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Sigma Convergence Versus Beta Convergence: Evidence from U.S. County-Level Data

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Abstract

This note outlines (i) why σ -convergence may not accompany β -convergence; (ii) cites evidence of β -convergence in the U.S.; (iii) demonstrates that σ -convergence does not hold across the U.S., or within most U.S. states; and (iv) demonstrates the robustness of this finding to increases in mean income. The distributions of shocks appear important towards accounting for income disparity.

I. Introduction

Barro and Sala-i-Martin (1995) and Sala-i-Martin (1996) draw a useful distinction between two types of convergence in growth empirics: σ -convergence and β -convergence. When the dispersion of real per capita income (henceforth, simply “income”) across a group of economies falls over time, there is σ -convergence. When the partial correlation between growth in income over time and its initial level is negative, there is β -convergence.²

When economists refer to the “convergence literature,” they refer to the large literature, typified by the seminal papers by Barro and Sala-i-Martin (1992) and Mankiw et al (1992), exploring β -convergence. Sala-i-Martin (1996, p. 1326), surveying this literature, concluded that “the estimated speeds of [β -]convergence are so surprisingly similar across [cross-sectional] data sets, that we can use a mnemonic rule: *economies converge at a speed of two percent per year.*” In other words, economies close the gap between their present level of income and their balanced growth level by 2 percent each year. Panel data studies find higher rates of β -convergence. See Islam (1995) and Evans (1997a).

β -convergence is not a sufficient condition for σ -convergence. Quah (1993) and Friedman (1992) both suggest that σ -convergence should be of interest since it speaks directly as to whether the distribution of income across economies is becoming more equitable. Still, β -convergence remains a primary focus of growth empirics, perhaps

² Sala-i-Martin (1996) makes a distinction between *conditional* β -convergence (as described above) and *absolute* β -convergence, where poor economies simply grow faster than wealthy ones. For simplicity, and since absolute β -convergence can be a specific case of conditional β -convergence where balanced growth paths are identical across economies, we focus on the conditional concept and call it β -convergence.

because, intuitively, it seems to be necessary for σ -convergence. As shown below, this is indeed the case.

Section II outlines why σ -convergence may not accompany β -convergence. Section III cites evidence of β -convergence in the U.S. Section IV describes U.S. county-level data that section V uses to demonstrate that σ -convergence does not occur across the U.S., or within a large majority of U.S. states. The lack of σ -convergence remains even if the measure of dispersion makes allowance for higher average income over time. Section VI concludes.

II. β -Convergence Versus σ -Convergence

This section follows Sala-i-Martin's (1996, pp. 1329-1330) notation. Assume that β -convergence holds for economies $i = 1, \dots, N$. Log income for i can be approximated by,

$$\log(y_{it}) = a + (1 - \beta) \log(y_{i,t-1}) + u_{it}, \quad (1)$$

where $0 < \beta < 1$ and u_{it} has mean zero, finite variance (σ_u^2), and is independent over t and i . Manipulating (1) yields,

$$\log\left(\frac{y_{it}}{y_{i,t-1}}\right) = a - \beta \log(y_{i,t-1}) + u_{it}, \quad (1)'$$

so that $\beta > 0$ implies the negative partial correlation between growth and initial log income.

The sample variance of log income in t is,

$$\sigma_t^2 = \left(\frac{1}{n} \right) \sum_{i=1}^N [\log(y_{it}) - \mu_t]^2, \quad (2)$$

where μ_t is the sample mean of log (income). The sample variance is close to the population variance when N is large, and (1) can be used to derive the evolution of σ_t^2 :

$$\sigma_t^2 \equiv (1 - \beta)^2 \sigma_{t-1}^2 + \sigma_u^2. \quad (3)$$

Only if $0 < \beta < 1$ is the difference equation stable, so β -convergence is necessary for σ -convergence. (If $\beta < 0$ the variance increases over time.) Given $0 < \beta < 1$, the steady-state variance is,

$$(\sigma^2)^* = \frac{\sigma_u^2}{[1 - (1 - \beta)^2]}. \quad (4)$$

The cross-sectional dispersion falls with β but rises with σ_u^2 . Combining (3) and (4) yields,

$$\sigma_t^2 = (1 - \beta)^2 \sigma_{t-1}^2 + [1 - (1 - \beta)^2] (\sigma^2)^*, \quad (5)$$

which is a first-order linear difference equation with constant coefficients. Using the methods discussed by Sargent (1987, pp. 176-183), the solution to (5) is,

$$\sigma_t^2 = (\sigma^2)^* + (1 - \beta)^{2t} \left[\sigma_0^2 - (\sigma^2)^* \right]. \quad (6)$$

Thus, as long as $0 < \beta < 1$, then $|1 - \beta| < 1$ and

$$\lim_{t \rightarrow \infty} (1 - \beta)^{2t} = 0, \quad (7)$$

which ensures the stability of σ_t^2 because it implies that,

$$\lim_{t \rightarrow \infty} \sigma_t^2 = (\sigma^2)^*. \quad (8)$$

Moreover, since $(1 - \beta) > 0$, the approach to $(\sigma^2)^*$ is monotonic.

It follows that the variance will increase or decrease towards its steady-state value depending on the initial σ_0^2 . Therefore, σ_t^2 can be rising even if β -convergence is the rule. Intuitively, economies can be β -converging towards one another while, at the same time, random shocks are pushing them apart.

The above example is stylized. In real economies, σ -convergence would also depend on whether or not disturbances are correlated, and have constant variances, across time and economies. Still, even in the stylized example, β -convergence is necessary but not sufficient for σ -convergence.

III. β -Convergence: The U.S. Case

Many studies have documented β -convergence in the U.S. Barro and Sala-i-Martin (1992), Evans and Karras (1996a and 1996b), Sala-i-Martin (1996), and Evans (1997a and 1997b) find evidence of β convergence when considering U.S. states. In separate papers, we use county-level data to document β -convergence across the U.S. and within 5 broad geographical regions (Higgins et al, 2003), and within individual states (Levy et al, 2003). Clearly, considerable evidence supports the necessary condition for σ -convergence.

IV. U.S. County-Level Data

We explore whether or not σ -convergence is occurring using county-level data. Our data set includes 3,058 counties, and 50 state sub-samples of various sizes. We use the personal income measure as defined by the U.S. Bureau of Economic Analyses (BEA). We net out government transfers and express values in 1992 dollars. Population measures from the U.S. Census are then used to construct per capita amounts. Real per capita income levels are expressed as natural logs and values are considered for both 1970 and 1998.³

³ For a more detailed discussion of the data, see our working papers and/or an appendix available from the authors. Also, see U.S. BEA (2001) for the personal income data concept and data gathering methods.

V. σ -Convergence: The U.S. Case

To our knowledge, the only study of U.S. regional σ -convergence is Tsionas (2000). He examines real Gross State Products (RGSP) and finds that “...the cross sectional variance has fluctuated very little in the 20-year period from 1977 to 1996” (pp. 235-236). In contrast, the time period we cover is nearly a decade longer. Moreover, we also have over 3,000 cross-sectional observations while Tsionas only has 50. As well, Tsionas apparently (and inexplicably) did not convert RGSP into per capita measures.⁴

Table 1 reports 1970 and 1998 cross-sectional standard deviations of log income for the entire sample of U.S. counties, and for sub-samples of the 50 U.S. states. The 1998 standard deviation for the full U.S. sample (0.2887) is greater than that of 1970 (0.2728). In only 3 out of 50 states is the 1998 standard deviation less than that of 1970. For the vast majority of states, as well as for the full U.S., σ -divergence is present.

One argument against interpreting **Table 1** as a deterioration of income equity is that it ignores the increase in the means of the distributions. We have not seen this argument explicitly made in the literature, but the intuition is (to use an international example) that a 1990 standard deviation of per capita income of \$100 is not a big deal in the U.S., but it certainly is in Mali (per capita GDP of \$521) (Barro and Sala-i-Martin, 1995, Table 10.1). As a consequence, we report coefficients of variation (COVs) in **Table 2**.⁵ Again, for the full sample the 1998 COV (0.0301) is larger than the 1970 COV

⁴ Consider this example: 50 states, 25 of which have population growing at 2 percent per year and 25 of which have no population growth. If none of the RGSPs change over the time period considered, Tsionas would have reported no change in cross-sectional distribution. Clearly, with the proper per capita measure, σ -divergence would have been evident.

⁵ The coefficient of variation is the standard deviation divided by the mean.

(0.0298); and, again, for the vast majority (42 out of 50) of states the 1998 COV is larger than the 1970 COV. (In one state the COVs are identical.)

Some have suggested that interpreting measures of dispersion may not be straightforward because the distributions may not be unimodal. See Quah (1997) and Desdoigts (1999). However, for the U.S., **Figure 1** demonstrates that the distribution is unimodal in both 1970 and 1998.⁶

VI. Conclusion

Given the evidence in favor of β -convergence in the U.S., our interpretation of σ -divergence is that the U.S. and its constituent states are approaching steady-state levels of income disparity from below. Another interpretation is that there is increasing disparity in balanced growth path heights or balanced growth rates. However, this seems unlikely considering the relative homogeneity of counties across the U.S. (and certainly within given states).

⁶ Unlike **Tables 1 and 2**, **Figure 1** is generated using income data, rather than in natural log form. This is simply for better visual presentation.

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Table 1: Standard Deviations for 1970 and 1998 Per Capita Income

| <u>Region</u> | <u>Number of Counties</u> | <u>1970 Per Capita Income Standard Deviation</u> | <u>1998 Per Capita Income Standard Deviation</u> |
|-----------------|---------------------------|--|--|
| United States | 3,058 | 0.2728 | 0.2887 |
| Alabama | 67 | 0.1949 | 0.2073 |
| Alaska | 9 | 0.4785 | 0.4798 |
| Arizona | 9 | 0.2136 | 0.2987 |
| Arkansas | 74 | 0.1904 | 0.1911 |
| California | 58 | 0.1646 | 0.3328 |
| Colorado | 63 | 0.2862 | 0.3282 |
| Connecticut | 8 | 0.1491 | 0.2411 |
| Delaware | 3 | 0.2062 | 0.2886 |
| Florida | 67 | 0.2575 | 0.3360 |
| Georgia | 159 | 0.2065 | 0.2304 |
| Hawaii | 4 | 0.1513 | 0.2441 |
| Idaho | 44 | 0.2003 | 0.2098 |
| Illinois | 102 | 0.2044 | 0.2263 |
| Indiana | 92 | 0.1263 | 0.1819 |
| Iowa | 99 | 0.1089 | 0.1415 |
| Kansas | 106 | 0.2279 | 0.1804 |
| Kentucky | 120 | 0.3171 | 0.3151 |
| Louisiana | 64 | 0.2195 | 0.2389 |
| Maine | 16 | 0.1233 | 0.2002 |
| Maryland | 24 | 0.2213 | 0.2927 |
| Massachusetts | 14 | 0.1355 | 0.2155 |
| Michigan | 83 | 0.1966 | 0.2663 |
| Minnesota | 87 | 0.1887 | 0.1963 |
| Mississippi | 82 | 0.1929 | 0.2464 |
| Missouri | 115 | 0.2408 | 0.2464 |
| Montana | 56 | 0.1870 | 0.1911 |
| Nebraska | 93 | 0.1645 | 0.3475 |
| Nevada | 17 | 0.1853 | 0.2150 |
| New Hampshire | 10 | 0.0941 | 0.1444 |
| New Jersey | 20 | 0.1379 | 0.2768 |
| New Mexico | 32 | 0.2770 | 0.3055 |
| New York | 62 | 0.2028 | 0.2995 |
| North Carolina | 100 | 0.1971 | 0.2184 |
| North Dakota | 53 | 0.1562 | 0.2361 |
| Ohio | 88 | 0.1681 | 0.2241 |
| Oklahoma | 77 | 0.2724 | 0.2180 |
| Oregon | 36 | 0.1534 | 0.2163 |
| Pennsylvania | 67 | 0.1692 | 0.2214 |
| Rhode Island | 5 | 0.0830 | 0.1239 |
| South Carolina | 46 | 0.1924 | 0.2251 |
| South Dakota | 66 | 0.2091 | 0.3476 |
| Tennessee | 97 | 0.2136 | 0.2641 |
| Texas | 254 | 0.2744 | 0.3035 |
| Utah | 29 | 0.1732 | 0.2522 |
| Vermont | 14 | 0.0949 | 0.1934 |
| Virginia | 84 | 0.2408 | 0.3006 |
| Washington | 39 | 0.1672 | 0.2213 |
| West Virginia | 55 | 0.2318 | 0.2436 |
| Wisconsin | 70 | 0.1940 | 0.2177 |
| Wyoming | 23 | 0.1623 | 0.2308 |

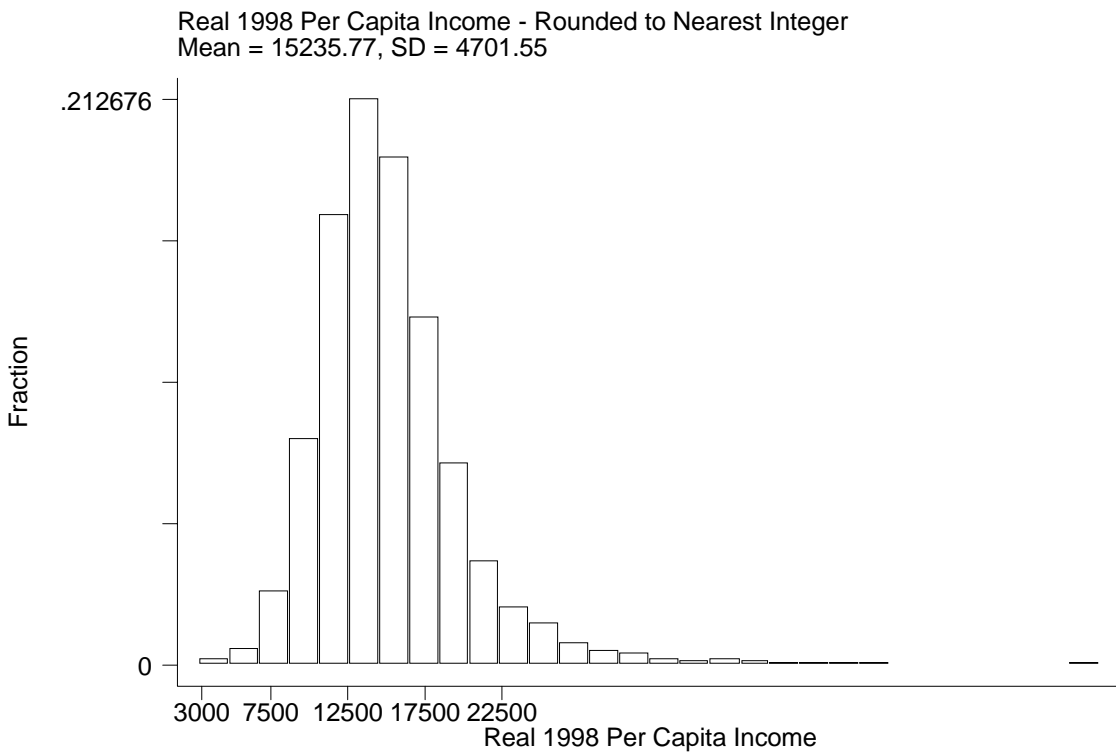
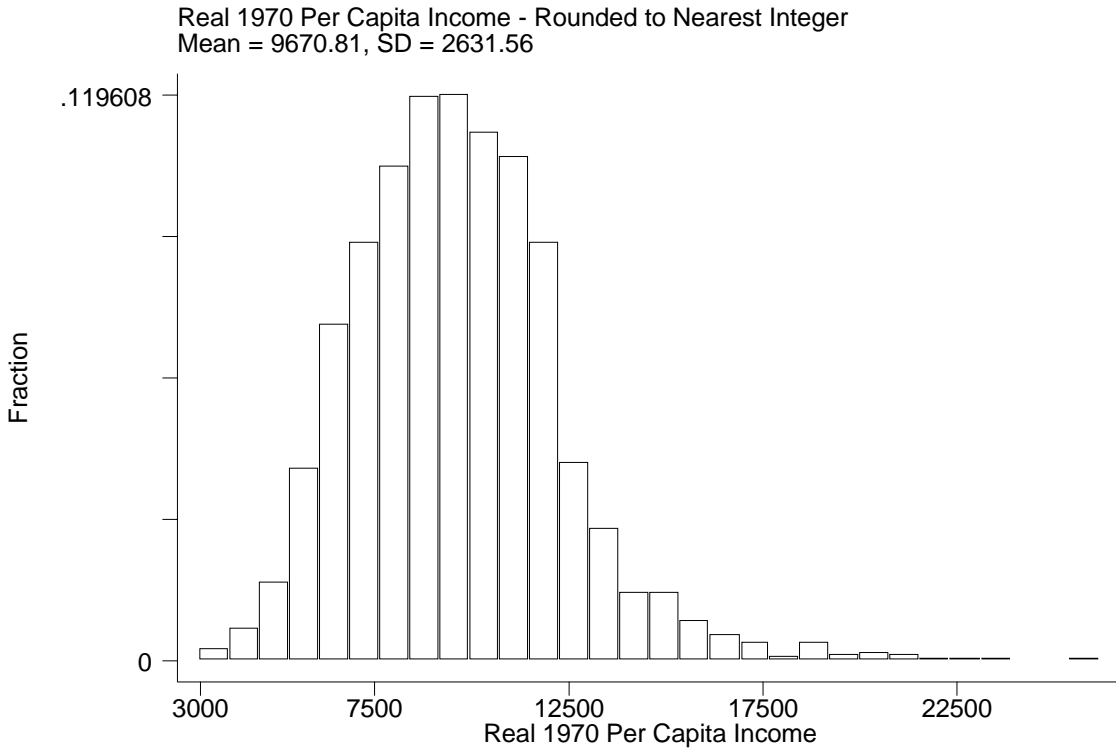
Note: Per capita income figures are in natural log form.

Table 2: Coefficients of Variation for 1970 and 1998 Per Capita Income

| <u>Region</u> | <u>Number of Counties</u> | <u>1970 Per Capita Income Coefficient of Variation</u> | <u>1998 Per Capita Income Coefficient of Variation</u> |
|------------------|---------------------------|--|--|
| United States | 3,058 | 0.0298 | 0.0301 |
| Alabama | 67 | 0.0218 | 0.0219 |
| Alaska | 9 | 0.0499 | 0.0490 |
| Arizona | 9 | 0.0232 | 0.0318 |
| Arkansas | 74 | 0.0214 | 0.0203 |
| California | 58 | 0.0174 | 0.0341 |
| Colorado | 63 | 0.0309 | 0.0336 |
| Connecticut | 8 | 0.0155 | 0.0237 |
| Delaware | 3 | 0.0218 | 0.0293 |
| Florida | 67 | 0.0281 | 0.0349 |
| Georgia | 159 | 0.0230 | 0.0241 |
| Hawaii | 4 | 0.0158 | 0.0251 |
| Idaho | 44 | 0.0216 | 0.0219 |
| Illinois | 102 | 0.0219 | 0.0233 |
| Indiana | 92 | 0.0136 | 0.0186 |
| Iowa | 99 | 0.0116 | 0.0149 |
| Kansas | 106 | 0.0244 | 0.0190 |
| Kentucky | 120 | 0.0356 | 0.0335 |
| Louisiana | 64 | 0.0246 | 0.0253 |
| Maine | 16 | 0.0134 | 0.0207 |
| Maryland | 24 | 0.0235 | 0.0296 |
| Massachusetts | 14 | 0.0142 | 0.0214 |
| Michigan | 83 | 0.0214 | 0.0277 |
| Minnesota | 87 | 0.0205 | 0.0201 |
| Mississippi | 82 | 0.0219 | 0.0264 |
| Missouri | 115 | 0.0266 | 0.0260 |
| Montana | 56 | 0.0201 | 0.0201 |
| Nebraska | 93 | 0.0178 | 0.0362 |
| Nevada | 17 | 0.0193 | 0.0218 |
| New Hampshire | 10 | 0.0101 | 0.0145 |
| New Jersey | 20 | 0.0144 | 0.0273 |
| New Mexico | 32 | 0.0306 | 0.0325 |
| New York | 62 | 0.0216 | 0.0308 |
| North Carolina | 100 | 0.0217 | 0.0226 |
| North Dakota | 53 | 0.0171 | 0.0242 |
| Ohio | 88 | 0.0181 | 0.0231 |
| Oklahoma | 77 | 0.0301 | 0.0231 |
| Oregon | 36 | 0.0164 | 0.0224 |
| Pennsylvania | 67 | 0.0182 | 0.0228 |
| Rhode Island | 5 | 0.0087 | 0.0123 |
| South Carolina | 46 | 0.0213 | 0.0236 |
| South Dakota | 66 | 0.0229 | 0.0362 |
| Tennessee | 97 | 0.0239 | 0.0278 |
| Texas | 254 | 0.0301 | 0.0319 |
| Utah | 29 | 0.0190 | 0.0265 |
| Vermont | 14 | 0.0102 | 0.0198 |
| Virginia | 84 | 0.0264 | 0.0311 |
| Washington | 39 | 0.0178 | 0.0228 |
| West Virginia | 55 | 0.0259 | 0.0260 |
| Wisconsin | 70 | 0.0211 | 0.0224 |
| Wyoming | 23 | 0.0173 | 0.0236 |

Note: Per capita income figures are in natural log form

Figure 1: Dispersion of Per Capita Income – 1970 & 1998



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