
ECONOMIC INTEGRATION AND CONVERGENCE: THE CASE OF CENTRAL APPALACHIA IN THE US

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ABSTRACT

Using time-series regression techniques and the notion of stochastic convergence, the paper analyzes the long term real income per capita trends in the Central Appalachian counties in the US to determine whether economic integration has resulted in the lagging Appalachian region converging to the national economy. Results from the empirical analysis show little evidence of convergence or catching-up of per capita income in the region to that of the nation. The results, however, provide evidence of catching-up to the average per capita income in the states where the Central Appalachian counties are located. **JEL Classifications:** R11, R58

INTRODUCTION

The question whether economic integration among countries or regions within a country leads to economic convergence has been widely debated in the growth and development literature over the last two decades. Real income convergence among a group of countries (regions) is understood to mean the approximation of the levels of some measures of economic welfare, such as real per capita income, among those countries (regions) in the long run (Barro and Sala-i-Martin 1995). Since economic convergence can occur if poorer countries or regions grow more rapidly than the richer countries or regions, the notion of economic convergence, in effect, deals with the important question of whether poorer countries (regions) grow faster than richer countries (regions) and see their per capita incomes converge to that of rich countries (regions) in the long run. There is a large body of literature - theoretical and empirical - that attempts to address this question. The theoretical literature on the subject is dominated by two opposing views. The neoclassical growth theory championed by Solow (1956) and Swan (1956) built on the assumptions of diminishing returns to capital and factor mobility predicts that economic integration among national and regional economies would inevitably result in income per capita convergence. In the presence of diminishing returns, each additional capital input yields smaller returns in richer than in poorer countries (regions). Hence, assuming that technologies are identical and exogenous and preferences (saving and consumption

patterns) are similar across the economies, the process of economic integration would accelerate the flow of capital to capital-scarce countries (regions) in search of higher returns. This should lead to more capital accumulation and faster economic growth in poor countries (regions) than in rich ones resulting in economic convergence towards a common level of per capita income in the long run. This phenomenon is commonly known as the convergence hypothesis in the economic literature.

In contrast to the neoclassical growth theory, the new (endogenous) growth theory, advanced by Paul Romer (1986) and Robert Lucas (1988) and the new trade theory also known as 'new economic geography', developed by Paul Krugman (1991) and Krugman and Venables (1995), maintain that economic integration may not lead to income convergence or its effects is not as inevitable as the prediction of the Solow model suggests. The former, built on the assumptions of increasing returns in physical or human capital and positive externalities, maintains that countries or regions with higher levels of physical or human capital may continue to grow more rapidly as growth generates positive spillover effects that produce further growth. Conversely, poorer countries (regions) may not be able to accumulate the required physical and human capital to generate the positive spillovers that facilitate self-sustained economic growth. Because the model emphasizes the role of externalities and increasing returns in economic growth it, in contrast to the neoclassical growth model, grants public policies an important role in the determination of long run economic growth and convergence (Craft, 1996). In a similar vein, the new trade theory argues that although economic integration creates new opportunities for economies of scale and specialization resulting from increased trade and factor mobility, it does not necessarily follow that all integrating countries (regions) benefit from it equally. Earlier stages of integration tend to bring larger gains for already more industrialized regions, as firms exploit economies of scale by concentrating production close to markets where they have more customers and suppliers. This process tends to increase income differences between rich and poor countries (regions)¹.

The empirical literature has proceeded in many directions, using different definitions and methodologies (see Temple 1999; Islam, 2003; Durlauf et al. 2005, for an extensive review of the literature). While most of the early studies have concentrated on examining convergence across countries, the subject (the integration - convergence nexus) has become one of the primary focus of regional economic research in recent years. Since regions within a country represent homogenous economic systems characterized by similar technological levels, institutional environments, and unrestricted inter-region factor mobility, they may be expected to show greater evidence of long-run convergence (Barro and Sala-i-Martin, 1995). This belief has led to numerous convergence studies among closely integrated regional economies such as the European Economic and Monetary Union (EMU) and the US states, among many others (see, Martin and Sunley, 1998; Durlauf et al. 2005 for a review of this literature). However, the empirical evidences provided by these studies have been mixed. They tend to vary with the techniques used (panel, time series, cross-section), and the level of regional aggregation and the time period of the data observed.² Thus, the nature of the regional integration-convergence relationship has remained a subject of an ongoing debate.

The purpose of this study is to contribute to the ongoing discussions on the regional economic integration and real income convergence relationship by examining the long term real income per capita trends in the Appalachian region of the United States³. The Appalachian case provides a unique opportunity to study the

subject for two main reasons. First, as indicated above, there is a general agreement in the literature that if economic integration promotes convergence, it is more likely to occur among regions within a country because of the relative absence of barriers - geographic, economic, legal, and institutional-that could preclude convergence. Also, economic agents within a country tend to have access to similar technologies and similar tastes compared to agents of different countries (Lucas, 1988; Barro and Sala-i-Martin, 1995). This makes the Appalachian region a unique empirical site for testing the integration-convergence relationships. Second, since 1965, the Appalachian region has been the focus of a unique regional development program supported and coordinated by the Appalachian Regional Commission (ARC)-a joint Federal and State organization-designed to promote economic growth and development in the region. Of particular significance of the development program in this study is that, it has, from the beginning, adopted economic integration of the Appalachian region with the national economy primarily by removing geographic isolation of the region as the single most important development policy for achieving its objectives. Hence, almost five decades later, the effects of economic integration should be already empirically evident, in accordance to the convergence hypothesis. In view of the distinct development experience of the region, the Appalachian case provides a unique opportunity for testing the efficacy of a regional policy intervention aimed at promoting growth and development and regional economic convergence⁴.

The study uses long term county real per capita personal income data and the notion of stochastic convergence to empirically assess whether there has been a systematic tendency for the per capita personal income in Central Appalachia to converge to the real per capita personal income levels in the states they are located and the real per capita personal income in the nation as whole. The focus is on the experience of Central Appalachia, as opposed to the Appalachian region as a whole, because the identified barrier to convergence, primarily, geographic isolation (caused by mountainous terrain), applied to the geographically contiguous counties in Central Appalachia more than the other sub-regions of Appalachia (Isserman and Rephann, 1995, pp. 346)⁵.

The rest of the paper is organized as follows. The second section provides a general outline of the objectives and strategies of the regional development program that has been implemented to bring about growth and development in the Appalachian region. The third section presents brief descriptions of the alternative notions of income convergence and the corresponding statistical methods employed to test the presence or absence of convergence. The fourth section describes the time-series method used in this study for testing convergence. The fifth section covers the empirical analysis, and the last section offers some conclusions.

REGIONAL DEVELOPMENT PROGRAM IN APPALACHIA

Historically, the Appalachian region in general and the Central Appalachia sub-region in particular, have long been among the poorest regions in the United States. In the mid of the 1960s, per capita income in the region amounted to 73% of the per capita income in the rest of the country and nearly one in three of Appalachian families lived in poverty, while the corresponding figure for the nation as whole was one in five (PARC 1964). A long-standing explanation for the region's persistent economic problem is centered on geographic isolation stemming from the mountainous terrain that characterizes the region. Paradoxically, prior federal government investments had

generally bypassed the Appalachian Region (PARC 1964). This was especially true with investments in transportation infrastructure. A report by the ARC indicates that “when the builders of America’s Interstate Highway System confronted the rugged terrain of Appalachia, they chose to build around the Region rather than to penetrate this mountainous land with their modern highway system, a system that would shape American economic prosperity for the remainder of the 20th century” (ARC 2010, pp. 1). This explanation formed the basis for initiating a development program for Appalachia which has heavily emphasized on integrating the lagging Appalachian region with the national economy through infrastructure development mainly highway construction (Hansen 1966, 1970; Raitz and Ulack 1984; PARC, 1964)⁶. As stated in the U.S. President’s report to Congress “The Appalachian [development] program will be many programs, unified only by their singleness of focus: the introduction of Appalachia and its people into fully active membership in the American society” PARC (1964, pp. 65)⁷. The presumption is that economic integration and market forces would necessarily promote economic growth and development in the region and eventually convergence of its per capita income to that of the nation. From 1965 through the fiscal year 2012, the Appalachian Regional Commission(ARC), along with state and local governments in Appalachia, have spent more than \$26 billion on economic and social development programs throughout the Appalachian Region (ARC 2012). Consistent with the main objective of the program, about half the outlays have been used to finance the expansion of the Appalachian Development Highway System (ADHS), while the remaining funds have supported "area development" projects. Such projects are aimed at promoting business and community development and improving education, health, housing quality, and infrastructure in the region⁸. The ADHS is the first highway system designated by Congress to be built primarily for economic development purposes⁹. According to the ARC, nearly 85% of the ADHS is complete and the economic and social impact of ADHS has been both widespread and profound (ARC 2010), and “the Region is well on its way to reducing geographic isolation” (ARC 2012).

DEFINING AND TESTING CONVERGENCE

Several distinct concepts of convergence have been suggested in the literature each being analyzed using different methods. The most common ones are sigma (σ) convergence, beta (β) convergence, and stochastic convergence.

σ - convergence refers to the decline in the dispersion of per capita incomes (measured, for example, by their standard deviation) across a group of countries or regions. In other words, σ - convergence exists among a group of economic units, if

$$\sigma_{t+T} < \sigma_t \tag{1}$$

Where σ_t is the time t standard deviation of $\log(y_{it})$ across i and y_{it} represents economy i 's per capita income at time t . Usually, a graph depicting the time trend of the dispersion measure is used to gain the impression of how the distribution of cross-section income evolves over time (convergent or divergent). Clearly, the size of the initial income gap and the differential rates of income growth between lower income and higher income economies determine movements in σ -convergence.

The second type, beta (β) convergence, describes a condition where a poor economy grows faster than a rich one. This approach derives from the conventional

neoclassical growth model, whose empirical interpretation implies that growth rates of an economy are inversely related to its initial level of income, suggesting that there is negative association between the initial level of the per capita income with its growth rate (Barro & Sala-i-Martin, 2004). This form of convergence has been the primary focus of economists and there is a large body of empirical literature that tests this form of convergence among regional (national) economies. Testing for this notion of convergence involves running cross section regressions of the following form:

$$\Delta y_{it,t+T} = \alpha - \beta \log(y_{it}) + \varepsilon_{it} \quad (2)$$

Where $\Delta y_{it,t+T} = \log(y_{it,t+T}/y_{it})/T$ is economy i 's annualized growth rate of income per capita between t and $t+1$ and $\log(y_{it})$ is the logarithm of economy i 's income per capita at time t . If $\beta > 1$, it means that the data set exhibits unconditional or absolute convergence. That suggests tendency for per capita income to equalize across economies. If the test equation contains control variables, the test approach investigates conditional β -convergence.¹⁰

The third notion of convergence, the stochastic convergence, interprets convergence to mean that the expected per capita income level differences between two economies approaches zero in the long run (Bernard and Durlauf, 1996; Carlino and Mills, 1996). In particular, given the information I_t at time t , two economies i and j are said to exhibit stochastic convergence if the long run forecasts of income are equal, that is:

$$\lim_{T \rightarrow \infty} E(\log y_{i,t+T} - \log y_{j,t+T} / I_t) = 0 \quad (3)$$

Given the meaning of stochastic convergence, a common test (described below) for stochastic convergence involves testing for a unit root in the log of the difference in per capita income. Failure to reject the unit root null hypothesis is evidence of stochastic divergence, while rejection of the unit root null supports stochastic convergence.

While not universal, the cross-sectional (β -convergence) studies conducted using data of relatively homogeneous groups of economic units (regions, counties, states) have found evidence of unconditional convergence.¹¹ However, several questions have been raised about the reliability of the estimates and the suitability of the cross-sectional method of estimation employed. Quah (1993) indicates regression to the mean problems that bias the results in support of convergence. This bias is similar to Galton's fallacy where convergence is characterized by the reduction in income differentials within a specific group of countries over time. Bernard and Durlauf (1995, 1996) make the point that cross-section tests cannot identify single or groupings of economic units that are converging, when others are not. They show that the growth regressions impose cross-sectional homogeneity on coefficients that in reality may vary across regions or groups of regions included in the cross-section studies. Another problem is that the cross-sectional approach can only test for convergence in the sense of it being a 'catch-up' process. In other words, the model estimates whether (on average) the distance between observations at the end of a period is less than at the start. Thus, results can be interpreted as evidence of catching-up not convergence.

With respect to the stochastic type of convergence (time series) studies, the first generation of tests, including, Bernard and Durlauf (1995) and Carlino and Mills (1993) find no evidence of convergence. However, when the convergence

test accounts for the possibility of structural breaks in the data series, evidence of convergence is reported. See, Carlino and Mills (1996), Loewy and Papell (1996), Vogelsang and Tomljanovich (2002), and Strazicich et al. (2004).¹²

TIME-SERIES TEST FOR CONVERGENCE

Given the definition of stochastic convergence stated above, testing for convergence between two economies i and j hinges on the time series properties of $y_i - y_j$, where y is per capita income. Also, as indicated above, time series tests of convergence have typically been implemented using unit root tests. The standard approach to test for unit root involves estimating an augmented Dickey-Fuller (ADF) unit root equation of the following type:

$$\Delta(y_{it} - y_{jt}) = \mu + \alpha(y_{i,t-1} - y_{j,t-1}) + \beta t + \sum_{k=1}^n \delta_k \Delta(y_{i,t-k} - y_{j,t-k}) + \epsilon_t$$

$\epsilon_t \sim iid$ (4)

Where y denotes the logarithm of per capita income; $\Delta(y_{i,t-k} - y_{j,t-k})$ is the lagged differences to accommodate serial correlation in the error term; ϵ_t represents the error term; t is time trend, and $\alpha, \mu, \delta, \beta, \delta_k$ are the parameters to be estimated.

If $\alpha=1$, it signifies that the data series (the difference in per capita income) contains a unit root indicating that income per capita in the two economies will diverge over time. The absence of unit root, that is, $\alpha < 1$, signifies convergence of per capita income. Furthermore, if the test result shows absence of unit root ($\alpha < 1$), distinction between convergence as catching-up or long run convergences can be made depending on whether the parameter β is significantly different from zero or not. Following Bernard and Durlauf (1996), Li and Papell (1999), Carlino and Mills (1993), convergence is of the catching-up type if $\alpha < 1$ and $\beta \neq 0$, and of the long-run convergence type, if $\alpha < 1$ and $\beta = 0$. Additionally, if the test result shows long-run convergence ($\beta = 0$, $\alpha < 1$), it is possible to distinguish between the two types of convergence-unconditional (strong) and conditional (weak) convergence by testing the significance of the constant term (μ). If the results confirm a zero mean, then convergence is of the unconditional type, but if the results show a nonzero mean, then convergence is of the conditional type. That is, the convergence is said to be conditional upon the region-specific fixed effects.

However, Peron (1989) shows that in the presence of structural break in the data series, the ADF test is biased towards a spurious acceptance of non-stationarity because of misspecification bias and size distortions. This problem has been commonly addressed by accounting for the effects of discontinuities when investigating the statistical properties of long-run time series data. Zivot and Andrews (1992), Peron (1997), Lumsdaine and Papell (1997), among others, have developed methods for determining the location of the structural breaks endogenously from the data and conducting unit root tests that accommodate such breaks. However, these methods were criticized for their treatment of breaks under the null hypothesis. As demonstrated by Nunes et al. (1997) and Lee and Strazicich (2001, 2003), these methods derive their critical values while assuming no break(s) under the null. This assumption leads to size distortions in the presence of a unit root with one or two breaks which, when used to conduct unit root tests with endogenously determined breaks, might show stationarity of the data series, when in fact it is non-stationary. This study uses the minimum

Lagrange Multiplier (LM) unit root test method developed by Lee and Strazicich (2001, 2003, 2004) to test for unit root. As shown below, the method not only endogenously determines structural breaks but also allows for endogenous breaks both under the null and the alternative hypothesis thus avoiding the above described problems of bias.

Lee and Strazicich (2003) developed two versions of the LM unit root with structural break(s): Model A that allows a one-time or two-time break(s) or shift(s) in the intercept (level) and Model C that extends Model A to include a one-time or two time changes in the intercept and the slope (trend).

Following the literature, the LM unit root test can be explained using the following data generating process (DGP):

$$y_t = \delta'Z_t + e_t, \quad e_t = \beta e_{t-1} + \varepsilon_t \quad (5)$$

Where Z_t consists exogenous variables and e_t is white noise error term. Model A can be described by $Z = [1, t, D_t]'$, where, the dummy variable, $D_t = 1$ for $t \geq T_B + 1$, and zero otherwise, T_B is the date of the structural break, and $\delta' = (\delta_1, \delta_2, \delta_3)$. Model C can be described by $Z = [1, t, D, DT_t]'$. Here, $DT_t = t - T$, for $t \geq T + 1$, and zero otherwise.

Model A can be modified to allow for two shifts in the intercept and is described by $Z_t = [1, t, D_{1t}, D_{2t}]'$ where $D_{jt} = 1$ for $t \geq T_{Bj} + 1$, $j = 1, 2$, and 0 otherwise. T_{Bj} denotes the date when the breaks occur. Note that the DGP includes breaks under the null ($\beta = 1$) and alternative ($\beta < 1$) hypothesis in a consistent manner. Similarly, Model C that accommodates two changes in the intercept and the slope is described by $Z_t = [1, t, D_{1t}, D_{2t}, DT_{1t}, DT_{2t}]'$ where $DT_{jt} = t - T_{Bj}$ for $t \geq T_{Bj}$, $j = 1, 2$, and 0 otherwise.

Following the LM principle, the LM unit root test statistic is obtained from the following regression model:

$$\Delta y_t = \delta' \Delta Z_t + \phi \tilde{S}_{t-1} + \sum_i^p \gamma \Delta \tilde{S}_{t-1} + \mu_t \quad (6)$$

where Z_t reflects the deterministic components, $\tilde{S}_t = y_t - \tilde{\psi}_x - Z_t \tilde{\delta}$, $t = 2, \dots, T$; δ' are coefficients in the regression of Δy_t on ΔZ_t ; $\tilde{\psi}_x$ is given by $y_t - Z_t \delta'$; and y_1 and Z_1 represent the first observations of y_t and Z_t respectively. The LM test statistic is given by:

$$\tau = t\text{-statistic for testing the unit root null hypothesis that } \phi = 0. \quad (7)$$

The null hypothesis is that the data series of interest is integrated with structural break(s), against the alternative that the series can be represented by a trend stationary process with a breakpoint(s) occurring at some endogenously determined time. The general to specific recursive procedure is used to select the appropriate lag length to ensure the residual of unit root test regressions are white noise. Following the procedure, first the unit root test regression is estimated with a sufficiently long period of lag length (k^{max}) and sequentially drop the last included lag if it is not statistically significant.

EMPIRICAL RESULTS

Annual per capita personal income data, net of government transfers, in the Central Appalachian counties of Kentucky, Tennessee, Virginia and West

Virginia, the four states (Kentucky, Tennessee, Virginia and West Virginia; henceforth referred to as regional states), and the US are used as measures of per capita income in this study. Population data in each of the counties and regional states are used to obtain weighted average per capita income series for the Central Appalachian counties and the regional states. The data covers the period 1969–2010 for which personal income data for U.S. counties is available. The income measures are expressed in 1992 dollars using the U.S. CPI. The personal income and population data are obtained from the US Bureau of Economic Analysis (www.bea.gov) and the data on CPI from the US Bureau of Labor Statistics (www.bls.gov).

As explained above, the basis for testing for convergence centers on testing for unit root in the data series by estimating Equation (4). The results obtained are presented in Table 1. APPC-STATE and APPC-US refer to real per capita income difference between Central Appalachian counties and the regional states and the US, respectively. STATE-US refers to the difference of real per capita income difference between regional states and the US. The figures are the t-statistic based on the ADF model (Equation 4).

Based on the results obtained, the null hypothesis of unit root cannot be rejected for any of the data series in all three cases. This means, the data does not provide evidence of convergence (conditional or unconditional) in real per capita personal income in Central Appalachian to that of the regional states and the nation as a whole. The same is true with regards to income convergence between real per capita incomes in the regional states and the country as whole. However, as explained above, when there are structural breaks in the data series, the conventional ADF unit root test is biased towards acceptance of unit root. In view of such possibility occurring, the minimum Lagrange Multiplier (LM) method developed by Lee and Strazicich (2003, 2004) that allows for possible structural breaks in the data series is applied to conduct unit root tests of the data. In using the LM method, the following procedure is adopted: First, the two break minimum LM unit root test (Model C) is implemented. The results obtained are analyzed to test the significance of each break in the data, in addition to testing for the presence of unit root. If the results show the presence of a single structural break instead of two, then the one break minimum LM unit root test method (Model A) is applied to conduct unit root tests. However, if the results show absence of any structural breaks in the data series, then the results of the conventional ADF unit root tests as reported in Table 1 are used to draw conclusions about convergence of incomes.

The test results obtained based on the two break LM unit root test are reported in Table 2. They show that only one break is significant, implying that a one break LM unit root test method is more appropriate for the data under consideration. Therefore, additional tests are conducted using the one break LM unit root test.

The results are presented in Table 3. Based on the results obtained, the null hypothesis of unit root on the APPC-STATE series around a trend is rejected at the 5% significance level. These results provide evidence of stochastic convergence of real per capita income in Central Appalachia to the average per capita income in the regional states. Further, the results reveal that one structural break in trend is significant at the 1% level in the APPC-STATE series implying that the nature of per capita income convergence identified is of the catching-up type. On the other hand, the unit root null cannot be rejected for the APPC-US series, suggesting divergence of per capita income series in

Central Appalachia relative to the national average. Furthermore, the unit root hypothesis for the STATE-US income series is rejected. Given that one structural break in trend is significant at 1% level; the results show stochastic convergence of the

catching up type in income in the regional states with respect to the national income. These results signify that the lack of convergence of per capita income in Central Appalachia to that of the national average does not reflect or mirror the behavior of the average income in the regional states where the Appalachian counties are situated.

CONCLUSION

Whether economic integration among countries and regions within a country leads to economic convergence or divergence is a much discussed topic in the growth and development literature. This paper analyzes the real per capita income growth trends in the Central Appalachian counties of the U.S. over the 1969 – 2010 period to test whether economic integration leads to economic convergence. The Appalachian region provides a unique empirical site for testing the integration-convergence relationships because since 1969, the region has been the focus of a unique regional development program aimed at integrating the region with the national economy by removing geographic barriers that, according to the neoclassical growth theory, impede convergence of the region to the national economy. The study employs time series regression techniques and the notion of stochastic convergence to test whether the region has converged or is converging with the national economy. Results from the empirical analysis show little evidence of convergence or catching-up of per capita income in the region to that of the nation, although there is some evidence of catching-up to the average per capita income in the states where the Central Appalachian counties are situated. Overall, the study provides little support to the notion that closely integrated economies are set to converge and that the best way to ensure convergence over the long run is by allowing market forces to work more efficiently through eliminating barriers that segment markets. Clearly, more research need to be conducted to better understand the source of regional long term growth to be able to develop effective development strategies that reduce income disparity across regions through increasing the speed of regional convergence.

ENDNOTES

¹It should be noted that not all endogenous growth models imply an absence of convergence. Some versions of endogenous growth models point to more optimistic prospects for convergence among countries (regions). According to these models, economic integration allows access to superior technology embodied in goods or capital, or simply through knowledge spillover that allows greater productivity gains in the poorer countries (regions). Since imitation is cheaper than innovation, convergence through technological transfer is a likely outcome (See, Romer, 1986; Bernard and Jones, 1996; Acemoglu and Ventura, 2002; Lucas, 2000; Giannettia, 2001).

²Some examples of the major cross-sectional studies are: Barro and Sala-i-Martin (1991, 1992a, 1992b, 1995) who examined regional per capita income convergence among 48 US states, Japanese prefectures, the Canadian provinces, the EU(NUTS1) region; Chatterji and Dewhurst (1996) who conducted similar analysis for UK counties; Martin (2001), who studied convergence among the EU countries; Petrakos and Saratsis (2000), who analyzed per capita GDP inequalities among Greek

prefecture, Terrasi (1999), who studied convergence in per capita GDP among 20 Italian regions; Perrson (1997), who conducted similar analysis among Swedish Counties.

Almost all of the cross-sectional studies provided evidence of convergence. However, the rate of convergence (about 2% per annum) estimated by these studies, in addition to controversies regarding the method of estimation applied, is considered to be too slow relative to what is implied by the neoclassical view of the regional growth process. That raises fundamental questions over the validity of the neoclassical model. Also, regional convergence, according to the results, does not appear to be a simple monotonic process, but rather seems to vary or even stall over time (Barro Sala-i-Martin 1996; Martin and Surley 1998; Martin 2001).

Some of the time series studies include: Bernard and Durlauf (1995), who studies stochastic convergence among 15 OECD countries; Carlino and Mills (1993, 1996), who conducted similar studies among U.S. regions and U.S. states; Loewy and Papell (1996), who conducted similar study among U.S. regions; Tomljanovic and Vogelsang (2001), who carried similar study among U.S. regions; Carvalho and Harvey (2002), who conducted similar analysis for U.S. regions; and Strazicich et al. (2004), who conducted similar test for the OECD countries. The first generation of tests including, Bernard and Durlauf (1995) and Carlino and Mills (1993) find no evidence of convergence. However, when the convergence test accounts for the possibility of structural breaks in the data series, evidence of convergence was reported.

Panel data studies include, among others: Lall and Yilmaz (2001), who finds no evidence of absolute convergence among U.S. states; De la Fuente (2002), who estimates a convergence rate of 12.7 % for Spain; Funke and Strulick (1999), who report an average convergence rate of about 10% among German Länder.

³A map along with the history and socio-economic profile of the Appalachian region can be accessed here: http://www.arc.gov/research/MapsofAppalachia.asp?MAP_ID=31

⁴There exist only a few independent studies that have formally assessed the effects of the Appalachian development program on economic outcomes in the region and convergence of the region to the national economy. Ziliak (2012) and Glaeser and Gottlieb (2008) used standard econometric growth models to determine the effect of the Appalachian development program on poverty and per capita income and per capita income and population growth, respectively. Isserman and Rephann (1995) compares economic growth of the Appalachian counties to their “twins” outside of Appalachia. The evidence provided by these studies is mixed. While Ziliak and Isserman and Rephann show evidence of a positive impact, Glaeser and Gottlieb reported little or no evidence of such effect. Santopietro (2002) used the conventional cross-section regression method to test for convergence in income per capita between the Central Appalachian counties and non-Central Appalachian counties in the states over the period 1969 – 1998 and reported significant albeit very low unconditional convergence coefficient of -0.0089. The value of the coefficient implies a speed of convergence of 0.0003% per annum. However, cross-sectional regression approach to testing for convergence has come under severe criticism. It has been shown, among others, that the approach has an in built bias towards identifying convergence (Quah 1993). Thus, the limited convergence reported in the study may be an overestimation. Bernard and Durlauf (1994, 1995), among others, advocate for time-

series method for testing the convergence hypothesis.

⁵Isserman and Rephann (1995) describe the subregions as follows: “Each subregion was a textbook example of a lagging area, but for different reasons. Oversimplifying somewhat, Northern Appalachia was an old rustbelt, heavy manufacturing area, Central Appalachia a mountainous, isolated coal area, and Southern Appalachia an exhausted agricultural area.”

⁶In 1963 the Kennedy administration established the President’s Appalachian Regional Commission (PARC) and charged it to study the Appalachian region and “prepare a comprehensive action program” for its development (PARC 1964, pp. II). Congress agreed with PARC’s basic assessment and passed the Appalachian Regional Development Act (ARDA) of 1965. This gave birth to the Appalachian Regional Commission (ARC) - a federal-state-local partnership that supports and coordinates development efforts in the Appalachian region. Details about the history of PARC, ARDA and ARC can be found in Bradshaw (1992), Eller (2008), among others.

⁷The report’s emphasis on this issue is reflected in the following quote:

"Developmental activity in Appalachia cannot proceed until the regional isolation has been overcome... by a transportation network which provides access to and from the rest of the nation and within the region itself.... The remoteness and isolation of the region, lying directly adjacent to the greatest concentrations of people and wealth in the country, is the very basis of the Appalachian lag. Its penetration by an adequate transportation network is the first requisite of its full participation in industrial America." (PARC 1964, pp. 32).

⁸Ziliak (2012) reports that the Appalachian development program “has been the longest serving place-based regional development program in the U.S. after the Tennessee Valley Authority, which was established by President Roosevelt during the Great Depression, and to this day remains the largest in terms of geographic scope.” (pp. 19)

⁹The ADHS is a 3,090 mile near-interstate grade highway system composed of 31 individual corridors and designed to stimulate socioeconomic development throughout the 13-state Appalachian Region (ARC 2010).

¹⁰Controls for other factors that affect growth rates, such as: savings, trade distortions, and political, financial and institutional stability.

¹¹See, Endnote 2.

¹²See, Endnote 2

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Table 1. ADF Unit Root Tests on Real Per Capita Personal Income Differences

	With no regressors	with intercept	with intercept and trend
APPC-STATE	1.690	-0.592	-1.482
APPC-US	2.800	-0.388	-2.094
STATES-US	2.820	-0.234	-1.767

Notes: The critical values are: -2.62, -1.95, -1.61 for a model with no regressors, -3.58, -2.93, -2.60 for a model with an intercept, and -4.15, -3.50, -3.18 for a model with an intercept and a linear time trend. *, **, *** indicate significant at the 1%, 5% and levels, respectively. The lag length (k) is selected by using minimum Schwarz's Bayesian Criterion (SBC).

Table 2. LM Unit Root Tests on Per Capita Personal Income Differences with Two Break Points in Constant and Trend

	Constant	S_{t-1}	TB ₁	TB ₂	B ₁₁	B ₁₂	D ₁₁	D ₁₂
CAPP-STATE	-0.0925*** (-3.6850)	-0.7620*** (-5.3178)	1991	1997	-0.0510 (-1.2375)	0.0419 (1.2867)	0.1486*** (4.2726)	-0.0179 (-1.0447)
CAPP-US	-0.1244*** (-3.8064)	-1.7279 (-4.8267)	1984	2004	-0.0481 (-1.3838)	-0.0365 (-1.1550)	0.1358*** (4.2869)	0.0284 (1.6896)
STATE-US	0.0463*** (5.9560)	-1.5722*** (-6.7305)	1989	1999	0.1043*** (4.2884)	0.0029 (0.3436)	-0.0894*** (-5.6568)	0.0029 (0.3436)

Critical values for the LM unit root test statistic

λ_2	0.4			0.6			0.8		
λ_1	1%	5%	10%	1%	5%	10%	1%	5%	10%
0.2	-6.16	-5.59	-5.27	-6.41	-5.74	-5.32	-6.33	-5.71	-5.33
0.4	-	-	-	-6.45	-5.67	-5.31	-6.42	-5.65	-5.32
0.6	-	-	-	-	-	-	-6.32	-5.73	-5.32

Notes:

TB₁ and TB₂ are the break dates, S_{t-1} is the coefficient on the unit root parameter, B₁₁ and B₁₂ are the coefficients on the breaks in the intercept, D₁₁ and D₁₂ are the coefficients on the breaks in the slope, and k is the lag length. λ_j denotes the location of breaks (breakpoint $\lambda = TB / T$). Critical values for the coefficients on the dummy variables follow the standard normal distribution. ***, **, * denote statistical significance at the 1%, 5% and 10% levels respectively.

Table 3. LM One Break Unit Root Test (Model C)

	Constant	S_{t-1}	TB	B_t	D_t
CAPP -State	-0.0761*** (-3.2349)	-0.6573** (-4.9737)	1991	-0.0505 (-1.2215)	0.1395*** (4.1448)
CAPP-USA	-0.0022 (-0.1869)	-0.4372 (-3.3594)	1982	0.0548*** (2.1545)	0.0499*** (2.7708)
STATE-USA	-0.0833*** (5.2225)	-1.9074** (-5.2519)	1991	0.0548*** (2.7708)	-0.0499*** (-2.7708)

Critical values for the LM unit root test statistic

Location of break, λ	0.1	0.2	0.3	0.4	0.5
1% significance level	-5.11	-5.07	-5.15	-5.05	-5.11
5% significance level	-4.50	-4.47	-4.45	-4.50	-4.51
10% significance level	-4.21	-4.20	-4.18	-4.18	-4.17

Notes:

TB is the break date, k is the lag length, S_{t-1} is the coefficient on the unit root parameter, B_t is the coefficient on the break in the intercept and D_t is the coefficient on the break in the slope. Critical values for the dummy variables follow the standard normal distribution. *, **, *** denote statistical significance at 1%, 5% and 10%.