve conditional convergence at a point in time prior to 1998. For example, a region that converges to its equilibrium level in the mid 1950s and then maintains its equilibrium level thereafter may appear to have an insignificant trend for the entire sample period of 1929 -1998. Determining when beta becomes insignificant, stabilizes, or breaks becomes of paramount concern. It is not enough to search for a time period where the series has a significant beta with the appropriate sign. Concluding that a region converges at a certain point in time requires not only that beta be significant and inversely related to α (intercept term) up to this point in time, but also that beta becomes (and remains) insignificant after this point in time.

Several cross-sectional studies point to the immediate post-World War II period and the 1980s as points in time where convergence is achieved or changes in the rate of convergence occur. Economists looking at sigma-convergence especially point to the 1980s as a period of divergence (Sherwood 1996). Carlino and Mills conclude that regions achieve convergence by around 1946 and that the supposed 1980s divergence is merely a result of temporary shocks.

Using recursive estimates of beta and intercept term (α), this paper finds that the regions

⁹The impulse response functions generated from the vector autoregression (VAR) models (used later in this paper) for the effect on earnings from a positive shock to earnings are similar to Carlino and Mills' parametric tests. However, the VAR is limited to the years 1974-1998 due to data availability.

are conditionally beta-converging, but at varying rates and with each region achieving convergence at varying points in time (see Table 4). Three regions (Great Lakes, Plains, and Far West) continue to converge through 1998, and may still be converging. The New England and Rocky Mountain Regions converge until the mid-1950s, and then maintain a stable compensating differential, or equilibrium. The Mideast and Southeast regions converge until around 1980 and 1989, respectively. The Southwest region converges until around 1962. Graphs of the recursive coefficient estimates for the beta and intercept term (α) best illustrate these patterns of convergence (see figures 3-10). The graphs show changing betas and intercept terms with appropriate signs during the period of convergence that suggest a decelerating rate of convergence in most cases. Convergence is achieved once beta becomes (and remains) insignificant, which is indicated by the confidence interval including zero. The graphs show the recursive parameter estimates as well as confidence intervals at the 5% significance level.

Little support is found for a trend break in 1946 that would suggest convergence is achieved. New England shows a significant decrease in its rate of convergence, but the Great Lakes and Far West show an increased rate of convergence after 1946. The remaining regions show no significant change in convergence rates in 1946. Two factors may explain the apparent sigma-divergence during the 1980s. First, a positive shock affects New England during the 1980s. New England's convergence rate (see figure 7) becomes positive for about eight years before stabilizing again. Evidence suggests a divergent trend continuing for New England only into the early 1990's. Researchers commonly point to a surge in defense-related activities (Henderson 1990) and the role of financial services (Browne 1991) as possible explanations for positive shocks to the New England Region. Case (1991) argues that increased construction and real estate activity contributed to New England's boom as well as its subsequent bust. Second, a negative pulse shock affects the Great Lakes Region in the early 1980's, which decreases the region's compensating differential, or equilibrium level, and coincides with the beginning of a trend of convergence for the region. This negative pulse shock may reflect the recessions of 1980 and 1981-82.

Testing Conditional Convergence: A VAR approach

A region's equilibrium relative per capita earnings is not only a function of its steady-state determinants, but also of its labor force characteristics, industry mix, and prices (see equation 6).

These last three factors are perhaps more likely to differ across the U.S. regions than the steady-state determinants commonly referred to in growth theory (i.e. education, social climate, political institutions, etc.). But, including additional variables in a cross-sectional equation to account for these factors assumes they affect each region in the same manner and magnitude; it also assumes these factors are exogenous to relative earnings. I construct vector auto-regression (VAR) models for each region that incorporate variables for relative per capita earnings, relative per capita employment, and industry mix. Impulse response functions from these models confirm that shocks to labor force characteristics and industry mix affect each region's relative earnings differently, both in manner and magnitude. The impulse response functions also suggest a transient effect on relative per capita earnings from these shocks, which lends some comfort to the assumption made in the time-series approach of an equilibrium for each region's relative per capita earnings that is time-invariant.

In this paper, I use second-order (VAR) models for each region for the years 1972-1998. Along with relative per capita earnings, two variables are included in each VAR: relative per capita employment, used as a proxy for labor force participation and unemployment, and a variable measuring the similarity of a region's industry mix to the national industry mix. The variable measuring the similarity of a region's industry mix is based on earnings data for each industry and is calculated using the following formula:

$$SI_r = [1 - (\sum_{i=1}^n |S_{i,r} - S_{i,n}|)]$$

where SI_r is the similarity index for region r ; $S_{i,r}$ is industry i 's share of earnings in region r ; $S_{i,n}$ is industry i 's share of earnings in the U.S.¹⁰ A VAR approach allows one to examine the relationships among a set of economic variables without placing restrictions on feedback effects between each of the variables. In this way, one does not have to decide whether industry mix and relative employment are exogenous; therefore, endogenous growth theories are not ruled out through the modeling process.

The absence of Granger causality among the three variables (including for feedback effects) cannot be rejected for any of the eight regions, supporting the notion that these variables affect relative earnings and are not exogenous. Figures 11-18 show plots of the impulse response

¹⁰This index is borrowed from G. Andrew Bernat and Eric Repice (2000). The index is based on an index used by Sukko Kim (1995) and Paul Krugman (1991).

functions, which show the behavior of relative per capita earnings over time in response to shocks to itself, relative per capita employment, and industry mix. The impulse response functions show that all regions are not similarly affected by shocks to the variables. For example, a positive shock to relative employment has an initially negative impact on relative earnings in the Southeast Region and an initially positive impact on relative earnings in the Far West Region. Also, a positive shock to industry mix—which means a region’s industry mix becomes more similar to the national industry mix—has an initially negative impact on relative earnings in the New England Region and an initially positive impact on relative earnings in the Mideast Region. All impulse response functions suggest a degree of transience to the effects on relative earnings; though, the impacts on relative earnings tend to persist for 10-20 years.

One can garner some intuition to explain the differing impacts from shocks to industry mix. Of the two regions which converge during the entire 1974-1998 period (Far West Region and Plains Region), both show (see figures 12 and 18) increasing industry similarity generating a negative response on relative earnings. Since the Far West Region converges from above, the impulse response function suggests that the Far West Region converges as its industry mix becomes more similar to the nation’s industry mix. Since the Plains Region converges from below, the impulse response function suggests that the Plains Region converges as its industry mix becomes less similar to the nation’s industry mix. The Southeast Region (see figure 11), which converges from below until around 1989, shows increasing industry similarity generating a positive response on relative earnings, which suggests that the Southeast Region converges as its industry mix becomes more similar to the nation’s. The Great Lakes Region (see figure 17), which converges from above from the mid 1970's onward, appears to converge as its industry mix becomes less similar to the nation’s.

Conclusion

Using time series techniques, this paper finds that the U.S. regions are conditionally converging. Three regions (Great Lakes, Plains, and Far West) continue to converge through 1998, and may still be converging. The New England and Rocky Mountain Regions converge until the mid-1950s, and then maintain a stable compensating differentia, or equilibrium. The Mideast and Southeast regions converge until the late 1970's and late 1980's respectively. The Southwest region converges until the early 1960's. Thereafter, each region maintains a stable

compensating differential, or equilibrium. The apparent divergence of the 1980's is due mainly to positive shocks to the New England Region and due partly to a negative shock to the Great Lakes Region. Using Phillips-Perron tests, unit roots can be rejected for all regions, except perhaps New England.

Several cross-sectional studies note breaks in the trend toward convergence in the mid 1940's and late 1970's. The findings in this paper differ because the methodology does not implicitly assume that each region converges toward the same steady state and at the same rate. Points in time where some regions achieve conditional convergence while others continue to converge are not confused with a change in the trend, or rate, of convergence. The findings in this paper differ from Carlino and Mills, who find convergence virtually ceasing around 1946, because Phillips-Perron tests were used to test for unit roots and because recursive estimates of beta and the intercept term were used to interpret the convergence characteristics of each region over time.

VAR models for relative earnings in each region that incorporate variables for labor force characteristics and industry mix lend support for some of the criticism against using a cross-sectional approach to test for conditional convergence. The VAR models suggest that shocks to labor force characteristics and industry mix affect regions' relative earnings differently, both in manner and magnitude. The VAR models further suggest that factors such as labor force characteristics and industry mix should not be treated as exogenous. The VAR models also lend some comfort to the assumption made in the time-series approach of an equilibrium for each region's relative earnings that is time-invariant.

The findings in this paper suggest that, in the absence of barriers to trade and factor mobility, integrated regional economies will converge toward a stable compensating differential, or equilibrium. Using the U.S. regions as an example of closely integrated economies where labor and capital flow freely, these findings suggest that economic integration among national economies will tend to reduce disparities in national per capita earnings over time. However, these findings do not suggest that integration would eliminate disparities in per capita earnings. When economies conditionally converge, they may be converging toward unique steady-states that are very different.

References

- Barro, Robert and Xavier Sala-I-Martin.1992. "Convergence," *Journal of Political Economy*, Vol. 100, No. 2, pp.223-251
- Banerjee, Anindya, Juan Dolado, John W. Galbraith, and David F. Hendry. 1997. Co-integration, Error-correction, and the Econometric Analysis of Non-stationary Data. *Oxford University Press*.
- Baumol, William.1986. "Productivity Growth, Convergence, and Welfare," *American Economic Review*, Vol 76 (December): 1072-1085.
- Bernat Jr., G. Andrew and Eric Repice.2000. "Industrial Composition of State Earnings in 1958-1990," *Survey of Current Business*, Vol.80, NO. 2, pp.70-78
- Browne, Lynn.1991. "The Role of Services in New England's Rise and Fall: Engine of Growth or Along for the Ride?," *New England Economic Review*, (Jul./Aug.), pp. 27-44
- Carlino, Gerald and Leonard Mills.1996. "Convergence and the U.S. States," *Journal of Regional Science*, Vol.36, NO.4, pp.597-616.
- Cass, Karl. 1991. "The Real Estate Cycle and the Economy: Consequences of the Massachusetts Boom of 1984-87," *New England Economic Review*, (Sept./Oct.), pp. 37-46
- Ender, Walter.1995. Applied Econometric Time Series, *Wiley Series in Probability and Mathematical Statistics* New York: John Wiley & Sons, Inc.
- Garnick, Daniel.1990. "Accounting for Regional Differences in Per Capita Personal Income Growth: An Update and Extension," *Survey of Current Business*, Vol. 70, NO.1, pp.29-40.
- Henderson, Yolanda. 1990. "Defense Cutbacks and the New England Economy," *New England Economic Review*, (Jul./Aug.), pp.3-24
- Krugman, Paul.1991. Geography and Trade, Cambridge, MA: MIT Press.
- Mankiw, N.G., D. Romer, and D.N. Weil. 1992. "A Contribution to the Empirics of Economic Growth," *Quarterly Journal of Economics*, Vol CVII, No. 429, pp.407-437
- Perron, Pierre.1989. "The Great Crash, the Oil Price Shock, and the Unit Root Hypothesis," *Econometrica*, Vol. 57, pp.1361-1401.
- Sherwood-Call, Carolyn. 1996."The 1980's Divergence in State Per Capita Incomes: What Does It Tell Us?," *Economic Review: Federal Reserve Bank of San Francisco*, NO. 1, pp.14-25

Sukkoo, Kim.1995. "Expansion of Markets and the Geographic Distribution of Economic Activities: The Trends in U.S. Manufacturing Structure, 1860-1987," *The Quarterly Journal of Economics*, Vol.110, pp.881-908

$$RI_t = \alpha + \beta t + \rho RI_{t-1} + u_t :$$

$$\alpha = (RI^e + v_0)$$

[Table 1.]

1930-1998	α	β	ρ
New England	-.0034 (Prob = .5909)	.00016 (Prob = .1879)	.9710 (Prob = .0000)
Mideast	.0140 (Prob = .2680)	-.00011 (Prob = .4875)	.9122 (Prob = .0000)
Great Lakes*	.0324 (Prob = .0150)	-.0005 (Prob = .0181)	.7713 (Prob = .0000)
Plains*	-.0562 (Prob = .0019)	.00068 (Prob = .0216)	.5969 (Prob = .0000)
Southeast	-.0588 (Prob = .0612)	.00068 (Prob = .0923)	.8565 (Prob = .0000)
Southwest	-.0187 (Prob = .2926)	.00027 (Prob = .3491)	.9148 (Prob = .0000)
Rocky Mountain	-.0155 (Prob = .0602)	-.000002 (Prob = .8880)	.7134 (Prob = .0000)
Far West*	.0709 (Prob = .0021)	-.00089 (Prob = .0015)	.7490 (Prob = .0000)

* Region converges for entire period. This requires that the intercept and trend term show an inverse relation and that the trend term is significant at 5% level.

[Table 2.]

1930-1946	α	β	ρ
New England*	.1212 (Prob = .0144)	-.0037 (Prob = .0252)	.6760 (Prob = .0001)
Mideast*	.1985 (Prob = .0158)	-.0064 (Prob = .0195)	.3786 (Prob = .1112)
Great Lakes	.0669 (Prob = .0644)	-.0004 (Prob = .7856)	.3993 (Prob = .1152)
Plains*	-.2014 (Prob = .0040)	.0056 (Prob = .0580)	.0677 (Prob = .8027)
Southeast*	-.3675 (Prob = .0252)	.0082 (Prob = .0108)	.4352 (Prob = .0406)
Southwest*	-.2512 (Prob = .0103)	.0082 (Prob = .0108)	.4352 (Prob = .0406)
Rocky Mountain*	-.1112 (Prob = .0073)	.0045 (Prob = .0455)	.0316 (Prob = .9066)
Far West	.1975 (Prob = .0095)	-.00035 (Prob = .7651)	.2658 (Prob = .3154)

* Region converges for entire period. This requires that the intercept and trend term show an inverse relation and that the trend term is significant at 5% level.

$$RI_t = \alpha + \beta t + \rho RI_{t-1} + u_t :$$

$$\alpha = (RI^e + v_0)$$

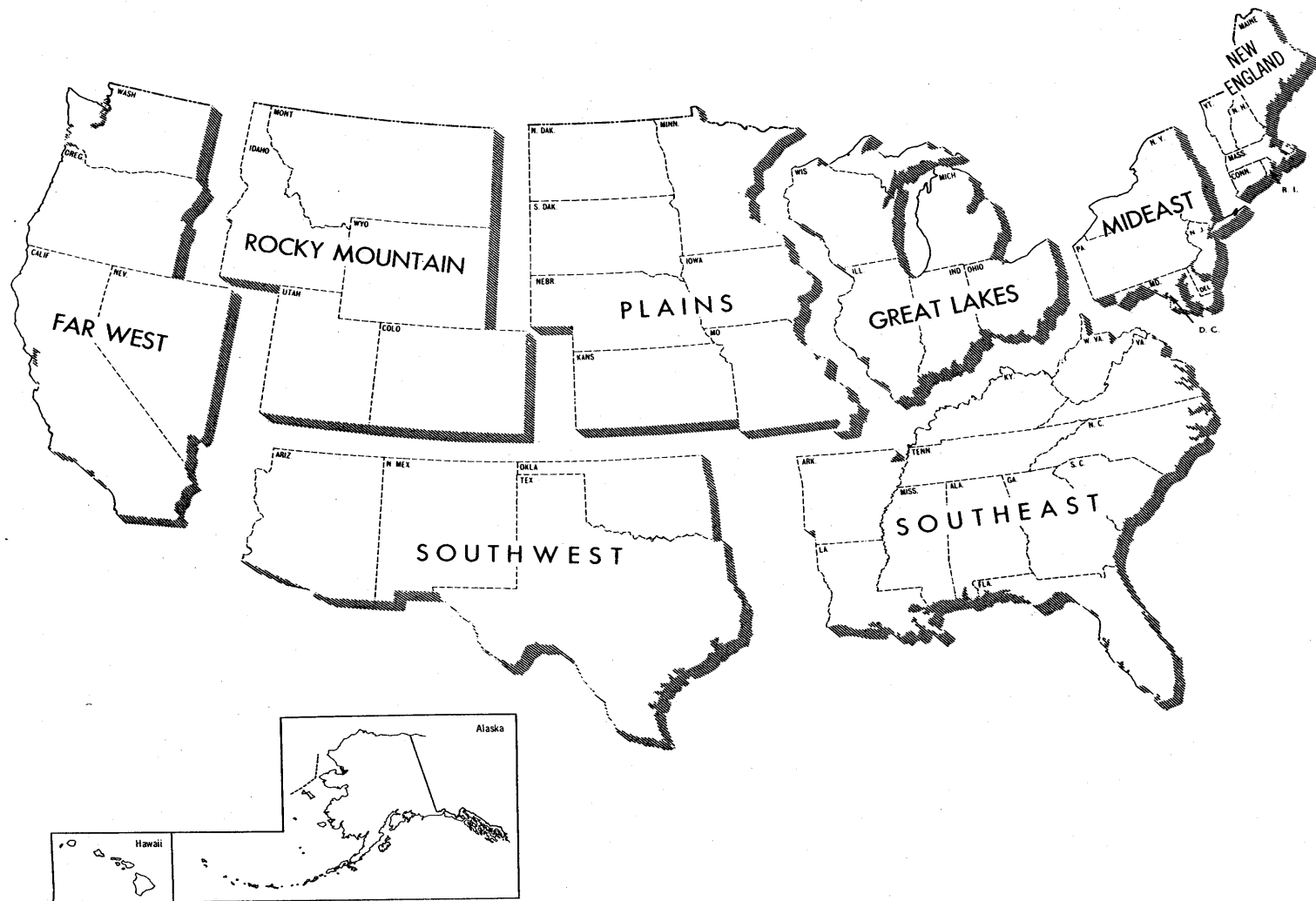
[Table 3.]

1930-1979	α	β	ρ
New England	.0129 (Prob = .3212)	-.00035 (Prob = .2604)	.9131 (Prob = .0000)
Mideast*	.0525 (Prob = .0360)	-.0009 (Prob = .0317)	.7852 (Prob = .0000)
Great Lakes*	.0588 (Prob = .0012)	-.0005 (Prob = .0402)	.5243 (Prob = .0001)
Plains*	-.1137 (Prob = .0001)	.0023 (Prob = .0005)	.3612 (Prob = .0101)
Southeast*	-.1802 (Prob = .0084)	.0027 (Prob = .0090)	.6603 (Prob = .0000)
Southwest	-.0621 (Prob = .0528)	.0013 (Prob = .0435)	.8128 (Prob = .6632)
Rocky Mountain	-.0284 (Prob = .0212)	.00032 (Prob = .2691)	.5954 (Prob = .0000)
Far West	.0897 (Prob = .0038)	-.0012 (Prob = .0517)	.6888 (Prob = .0000)

* Region converges for entire period. This requires that the intercept and trend term show an inverse relation and that the trend term is significant at 5% level.

[Table 4.] Unique Convergence Paths for each region

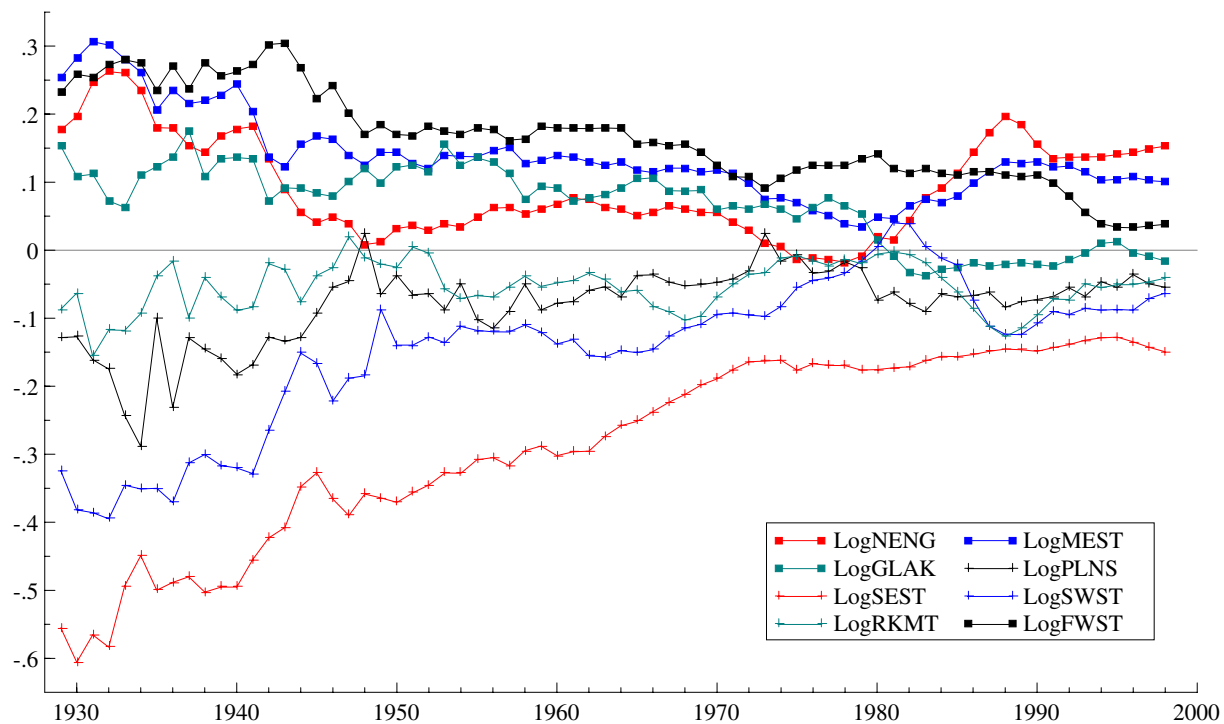
	Converged until approx:	α	β	ρ
New England	1955	.0870 (Prob = .0320)	-.0037 (Prob = .0252)	.6760 (Prob = .0001)
Mideast	1979	.0525 (Prob = .0360)	-.0009 (Prob = .0317)	.7852 (Prob = .0000)
Great Lakes	1998	.0324 (Prob = .0150)	-.0005 (Prob = .0181)	.7713 (Prob = .0000)
Plains	1998	-.0562 (Prob = .0019)	.00068 (Prob = .0216)	.5969 (Prob = .0000)
Southeast	1989	-.0933 (Prob = .0433)	.0013 (Prob = .0472)	.8070 (Prob = .0000)
Southwest	1962	-.1540 (Prob = .0192)	.0040 (Prob = .0215)	.6094 (Prob = .0003)
Rocky Mountain	1954	-.1034 (Prob = .0033)	.0040 (Prob = .0126)	.0660 (Prob = .7799)
Far West	1998	.0709 (Prob = .0021)	-.00089 (Prob = .0015)	.7490 (Prob = .0000)



[Figure 1]

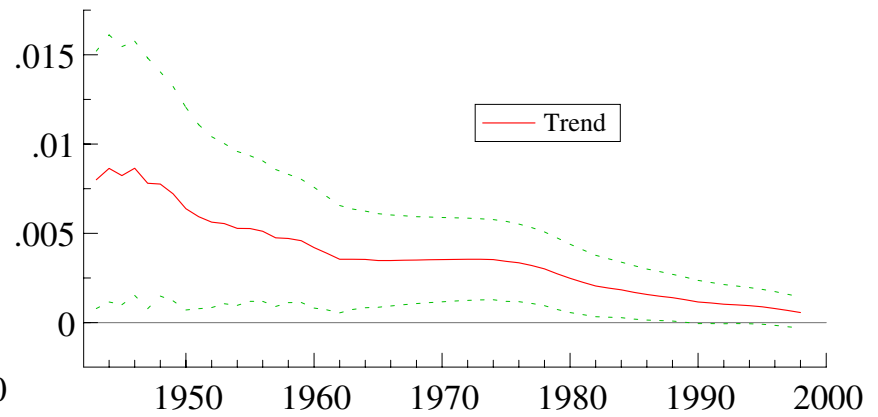
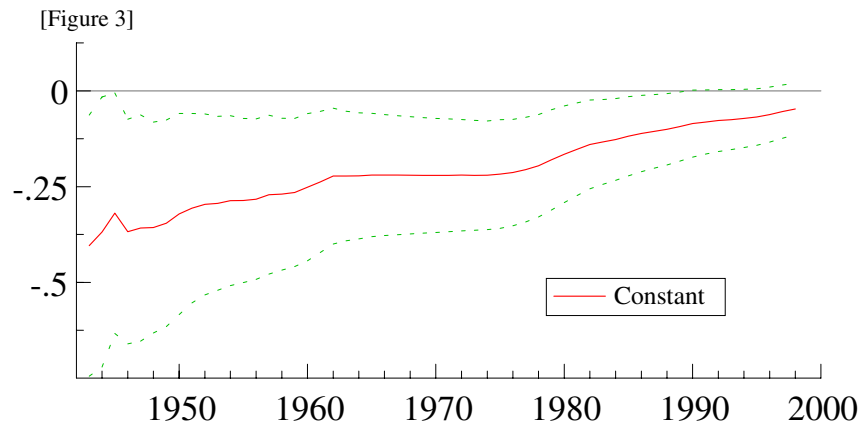
Logs of Relative Per Capita Earnings: 1929-1998 for U.S. Regions

[Figure 2]



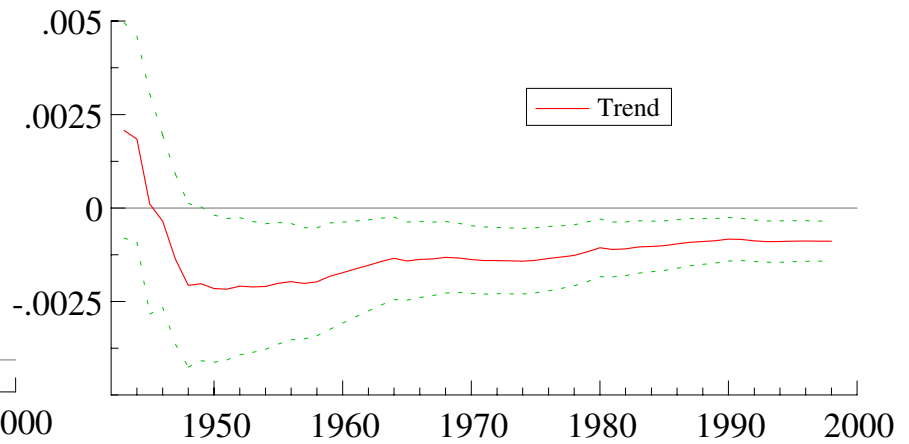
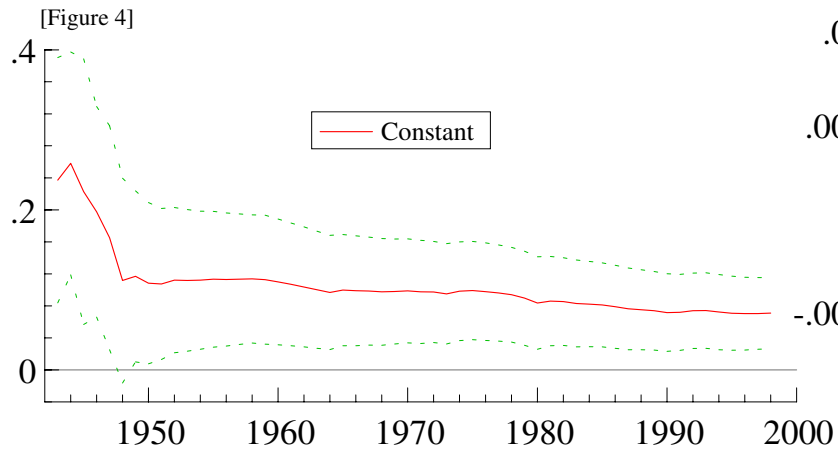
- 1) Midwest Region = LogMEST
- 2) Far West Region = LogFWST
- 3) New England Region = LogNENG
- 4) Great Lakes Region = LogGLAK
- 5) Rocky Mountain Region = LogRKMT
- 6) Plains Region = LogPLNS
- 7) Southwest Region = LogSWST
- 8) Southeast Region = LogSEST

Southeast Region

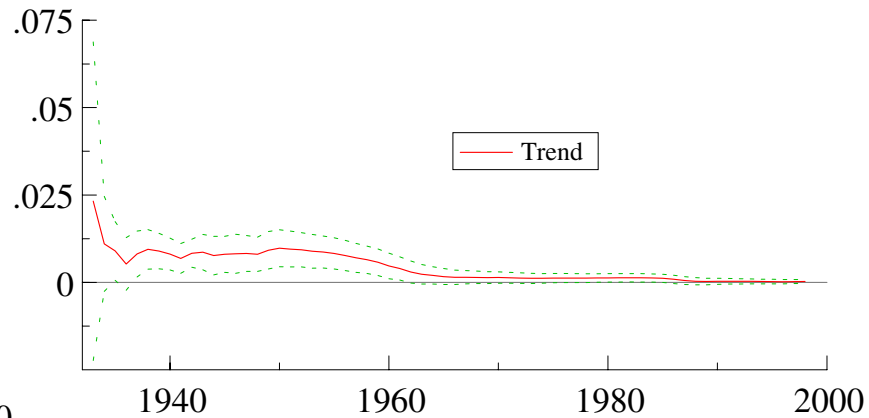
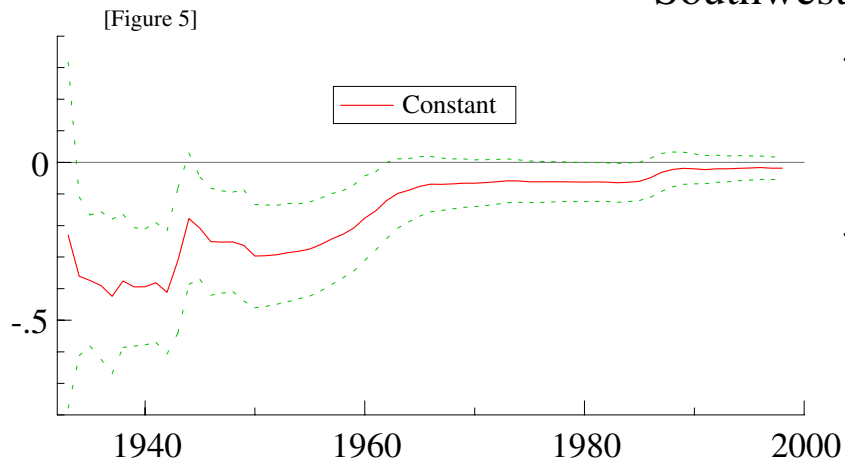


Recursive parameter estimates show Southeast Region converges until late 1980's and Far West Region continues to converge through 1998.

Far West Region

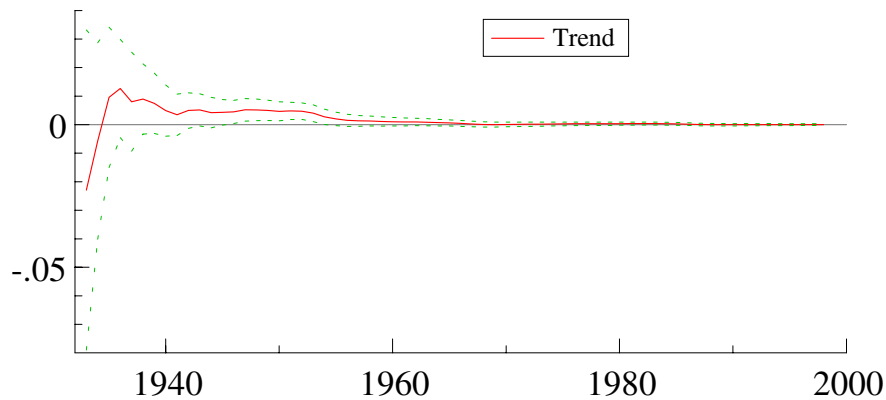
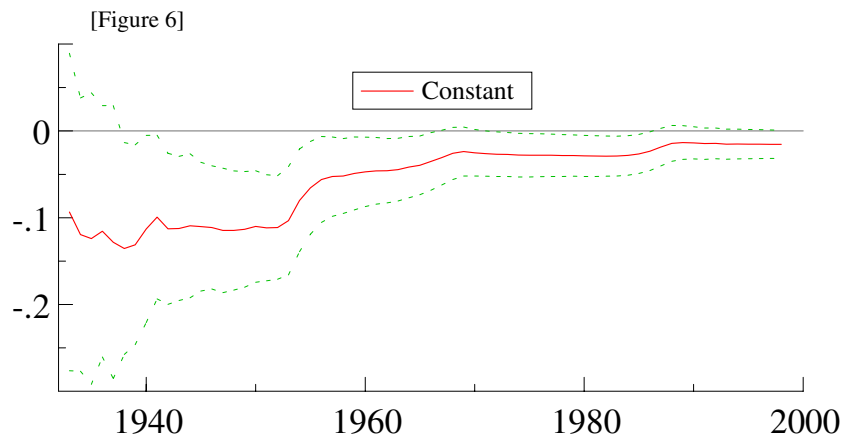


Southwest Region

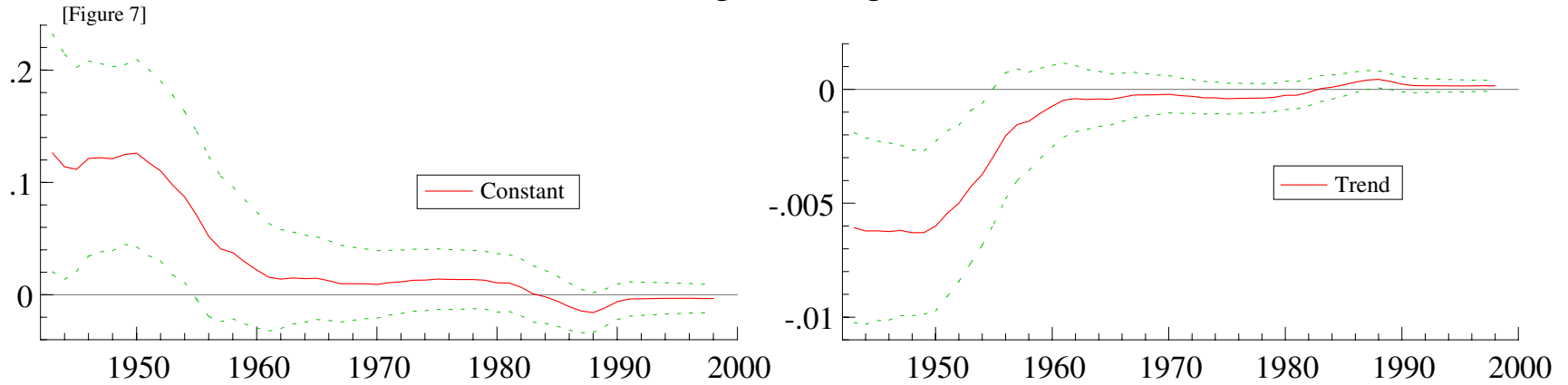


Recursive parameter estimates show Southwest Region converges until early 1960's and Rocky Mountain Region converges until mid or late 1950's.

Rocky Mountain Region



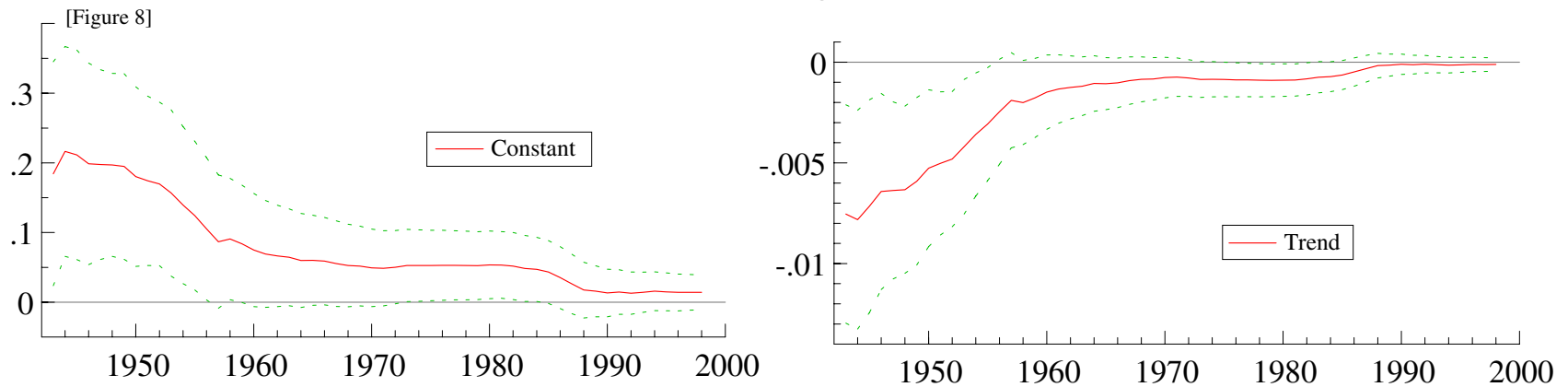
New England Region



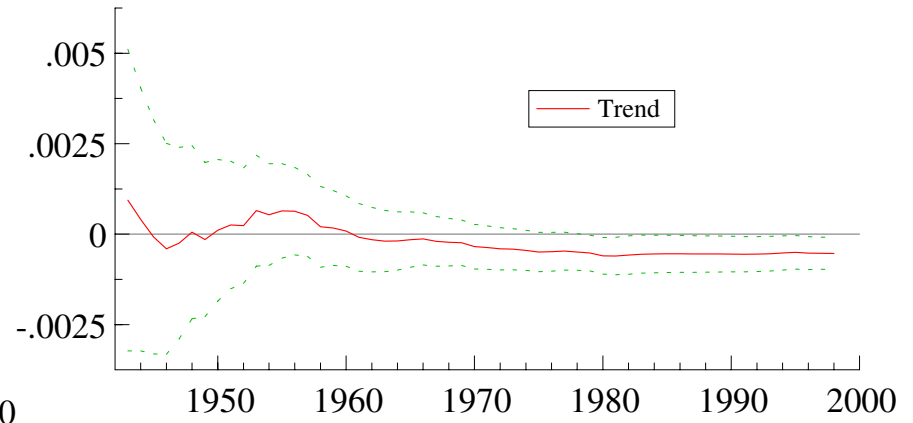
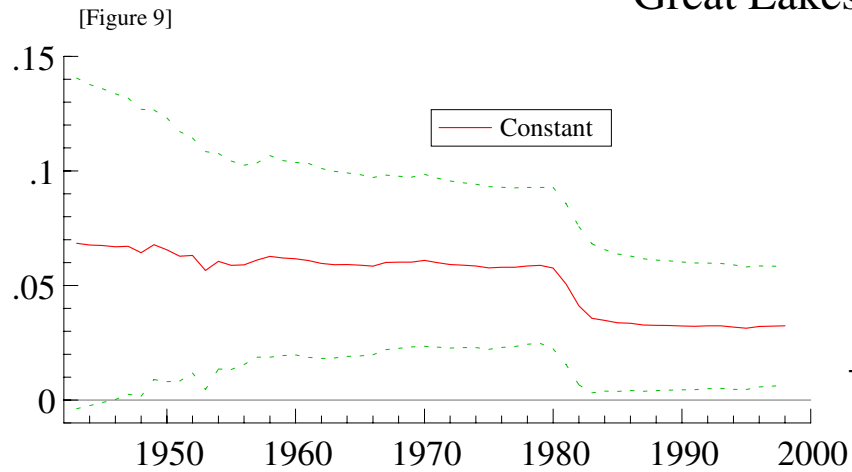
Recursive parameter estimates show New England Region converges at very unstable rate until mid 1950's. The trend appears to destabilize again during the 1980's.

Recursive parameter estimates show Mideast Region stops (or slows) converging during the 1960's, but then converges again during the 1970's.

Mideast Region



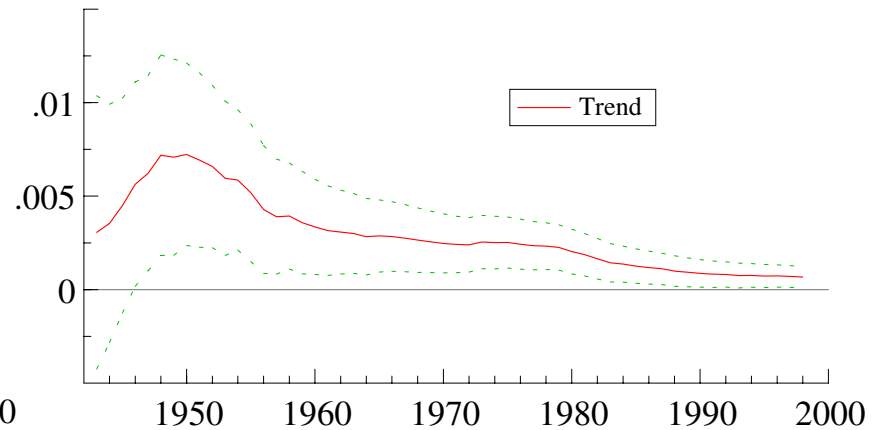
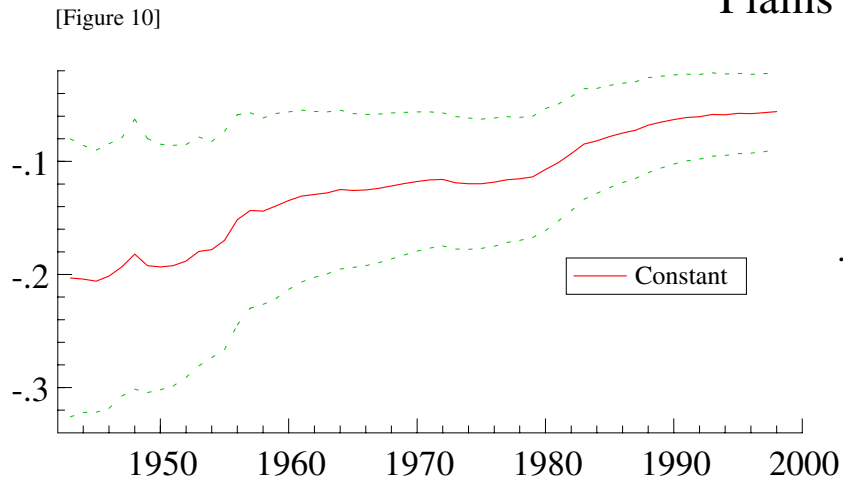
Great Lakes Region



Recursive parameter estimates show Great Lakes Region converges from the late 1970's through 1998. A negative shock to the intercept term occurs in the early 1980's.

Recursive parameter estimates show Plains Region continues to converge through 1998.

Plains Region



Impulse Response Functions: Years of data: 1972-1998

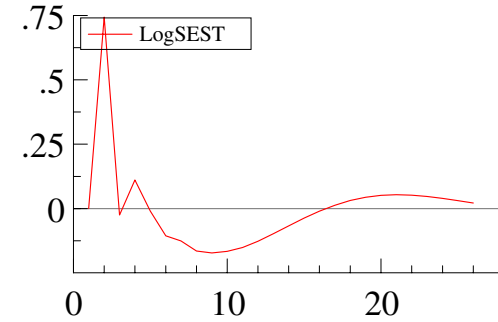
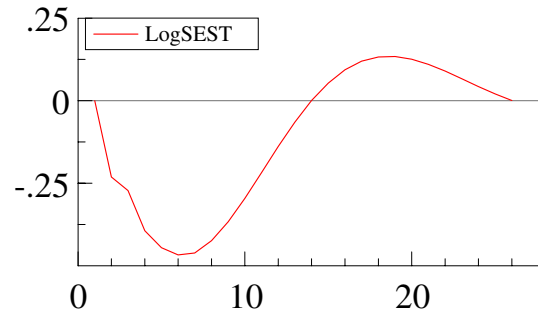
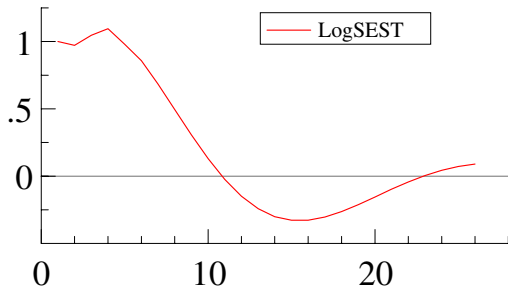
Positive shock to relative per capita earnings

Positive shock to relative per capita employment

Positive shock to industry similarity index*

[Figure 11]

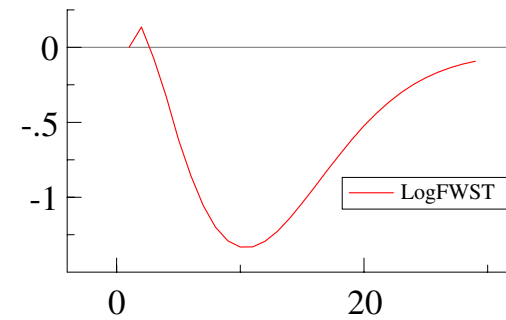
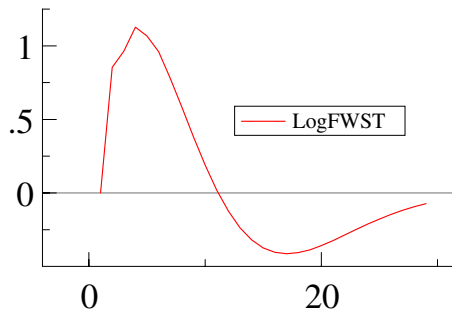
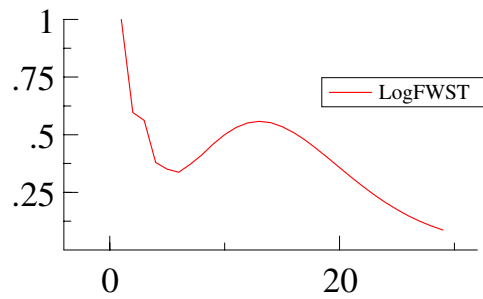
Southeast Region



LogSEST = relative per capita earnings for Southeast Region

[Figure 12]

Far West Region



LogFWST = relative per capita earnings for Far West Region

* A positive shock to industry similarity index means region's industry mix becomes more similar to national industry mix

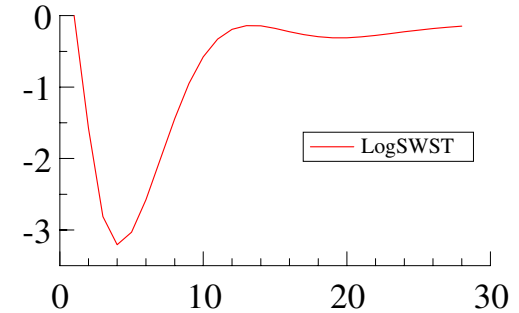
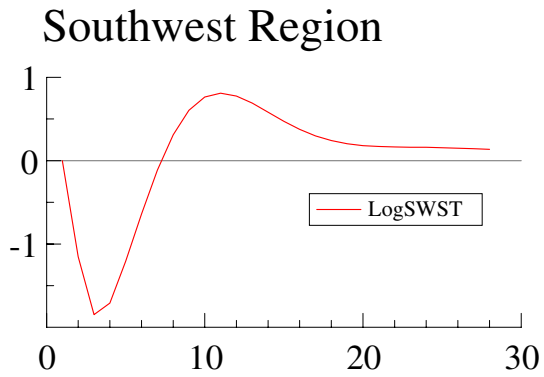
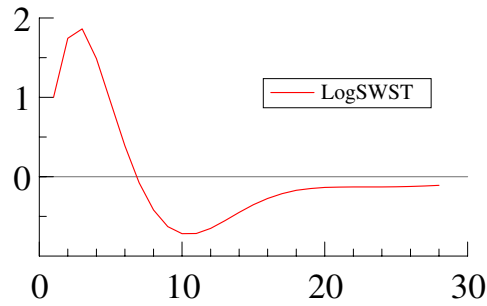
Impulse Response Functions: Years of data: 1972-1998

Positive shock to relative per capita earnings

Positive shock to relative per capita employment

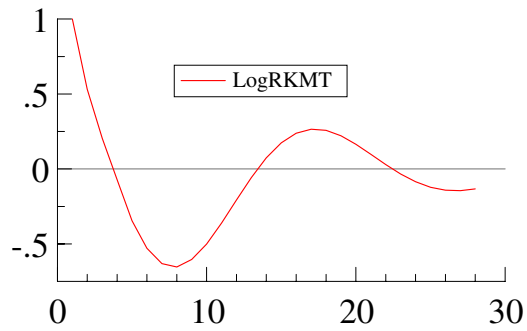
Positive shock to industry similarity index*

[Figure 13]

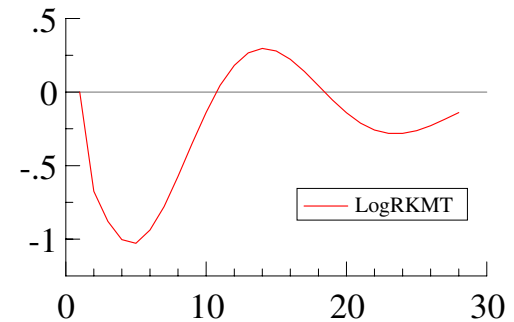
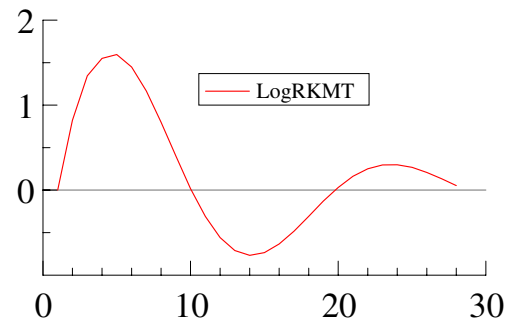


LogSWST = relative per capita earnings for Southwest Region

[Figure 14]



Rocky Mountain Region



LogRKMT = relative earnings per capita for Rocky Mountain Region

* A positive shock to industry similarity index means a region's industry mix becomes more similar to the national industry mix

Impulse Response Functions:

Years of data: 1972-1998

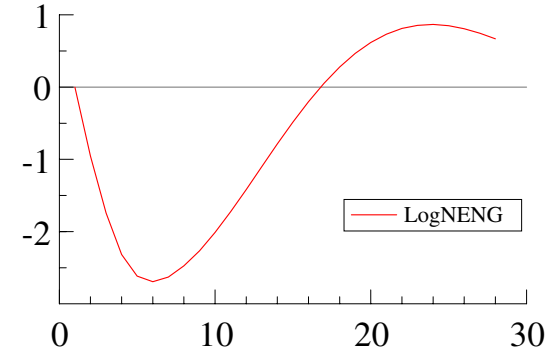
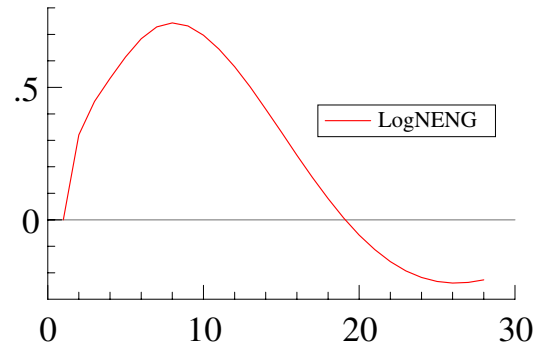
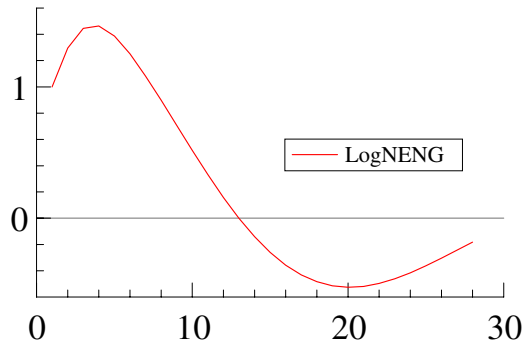
Positive shock to relative per capita earnings

Positive shock to relative per capita employment

Positive shock to industry similarity index*

[Figure 15]

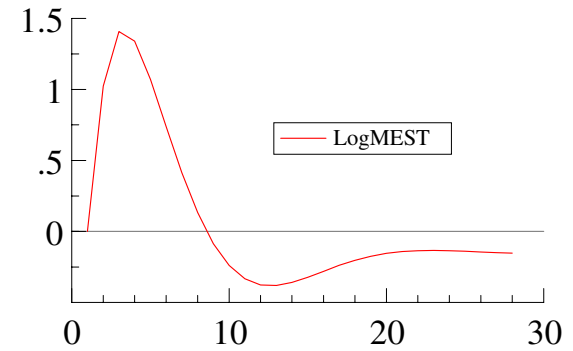
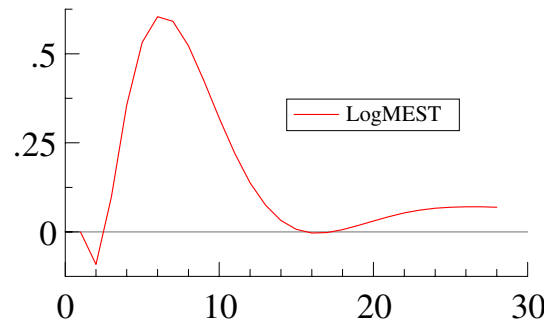
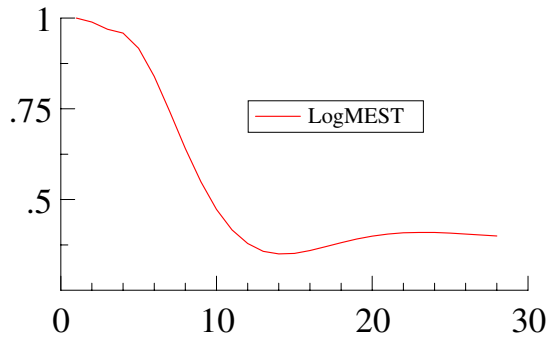
New England Region



LogNENG = relative per capita earnings for New England Region

[Figure 16]

Midwest Region



LogMEST = relative per capita earnings for Midwest Region

* A positive shock to industry similarity index means a region's industry mix becomes more similar to national industry mix

Impulse Response Functions:

Years of data: 1972-1998

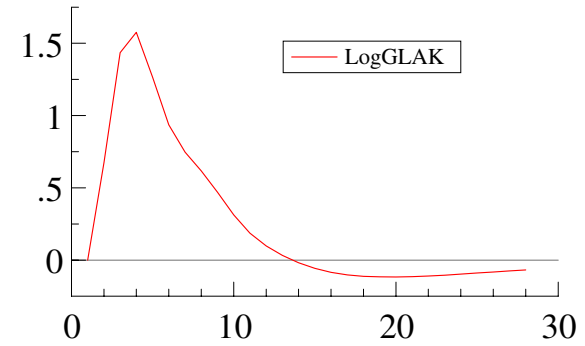
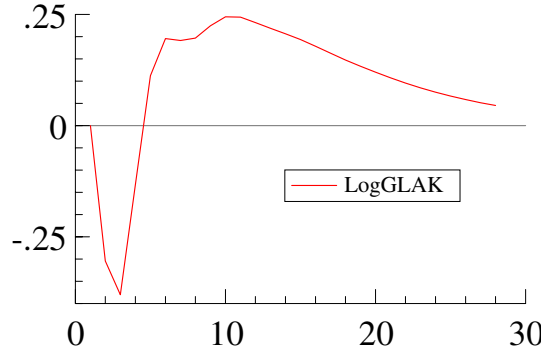
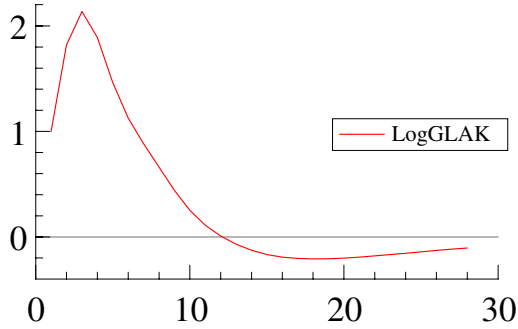
Positive shock to relative per capita earnings

Positive shock to relative per capita employment

Positive shock to industry similarity index*

[Figure 17]

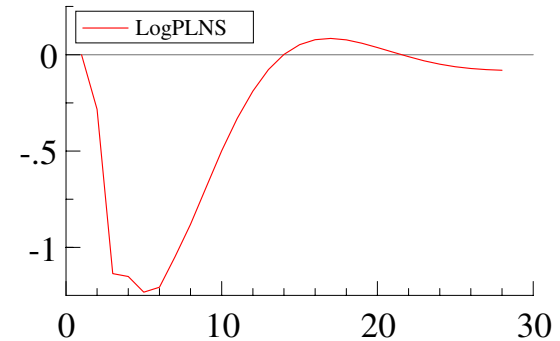
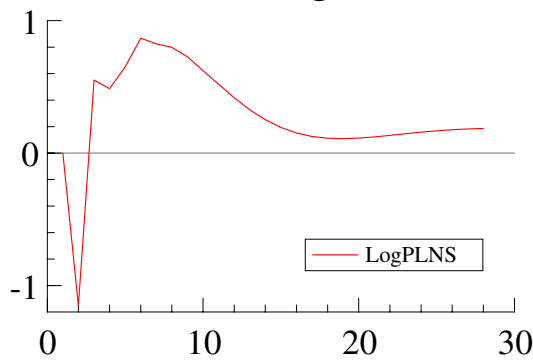
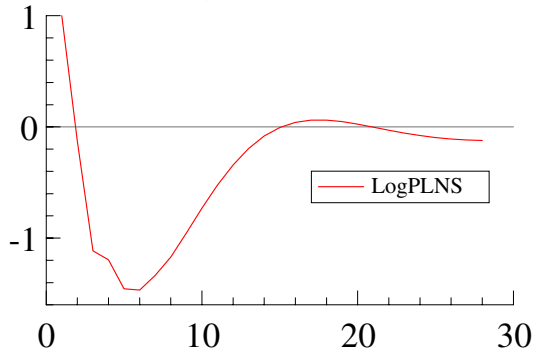
Great Lakes Region



LogGLAK = relative per capita earnings for Great Lakes Region

[Figure 18]

Plains Region



LogPLNS = relative per capita earnings for Plains Region

* A positive shock to industry similarity index means region's industry mix becomes more similar to national industry mix