Solow and the Native Americans: Technological Residuals and the Economic Performance of U.S. Native American Economies

Voxi Heinrich Amavilah[*]
Resource and Engineering Economics Publications Series (REEPS)
PO BOX 38061, Phoenix, AZ 85069-8061 USA

Abstract: This paper decomposes the large regression residuals of income across 84 U.S. Native American economies (USNAEs) into Solow and Solow-like parts. Decomposition is accomplished algebraically. The calculations find a weak to negative correlation between income and Solow residuals, and a strong correlation between income and Solow-like residuals, especially those associated with human capital and external technology. It also finds that technological residuals are skewed towards high income USNAEs. The reason seems to be that high income USNAEs are better able to build human capital which supports the Nelson-Phelps channel for transmitting technology from external sources.

JEL No. O47**,** R30, F43, D24, C31, P47, O51

Keywords: performance, Solow-Solow-like technological residuals, **U**.**S**. **N**ative **A**merican **e**conomie**s** (USNAEs), infrastructure, superstructure, growth

---

[*] Remark: AMAVILAH is an adjunct instructor of economics at Glendale College in Arizona (USA), and a principal of REEPS, which consults and publishes occasional papers on resource and engineering economics of growth and change of small open economies. The ideas expressed here and in an early version of this paper is available online are his own alone. He can be reached at either vhs@ziplip.com, amavilah@msn.com, or the address above.

Solow, Solow-Alikes, and the Native Americans: Technological Residuals and the Economic Performance of U.S. Native American Economies

0. Introduction

Economists appreciate the role of institutions in economic performance (North, 1990, Smith, 1974, Marx, 1906, Polanyi, 1957, Acemoglu, Johnson, and Robinson, 2001, Hall and Jones, 1999). Adam Smith's most powerful conception of all, specialization, expresses how factors of production interact in market institutions to bring about productivity, which in turn increases the size of the market through the exchange of comparative advantages (Smith, 1957, 1974, Angresano, 1992). In extending Smith, Sir W. Arthur Lewis (1965) argues that "institutions promote or restrict growth according to the protection they accord to effort, according to the opportunities they provide for specialization, and according to the freedom of manoeuvre they permit" (p.56).[1] Institutions organize resources into productive use. As such, institutions support factor productivity and therefore provide a relevant framework for the new growth models in which human capital is a key determinant (Temple, 1999, Romer,1994, Solow, 1994). Unfortunately, and for a long time now, economic growth theory has taken institutions for granted, often even dogmatically, which prompted Richard Nelson (2003) to call the "cannonization of markets" a normative "folk theory", clothed as positive theory, that ignores the role of government and misses institutional complexities, only to turn to them in an *ad hoc* way to address real problems associated with externalities and public goods. Thus, the recent return to Adam Smith's original thesis that institutions are central to economic performance has given economic growth theory a necessary facelift (Hall and Jones, 1999, Jones, 1997, 2000).

However, the current research emphasis on institutions revives the Denisonesque question (Denison, 1967): why do economies with similar institutions perform differently? I have suggested a simple, yet innovative, model for characterizing differential performance across embedded U.S. Native American economies (Amavilah, 2004a). In Amavilah (2004b) I applied the model to 50 U.S. reservation economies (Amavilah, 2004b), and followed up on that with a second application to 84 USNAEs (Amavilah, 2004c). The model I suggested and its applications broaden the base of the measure of human capital and frame it in a manner that permits separation of infrastructural and superstructural effects of institutions on economic performance. In the first application the results indicate that the effect of human capital on performance is generally negative, mainly because infrastuctures for human capital formation are either inadequate, weak, or both, and local superstructures also appear resistant to human capital accumulation. In the second application, infrastructural and superstructural effects on performance are a wash.[2] However, the large constant terms that reflect Solow and Solow-like technological residuals suggest that much of the variations

---

[1] I would recommend Lewis' book as one of the best books there is in economics.

[2] The discussion of conflict between infrastructures and superstructures goes to Karl Marx, but empirical evidence is recent, and not peculiar to USNAEs, see, e.g., Bury (1932), Derby and Williams (1960), and Hessenbruch (2000).

in performance are explained by unexplained technical factors (Solow, 1956, Solow, 1957, Henson, 2003).

This paper carries the conversation one step further. Starting with the theoretical models in Section 1 below, it takes a quick look at the possible composition of the technological residuals implied by the large constant terms. Section 2 restates the models developed in implementable ways, and is followed by the description of variables and data in Section 3. The results are the subject matter of Section 4, and the final section makes concluding remarks.

1. Theoretical Models

Let's measure the performance of the ith USNAE in terms of its aggregate income (Y_i), which is generated by combining local labor (L_i), local physical capital (K_i), and local human capital (H_i), given a Hicks-neutral local technology (A_i). In addition, the ith economy is affected by the condition of the host economy (Y_j) measured as the gross value of product so that the cross-sectional aggregate production function can be written as,

$$Y_i = A_i L_i^{\alpha} K_i^{\beta} H_i^{\gamma} Y_j^{\delta}. \tag{1.1}$$

In terms of average labor intensity (1.1) becomes

$$y_i = a_i k_i^{\beta} h_i^{\gamma} y_j^{\delta}, \tag{1.2}$$

where $y = Y_i/L_i$, $k = K_i/L_i$, $h_i = H_{i/}L_i$, and $y_j = Y_j/L_i$, and A_i, a_i, α, β, γ and δ are all positive constants to be estimated. Equations (1.1) and (1.2) assume that A_i and a_i are common to all local economies and are neutral with respect to all inputs, suggesting a Solow residual. This is one perspective.

Another perspective calls upon Swan (1956, 2002) as employed by Hall and Jones (2000) such that[3]

$$y_i = (a_i h_i) k_y^{\beta/\gamma} y_j^{\delta/\gamma}, \tag{1.3}$$

where $(a_i h)$ is local effective human capital, and $k_y = K_i/Y_i$ is the capital-output ratio.

Equation (1.3) is the Mankiw-Romer-Weil (1992) synthesis of Barro (1991), see also Cohen (1996).

---

[3] There is a new interest in Swan's work sparked by his Australian colleagues and former students like Dixon (2003) and Pitchford (2002).

While it advances Solow in a significant way, (1.3) lacks sufficient explanatory power in the case of embedded economies. In these economies local A_i is more likely than not to favor local L_i than H_i; whereas the technological spill-over of the host economy on the embedded economy passes through local human capital (H_i) such that the appropriate aggregate production function is:

$$Y_i=(A_iL_i)^{\alpha}K_i^{\beta}(A_jH_i)^{\gamma}Y_j^{\delta}, \tag{1.4}$$

where (A_iL_i) is local Solow effective labor, and (A_jH_i) is the interaction of local human capital with host technology. Note that A_iH_i is local Solow effective human capital not equal to A_jH_i.[4] Then taking L as *numeraire* (1.4) becomes

$$y=a_ik^{\beta}(a_jh)^{\gamma}y_j^{\delta}. \tag{1.5}$$

But for a developing economy local A_i is more likely to be embodied in local K so that A_i is Arrow (1962), see also Solow (1997), such that

$$A_i=K^{\eta}. \tag{1.6}$$

Substituting (1.6) into (1.4) and simplifying we obtain

$$Y=L^{\alpha}K^{\alpha\eta+\beta}(A_jH)^{\gamma}Y_j^{\delta}, \tag{1.7}$$

which upon normalizing with L gives average income as

$$y=k^{\alpha\eta+\beta}(a_jh)^{\gamma}y_j^{\delta}. \tag{1.8}$$

Here note that A_j is exogenous to the local economy. And if we agree with Romer's (1993, 1990) and Lucas's (1993, 1988) explanations outlined in Amavilah and Newcomb (2004), Rogers (2003), and Graca, Jafarey and Phillippopoulos (1995), A_j is a function of publicly, privately, or jointly financed research and development (R&D), and R& D depends on human knowledge of the whole

---

[4] With that in mind, (a) we drop the i-subscript from all local variables except A_i and a_i, and (b) associate uppercase A_i with the aggregate production and lowercase a_i with its corresponding intensive form.

economy, not just on the jth and ith sub-economies separately.[5]

We can also rewrite (1.7) as

$$y = (a_j h) k_y^{(\alpha\eta+\beta)/\gamma} y_j^{\delta/\gamma}, \tag{1.9}$$

where $a_j h$ is a Solow-like productivity shock, not to be confused with Solow local $a_i h$. The next section states the preceding models in implementable ways.

2. Empirical Specifications and Other Issues

2.1 Specifications

At the aggregate level we can estimate (1.1) as

$$\ln Y = A_1 + \alpha \ln L + \beta \ln K + \gamma \ln H + \delta \ln Y_j + \varrho \Rightarrow A_1 \equiv \ln A_i = lnY - \Psi \ln X. \tag{2.1}$$

where A_1 is a Hicks neutral technology, Ψ is a vector of estimated parameters, X is a vector of input levels, and ϱ is a normally distributed random error term.

In terms of average labor intensity

$$lny = a_1 + \beta \ln k + \gamma \ln h + \delta \ln y_j + \varrho, \ \Rightarrow a_1 \equiv \ln a = \ln y - \psi \ln x. \tag{2.2}$$

In this case a_1 is a Solow exogenous productivity shifter , and $x = X_i/X_j$ is labor (X_j) intensity of other inputs (X_i). Applying the same argument, from (1.3) we get

$$lny = a_2 + \beta/\gamma \ln k_y + \delta/\gamma \ln y_j + \varrho \Rightarrow a_2 \equiv \ln(a_i h) = \ln y - \psi \ln x, \tag{2.3}$$

observing that a_2 is local effective human capital such that

---

[5] From Lewis (1965, p.169ff), Rogers (1983), Mead (1954), Nisbet (1980), Rosenberg (1982), Scarbrough and Corbett (1992), and others it is clear that until the 20th century inventions and other technological developments depended less on organized science and research than on the drive of individuals, many not educated in the formal sense, and most of them working part-time and for no pay.

$$a_2 = \ln(a_i h) = a_1 \ln h. \tag{2.4*}$$

Logging both sides of (1.4) results in

$$lnY = A_2 + \alpha \ln L + \beta \ln K + \gamma \ln H + \delta \ln Y_j + e \Rightarrow A_2 \equiv lnA_i + lnA_j = lnY - \Psi \ln X. \tag{2.5}$$

Given $A_1 \equiv \ln A_i$,

$$A_2 = A_1 + \ln A_j, \tag{2.6*}$$

where A_1 is local Solow and A_2 is Solow-like. The average income corresponding to (2.5) is

$$\ln y = a_3 + \beta \ln k + \gamma \ln h + \delta y_j + e \Rightarrow a_3 \equiv a_1 + lna_j. \tag{2.7}$$

Equations (2.7) and (2.2) have the same form, but they differ in content; $a_2 \neq a_3$; because even when $\ln a_j = \ln h$ a_3 has a Solow and a Solow-like component.

From (1.7)

$$\ln Y = A_3 + \alpha \ln L + \alpha\eta + \beta \ln K + \gamma \ln H + \delta \ln Y_j + e, \Rightarrow A_3 \equiv \ln A_j, \tag{2.8}$$

which means that

$$A_3 = A_2 - A_1. \tag{2.9*}$$

In average terms (2.8) is

$$\ln y = a_4 + \alpha\eta + \beta \ln k + \gamma \ln h + \delta \ln y_j + e \Rightarrow a_4 \equiv \ln a_j = a_3 - a_1. \tag{2.10}$$

Here too (2.11) and (2.7) look the same, but they are not, unless $a_3 = a_4$.

Finally, from (1.9)

$$\ln y = a_5 + \frac{\alpha\eta + \beta}{\gamma} k_y + \frac{\delta}{\gamma} \ln y_j + e, \tag{2.11}$$

where

$$a_5 = \ln(a_j h) = a_4 \ln h = (a_3 - a_1)\ln h. \tag{2.12*}$$

2.2 Other Issues

I view human capital as

$$H = e^{\phi S_i} N_i = e^{\theta_0 + \theta_1 \bar{q}_i + \phi S_i}, \tag{2.13}$$

where N is the economically capable population, see, e.g., Amavilah (2004a, b, c), Lasky (1950), and Harris (1993).[6] Observe that at the aggregate level

$$\begin{aligned} A_1 &= lnA_i = A_2 - A_3 \\ A_2 &= A_1 + \ln A_j = A_1 + A_3 \\ A_3 &= lnA_j = A_2 - A_1, \end{aligned} \tag{2.14*}$$

On average

$$\begin{aligned} a_1 &= \ln a_i \\ a_2 &= a_1 + \ln h \\ a_3 &= a_1 + \ln a_j = a_1 + a_4 \\ a_4 &= \ln a_j = a_3 - a_1 \\ a_5 &= (a_3 - a_1) lnh = (a_3 - a_1)(a_2 - a_1), \end{aligned} \tag{2.15*}$$

Non-parametric methods are required to obtain unique solutions to the preceding specifications - and

---

[6] The appendix to this paper provides definitions and derivations of S_i and $\bar{q}_i$.

that is not an impossible task to accomplish. A simpler, but more difficult, concern is the identification problem. In linear form (2.1) = (2.5) = (2.8). I go around that problem by estimating only one of the three single equations. Similarly, (2.2) = (2.7) = (2.10) and (2.3) = (2.11), and here too I estimate only one from each group. Upon estimation of those three single equations, I derive Solow and Solow-like residuals algebraically from (2.14*) and (2.15*), and infer the level of technology and productivity shocks from there.

3. Variables, Data and Other Measurement Issues

Data collection focuses on a sample of 84 of the largest USNAEs listed in Table 0.0, and covers the variables described below, where capital letters represent aggregate, and lowercase letters stand for average, variables. Most data comes from *The Statistical Record of Native North Americans (1996)*, which draws its data from the U.S. Census Bureau (1990) and the Bureau of Indian Affairs. Another source of data used here is the U.S. Department of Commerce/EDA (1993).

3.1 Local Dependent Variables (Y, y)

The dependent variables are aggregate (Y) and average (y) income in thousands of 1990 US dollars. We assume that (Y,y) is approximately equal to the aggregate and average value of local production, and treat income and output interchangeably.

3.2 Local Independent Variables

Investment (I) and Capital (K, k)

In most empirical studies current capital stock (K) is calculated by the "perpetual inventory method" as the sum of current year investment (I) and depreciated previous year's capital stock (lag K - Δlag K), or $K = I + (1 - \Delta) lagK,$ where Δ is the rate of depreciation (time subscript is ignored for obvious reasons). Unfortunately, no data on either K or I is readily available. Instead, I found aggregate data on sales and receipts of all Native American-owned firms (ASR) by state and corresponding data on sales and receipts of Native American-owned firms with paid employees (WSR). I argue that if capital is not paid its wages, then the difference between ASR and WSR is *apparent profit* that was re-invested. This argument is no mere measuring without theory; the relationship between investment and expected profit can be defended on theoretical grounds: high profit expectations drive demand for capital, which makes profit is a reasonable proxy for capital, i.e., K ≈ ASR-WSR.[6]

---

[6] Exploratory attempts to use the ratio of apparent profit to income ((ASR-WSR)/Y ≈ I/Y ≈ K), produced unacceptable results and were abandoned. I also noticed that when this proxy is applied equally, as we did here, it favors smaller USNAEs located in large states like California. I offer no remedy for this bias at this time.

Total Labor and Workforce (L)

The labor force is workforce (L) plus the number of unemployed workers. The conventional and extended measures of human capital (E_1, S_1) are based on L.

Economically Capable Population (N)

The *economically capable population* includes people aged 14 - 74 years. Some people who are 16 - 65 years of age already belong to L, so that N_i is the sum of L, pre-L aged 14-15 years, and post-L aged 66-74 years.[1] A detailed investigation of the data shows that the majority of L is in the 22-59 year age group, and it is here where unemployment has the worst effect, because at that age many people are married or are considering marriage and family. But since graduation from both high school and college among Native Americans seems to come later in life, with 25 years of age not uncommon, it also appears that full-time careers start later in life, and often last past the typical retirement age of 65. Also past the typical retirement age, private sector employment of persons 66-74 years old falls, while self-employment and employment in traditional occupations increased, see Amavilah, op. cit.

Human Capital ($H_,$ h)

I note that S has three dimensions to it. The first dimension is educational attainment measured here in two ways. In the first E_{1i} is the ratio of workers with high school or higher education to the total workforce (L). The second measure of educational attainment is the number of people with high school or higher education relative to the economically capable population (N), which I designate by E_{2i}. From previous literature the E_k dimension accounts for two-thirds of the S index.

The second dimension of S is “Health”. The rationale for this dimension is that a healthy population is likely to be physically and mentally more productive than a “sick” population. High productivity enables a population to earn high income. *Ceteris paribus*, with the high incomes a healthy population can stimulate and sustain human capital accumulation, reduce human capital depreciation, and probably increase the rate of human capital drain (cf. Amavilah, op. cit., Bloom, Canning, and Sevilla, 2004). I measure “Health” by the average life expectancy (Life) of Native Americans over the 1980-1990 decade, calculated as

$$Life = \frac{LifeAct - LifeMin}{LifeMax - LifeMin} = \frac{71.5 - 61}{74.9 - 61} = 0.755, \qquad (3.1)$$

where *LifeAct* is actual life expectancy; *LifeMin* is the minimum life expectancy, which is what life expectancy was in the 1960s-1970s; and *LifeMax* is average life expectancy of all U.S. racial groups.

The third and last dimension of S, “Other”, approximates the percentage sum of Native American

---

[1] I wanted 70 years to be our cutoff age, but the data is not recorded that way.

representations in radio and television (0.002), law and law enforcement (0.005), electoral process (0.2002), as well as Native Americans' impartial and objective attitudes toward governance (0.4763), i.e., Other = 0.002+ 0.005 + 0.2002 + 0.4763 = 0.7215.

The "Health" and "Other" variables account for 1/6th of S_i, each such that

$$\begin{aligned} S_{1i} &= 1.47265 \; + \; 0.667 * E_{1i} \\ S_{2i} &= 1.47265 \; + \; 0.667 * E_{2i}. \end{aligned} \qquad (3.2)$$

In general $S_{ki} = a_0 + bE_{ki}$, which implies that all USNAEs are equally disposed to human capital accumulation, given the initial condition, $a_0 = 1.47265$.

The three dimensions of S reflect institutional processes and systems that require investment in physical capital (schools, hospitals, public systems, etc.). Hence, they represent infrastructural aspects of institutions. To measure superstructural aspects of institutions I construct $\bar{q}_i$ as an index of local cultures and traditions that assist or resist H_i building, and through it the transmission of A_j. I argue that cultures and traditions can be open or closed to external influences, and model $\bar{q}_i$ in a multidimensional way so that it is capable of capturing superstructural effects of institutions. First, I consider the ratio of Native American people who have served or are currently serving in the U.S. military to N (r_{m2n}). The military exposes servicemen and women to other cultural and traditional experiences. Hence, a high military-N ratio implies greater cultural/traditional openness. Second, I look at the ratio of languages spoken at home to the English language (r_{h2e}). In a closed economy people are more likely to speak their home language than foreign languages, including English if that is foreign to them, and the ratio should be high. Third, I take the ratio of Native Americans residing in tribal areas to those enrolled in respective tribes (r_{r2e}). If $r_{r2e} = 1$, the tribal economy is completely closed; if $0 < r_{r2e} < 1$, the economy is *open inwards*, hence more people live on tribal land than are enrolled in that tribe. And if $r_{r2e} > 1$, the economy is *open outward*, i.e., more people are enrolled in the tribe than reside on tribal lands. An inwardly open economy is potentially more accepting of the inward flow of A_j than an outwardly open economy. Fourth, I consider the ratio of people in tribal occupations to N (r_{t2n}). The higher this ratio, the more closed the economy. Finally, I take the ratio of people with telephones to those without (r_{t2nt}), the rational being that one would have telephone services only if external communication needs to be maintained. For $r_{t2nt} > 1$, the economy is open and accepting of external technologies. Thus,

$$\bar{q}_i \; = \; \sum_{i=1}^{M=5} r_i, \;\; 0 < r_i < 100\%. \qquad (3.3)$$

A priori expectations are for the effects of S and $\bar{q}_i$ on performance to be positive and negative, respectively, see Amavilah (op. cit.).

3.3 E**xternal Independent Variables**

Conditions of State and National Economies (Y_j, y_j) and Technology (A_j)

The condition of U.S. states (Y_s, y_s), and those of the entire U.S. economy (Y_u,y_u) affect the performance of Native American economies, where (Y_u,y_u) = real U.S. GDP MINUS (Y_i, y_i), real state products (Y_s, y_s) LESS (Y_i, y_i). These relationships should not be surprising as many Native Americans have full-time equivalent (FTE) employment with the federal, and local and state governments. In addition different federal departments support many programs for Native Americans, and such support for these programs ebbs with the condition of the national economy. GDP data for these variables comes from the *Statistical Abstract of the United States: 2003*, 123rd Edition, while A_j is assumed to be exogenous and to flow to USNAEs via H_i**.**

4. Results

4.1 Basic Regression Findings

Determining aggregate income

Table 1 presents aggregate estimation results, where the first-*numbered* column is based on a production function in which human capital is measured by S_1 and $\overline{q}_i$, and the second column is for human capital as measured by S_2 and $\overline{q}_i$. Aggregate income is also influenced by the economic conditions of the states (Y_s) in which USNAEs are located. Columns 3 and 4 are exactly like Columns 1 and 2, except that in this case, instead of economic conditions of states, the state of the U.S. economy as a whole (Y_u) is considered to be important.

From these findings the elasticity of aggregate income with respect to local capital ranges from 0.20 to 0.40, and with respect to labor from 0.23 to 0.30. In other words, a one percent rise in capital and labor, induces an increase of at least 20% each in aggregate income per year. In addition, a 10% increase in human capital measured as S_1 contributes an additional 18% to aggregate income. These results are consistent with Bloom, Canning and Sevilla (2004). While the contribution is not statistically significant, it is nonetheless substantial in view of a decline in income due to an increase in $\overline{q}_i$. In terms of S_2, a percentage point increase in H leads aggregate income to fall by as much as $12.40 per year. The fall in aggregate income occurs despite a marginal rise of one-twenty-fifth of one percent resulting from an increase in $\overline{q}_i$. The results also show the effects of the economic conditions of the states and the USA as a whole to be strongly negative and positive, respectively. Overall the findings are reasonable, but the large constant terms provide a good motivation for looking at why this is the case. We do that after taking a look at the situation in terms of average income. ***Put Tables 1-2 around here***

Determining average income

Turning to Table 2 we note that Columns 1-8 present basic cross-regressions of average income. From there the impact of the capital-labor ratio on average income is high at between 0.34 and 0.61 (Columns 1-6). Holding the capital-labor ratio constant, human capital, measured as S_1 and reflecting infrastructural aspects of institutions, contributes 19-25% to average income annually. However, superstructural elements represented by $\overline{q}_i$ reduce the effects of human capital. The effects of human capital are significantly negative when human capital is measured as S_2. An increase of 10% in S_2 leads to a decline in average income of at least $12, although superstructural aspects of institutions are positive in this case. As the table shows, the economic conditions of the states in which USNAEs are located and of the U.S. general economy are both negatively related to the average income of USNAEs, with at least 30% of variations in average income explained by the included variables.

The last two columns of Table 2 deal with average income as a function of the capital-output ratio ($k_y = K/Y$), among other factors. There is a significantly negative correlation between capital-output ratio and average income. As Thirlwall (1978) demonstrates this is a normal result when capital is measured as a stock rather than a service. First, since investment rate is generally more stable than other inputs, aggregate income - the denominator Y - may fall or rise, causing the ratio and average income to rise or fall in response. Second, if other inputs are more important to average income than capital stock, it is possible for the effect of the capital-output ratio on average income to be negative. The latter appears to be the case here because the effects of host economies on USNAEs are significant.

4.2 Solow and Solow-like Technological Residuals

Income and technological residuals

I calculate (2.14*) and (2.15*) and summarize the results in Figures 1 - 6. Figures 1 and 2 explore the correlation between aggregate income and the three measures of technological residuals. With respect to Figure 1, external technology (A_3) is positively related to income. The Hicks-neutral local technology (A_1) is the least associated with aggregate income, while human capital allied local technology (A_2) falls in between A_3 and A_1. In all three cases, we observe that high levels of technology are associated with high aggregate income economies, but low-income economies seem to experience high rates of technological change judging from the slopes of the curves. If this observation is correct, then low income economies stand to gain the most from the inflow of A_j, but they are least capable of hosting even their local technology as judged by A_2.

Regarding Figure 2, A_3 has the steepest gradient at the lower levels of income, followed by A_2, and last by A_1. In fact, A_1 in this case is flatter than A_1 in the previous case. This suggests that local technology, even when abetted by human capital, has the least impact on aggregate income.

Figure 3 plots average income against technological residuals. One difference here is that we have $a_{21} = a_1 + \ln[h \equiv S_1]$ and $a_{22} = a_1 + \ln[h \equiv S_2]$. It turns out that average income is an increasing function of all productivity shocks except a_{21}. The implication here is that conventional human capital has exaggerated effects on performance, which biases technological residual down. ***Put Figures 1-3 around here***

Technological residuals across USNAEs

Figures 4 and 5 chart aggregate Solow, and Solow-like residuals across USNAEs, while Figure 6 focuses on average residuals. In the former two cases A_1 is practically zero; A_2 and A_3 both tend to zero across economies. Regarding the latter, with some exceptions low-income economies are associated with low technology levels. The negative trend across economies is discernible. ***Put Figures 4-6 around here***

5. Concluding Remarks

This paper continued the conversations about the economic performance of USNAEs initiated in Amavilah (2004a, b, c). Here, as there, estimation results show aggregate and average income to be strongly associated with local physical capital and labor, and their productivity. Generally Native American income is inversely related to measures of human capital and the capital-output ratio. These results suggest that the economic performance of USNAEs, like that of other developing areas around the world, depends on objects rather than ideas (Romer, 1993, 1994). The reason for this is that infrastructural effects of institutions are not strong enough to neutralize superstructural effects such as cultural resistance to human capital accumulation. Human capital formation is resisted because it is, or is perceived to be, incognizant of local Solow values.

The results also show large residuals, suggesting that some of the variations in performance are explained by Solow and Solow-like technical factors. While I am unable to identify these factors at this time, I successfully decomposed apparent Solow and Solow-like technological residuals from a set of basic regressions. Assuming Hicks neutrality, Solow residuals are least associated with both aggregate and average income. In an anti-logarithmic space, there is a discernible negative relationship between income and local technologies (A_1, a_1) and (A_2, a_2), and a positive association between income and external technologies (A_j, a_j). Altenatively, in a logarithmic space, technology has two distinct phases: a steep rise at lower levels of income, and a decreasing increase at higher income levels. The policy implication is that USNAEs would benefit from increased "imports" of A_j. The increased inflow of A_j is facilitated by enlarging or unclogging the Nelson-Phelps (1966) channel through which A_j can pass. However, enlarging and/or unclogging the Nelson-Phelps conduit requires aligning infrastructural and superstructural effects of institutions which determine the marginal impact of human capital on the aggregate and average incomes of USNAEs. There is, thus, a further need for focused investigations of institutional infrastructures and superstructures, and it seems Cornell and Kalt (1997, 1998), Mushinski and Pickering, (2000) and Pickering and Mushinski (2001) may have offered research in this area a headstart.

References

Acemoglu, D., S. Johnson, and J. A. Robinson (2001). The Colonial Origins of Comparative Development: An Empirical Investigation. *American Economic Review* 91(5):1369-1401.

Amavilah, V.H.S. (2004a). Determinants of Economic Growth Across Embedded Economies: A Transformational Analogy of Mining Population for Human Capital. <http://econowpa.wustl.edu/eprints/dev/papers/0402/0402001.abs>

Amavilah, V.H. S. (2004b). Human Capital: Infrastructural and Superstructural Constraints to Economic Performance across U.S. Native American Reservations and Trust Lands (USRATLs). <http://econowpa.wustl.edu/eprintss/ge/papers/0405/045001.abs>

Amavilah, V.H.S. (2004c). Economic Performance in a Cross-section of U.S. Native American Economies. <http://econowpa.wustl.edu/eprints/dev/papers/0402/0405003.abs>

Amavilah, V.H.S., R.T. Newcomb (2004). Economic Growth and the Financial Economics of Capital Accumulation under Shifting Technological Change. <http://econowpa.wustl.edu/eps/ge/papers/0404/0404001.abs>

Angresano, J. (1992). *Comparative Economics*. Englewood Cliffs, NJ: Prentice Hall.

Arrow, K. J. (1962). The Economic Implications of Learning- by-Doing. *Review of Economic Studies* 29: 155-173.

Barro, R. (1991). Economic Growth in a Cross Section of Countries. *Quarterly Journal of Economics* CVI(2): 407-43.

Bloom, D., D. Canning, and J. Sevilla (2004). The Effect of Health on Economic Growth: A Production Approach. *World Development* 32(1): 1-13.

Bury, J.B. (1932). *The Idea of Progress: An Inquiry into Its Growth and Origin*. New York: Dover Publications, Inc.

Cohen, D. (1996). Tests of the “Convergence Hypothesis”: Some Further Results. *Journal of Economic Growth* 1(3):351-361.

Cornell, S., and J. Kalt (1997). Successful Economic Development and Heterogeneity of Governmental Form on American Indian Reservations. <http://www.ksg.harvard.edu/prg/kalt/govtform.htm>

Cornell, S., and J. Kalt (1998). Sovereignty and Nation-Building: The Development Challenge in Indian Country Today. *American Indian Culture and Research Journal* 22(3): 187-214.

Denison, E. (1967). *Why Growth Rates Differ*. Washington D.C.: Brookings Institution.

Derby, T.K. and T. Williams (1960). *A Short History of Technology: From the Earliest Times to A.D. 1900.* New York: Oxford University Press.

Dixon, R. (2003). Trevor Swan on Equilibrium Growth with Technical Progress. *Economic Record*

79(247): 487-90.

Graca, J., S. Jafarey, and A. Philippopoulos (1995). Interaction of Human and Physical Capital in a Model of Endogenous Growth. *Economics of Planning* 28: 93-118.

Gyimah-Brempong, K., and M. Wilson (2004). Health Human Capital and Economic Growth in Sub-Saharan African OECD Countries. *Quarterly Review of Economics and Finance* 44(2): 2096-320.

Hall, R., and C. I. Jones (1999). Why Do Some Countries Produce So Much More Output Per Worker Than Others? *Quarterly Journal of Economics*, 114(1): 83-116.

Harris, D.P. (1993). Mineral Resource Stocks and Information. In Allen V. Kneese and Jones L. Sweeny (Eds.) *Handbook of Natural Resource and Energy Economics,* Volume III, North Holland.

Henson, E.C. (2003). Hearing on S. 519: The Native American Capital Formation and Economic Development Act of 2003. Statement before the U.S. Senate Committee on Indian Affairs (April).

Hessenbruch, A. (2000). Technology. In *Readers' Guide to the History of Science*. Chicago: Fitzroy Dearborn Publishers. Pp.716-720.

Jones, C. (1997). Convergence Revisited. *Journal of Economic Growth* 2(2) 131-153.

Jones, C. (1999). Sources of U.S. Economic Growth in the World of Ideas. *American Economic Review*, 92(1) 220-239.

Lasky, S.G. (1950). How Tonnage and Grade Relations Help Predict Ore Reserves. *Engineering and Mining Journal*, 151, 81-85.

Lewis, W.A. (1965). *The Theory of Economic Growth*. New York: Harper Torchbooks.

Lucas Jr., R. (1993). Making a Miracle. *Econometrica* 61(2) 251-272

Lucas Jr., R. (1988). On the Mechanics of Economic Development. *Journal of Monetary Economics* 22(1) 2-42.

Mankiw, N.G., D. Romer, and D. Weil (1992). A Contribution to the Empirics of Economic Growth. *Quarterly Journal of Economics* 107(2) 407-437.

Marx, K. (1906). *Capital: A Critique of Political Economy*. New York: The Modern Library.

Mead. M. (1954). *Cultural Patterns and Technical Change*. New York: Mentor Book.

Mushinski, D., and K. Pickering (2000). Inequality in Income Distributions: Does Culture Matter? An Analysis of Western Native American Tribes. *Journal of Economic Issues*, XXXXIV(2): 403-412.

Nelson, R. (2003). On the Complexities and Limitations of Market Organization. *Review of International Political Economy* 10(4):697-710.

Nelson, R., and E. Phelps (1966). Investment in Humans, Technological Diffusion, and Economic Growth. *American Economic Review* 56: 69-75.

Nisbet, R. (1980). *History of the Idea of Progress*. New York: Basic Books Inc., Publishers.

North, D.C. (1990). *Institutions, Institutional, and Economic Performance*. Cambridge: Cambridge University Press.

Pickering, K., and D. Mushinski (2001). Making the Case for Culture in Economic Development: A Cross-section Analysis of Western Tribes. *American Indian Culture and Research Journal* 25(1): 45-64.

Pitchford, J. (2002). Trevor Swan's 1956 Economic Growth Seminar and Notes on Economic Growth. Economic Record 78: 381-7.

Polanyi, K. (1957). *The Great Transformation*. Boston: Beacon Press.

Reddy, M. A., Ed. (1996). *The Statistical Record of Native North Americans,* 2nd Edition. Gale Research Inc.

Rivera, B., and L. Currais (2004). Public Health Capital and Productivity in the Spanish Regions: A Dynamic Panel Data model. *World Development* 32(5): 871-885.

Rogers, M. (2003). A Survey of Economic Growth. *Economic Record*, 79(244): 112-135.

Rogers, E.M. (1983). *Diffusion of Innovations*, 3rd Edition. New York: The Free Press.

Romer, P. (1990). Endogenous Technological Change. *Journal of Political Economy* 98(5), S71-S102.

Romer, P. (1993). Idea Gaps and Object Gaps in Economic Development. *Journal of Monetary Economics* 32(3), 543-573.

Romer, P. (1994). The Origins of Endogenous Growth Theory. *Journal of Economic Perspectives* 8(1) 3-22.

Rosenberg, N. (1982). *Inside the Black Box: Technology and Economics*. Cambridge: The Cambridge University Press. Chapter 2.

Scarbrough, H., and J.M. Corbett (1992). *Technology and Organization: Power, Meaning, and Design*. New York: Routledge. Chapters 4, 5, and 8.

Smith, A. (1957). *Selections from the Wealth of Nations*, George J. Stigler (Ed.), Harlan Davidson Inc. Arlington Heights, IL.

Smith, A. (1974). *The Wealth of Nations*, Andrew Skinner (Ed.) New York: Penguin Books., Book 2.

Solow, R.M. (1994). Perspectives on Growth Theory. *Journal of Economic Perspectives* 8(1), 45-54.

Solow, R. (1997). *Learning from "Learning by Doing": Lessons for Economic Growth*. Paolo Alto: Stanford University Press.

Solow, R. (1957). Technical Change and the Aggregate Production Function. *Review of Economics and Statistics*, 39() 312-320.

Solow, R. (1956). A Contribution to Economic Growth. *Quarterly Journal of Economics*, LXX:65-94.

Swan, T. (2002). Economic Growth. *Economic Record* 78: 375-80.

Swan, T. (1956). Economic Growth and Capital Accumulation. *Economic Record* 32: 334-61.

Temple, J. (1999). The New Growth Evidence. *Journal of Economic Literature* XXXVII(1), 112-156.

Thirlwall, A.P. (1978). *Growth and Development, with Special Reference to Developing Economies*, 2nd Edition. London: The MaMillan Press Ltd.

U.S. Department of Commerce (2003). *The Statistical Abstract of the United States: 2003*, 123 Edition (December)

U.S. Department of Commerce/EDA (1993). *American Indian Reservation and Indian Trust Areas*. <www.doc.gov/eda/html/1g3_researcrpts.htm>

Vinje, D.L. (1996). Native American Economic Development on Selected Reservations: A Comparative Analysis. *American Journal of Economics and Sociology* 55: 42-442.

Table 1: Cross-regressions of aggregate income of USNAEs given the economic conditions of the U.S. states (Dependent Variable: lnY, Mean lnY = 18.517, No. of Observations: 84)[a]

Variable	**1**	**2**	**3**	**4**
Constant	10.819(4.074)	17.249(9.873)	No Constant	No Constant
lnL	0.671(6.282)	0.815(14.195)	0.731(6.536)	0.857(13.422)
lnK	0.475(3.545)	0.258(2.933)	0.454(3.192)	0.236(2.383)
S_1	0.187(0.849)		0.252(1.079)	
S_2		-12.437(-10.709)		-12.775(-9.776)
$\bar{q}$	-0.249(-2.723)	0.002(0.028)	-0.266(-2.771)	-0.004(-0.064)
$\ln Y_s$	-0.172(-3.366)	-0.155(-4.734)		
$\ln Y_u$			0.222(2.635)	0.466(7.700)
R^2	0.5292	0.8077	0.4608	0.7524
SEE	1.2911	0.8252	1.3729	0.93038
DW(ρ)	2.2478(-0.1261)	1.8986(0.0478)	2.4519(-0.2275)	2.1620(-0.0831)

---

[a] Parentheses are t- ratios at the 5% significance level.

Table 2: Cross-regressions of average income of USNAEs given the economic conditions of the U.S. states[a] (Dependent Variable: lny, Mean lny = 12.158, No. of Observations: 84)[b]

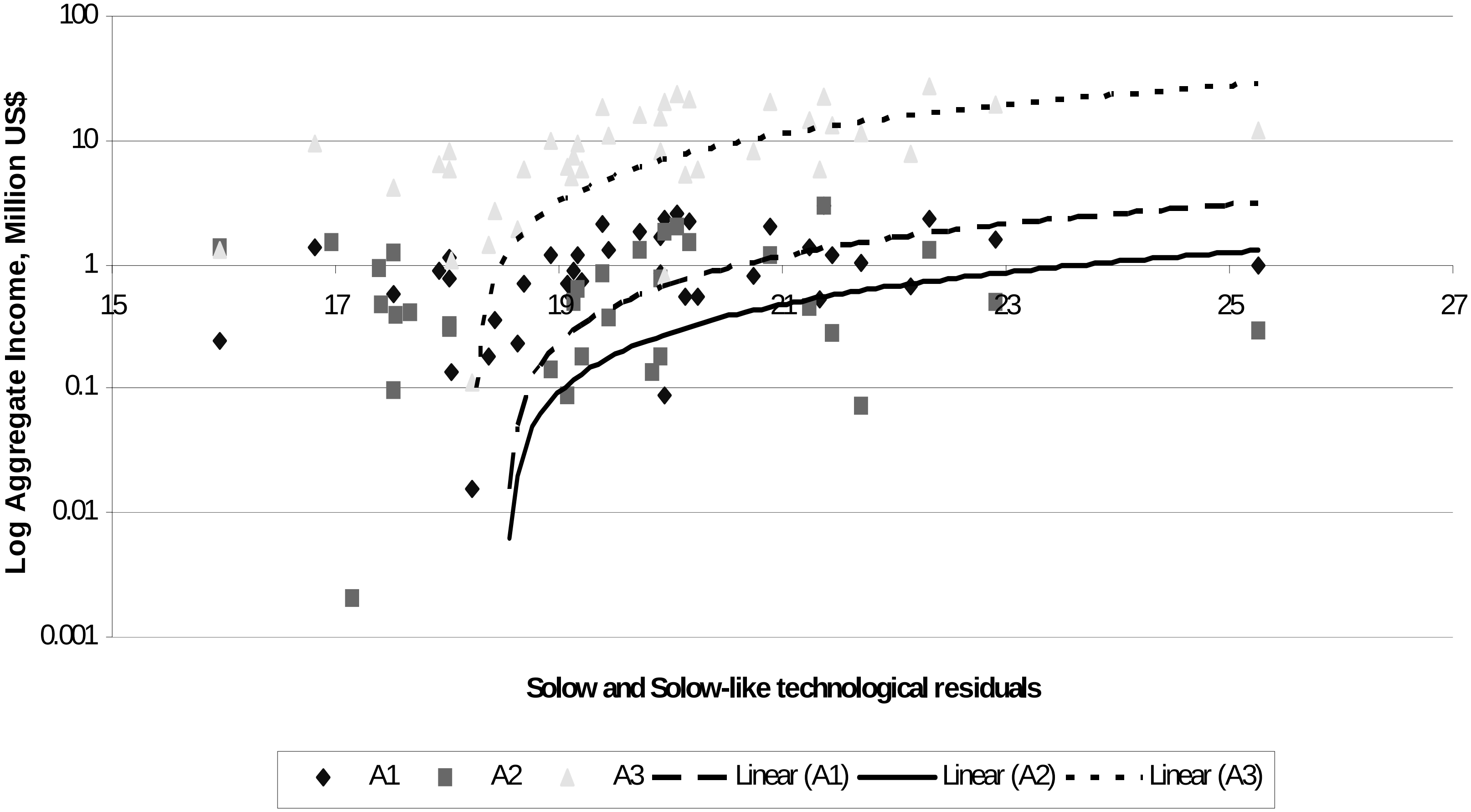
Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Constant	*10.206(10.73)*	*10.879(11.25)*	*16.627(20.32)*	*10.905(3.595)*	*11.992(3.809)*	*16.452(7.951)*	*5.562(3.649)*	*-10.882(-5.30)*
lnk	*0.614(6.802)*	*0.521(5.211)*	*0.341(5.581)*	*0.543(3.780)*	*0.455(3.199)*	*0.237(2.391)*		
lnk_y							*-0.523(-4.688)*	*-0.757(-9.910)*
S_1		*0.199(0.944)*			*0.253(1.082)*			
S_2			*-12.60(-10.75)*			*-12.77(-9.776)*		
$\overline{q}$		*-0.247(-2.703)*	*0.009(0.151)*		*-0.266(-2.771)*	*-0.004(-0.063)*		
lny_s	*-0.222(-3.259)*	*-0.209(-3.157)*	*-0.190(-4.471)*				*0.295(3.997)*	
lny_u				*-0.175(-0.969)*	*-0.186(-1.016)*	*-0.094(-0.794)*		*0.921(10.9800*
R^2	*0.3750*	*0.4285*	*0.7653*	*0.3011*	*0.3647*	*0.7082*	*0.2276*	*0.6284*
SEE	*1.3447*	*1.3020*	*0.8344*	*1.4219*	*1.3728*	*09300*	*1.4949*	*1.0369*
$DW(\rho)$	*2.175(-0.109)*	*2.303(-0.154)*	*1.907(0.042)*	*2.337(-0.189)*	*2.453(-0.228)*	*2.162(-0.083)*	*1.346(0.320)*	*0.956(0.517)*

---

[a] For Columns 2 - 6, k = K/L; for Columns 7 and 8, k_y = K/Y.

[b] Parentheses are t-ratios at the 5% significance level.

Figure 1 - Aggregate income and technological residuals across USNAEs given the economic conditions of U.S. states



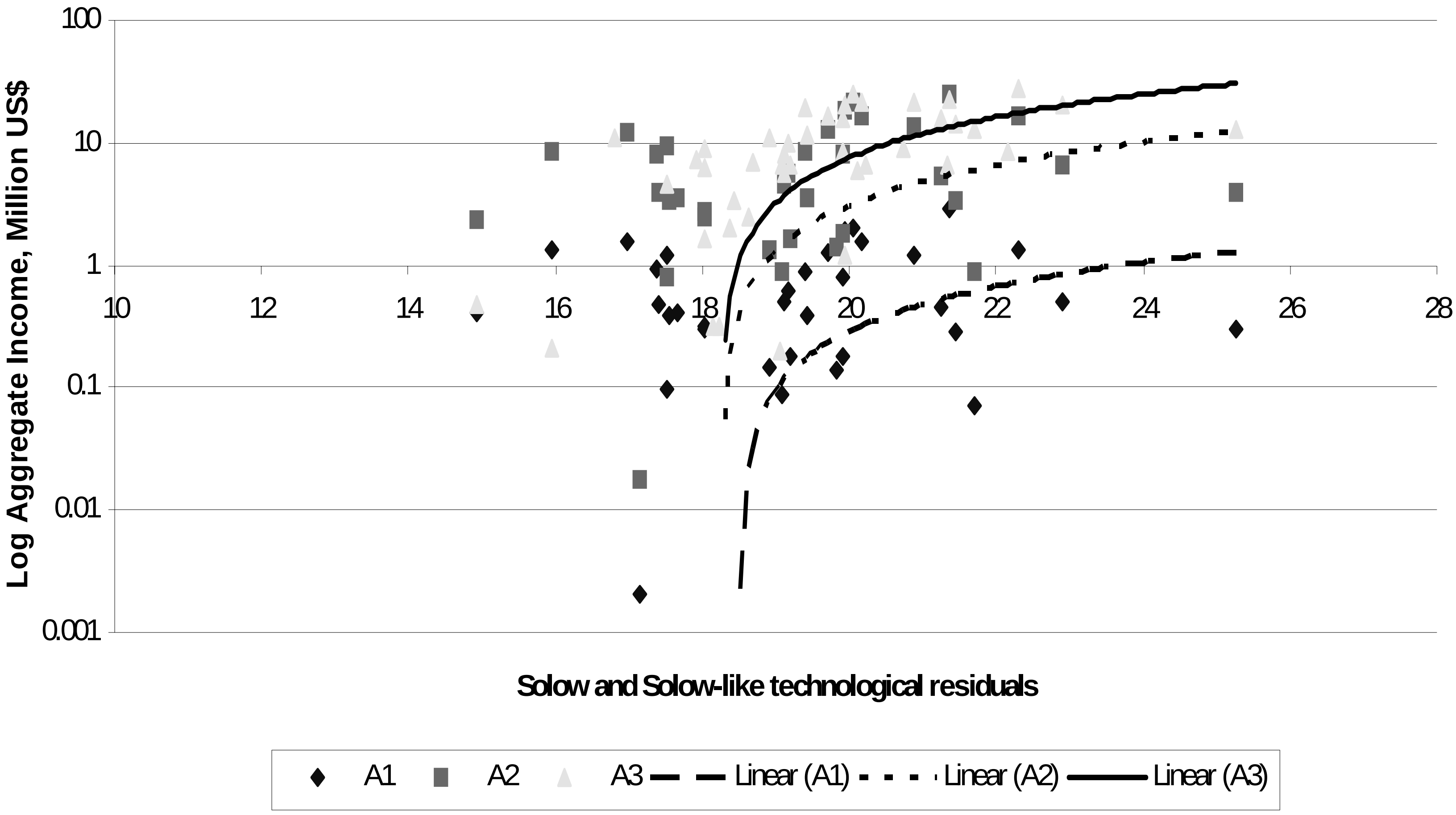


Figure 2 - Aggregate income and technological residuals given the economic condition of the USA as whole
Log Aggregate Income, Million US$
100
10
1
0.1
0.01
0.001
10
12
14
16
18
20
22
24
26
28
Solow and Solow-like technological residuals
A1
A2
A3
Linear (A1)
Linear (A2)
Linear (A3)

Figure 3 - Average income and technological residuals of USNAEs given the economic condition of host economies

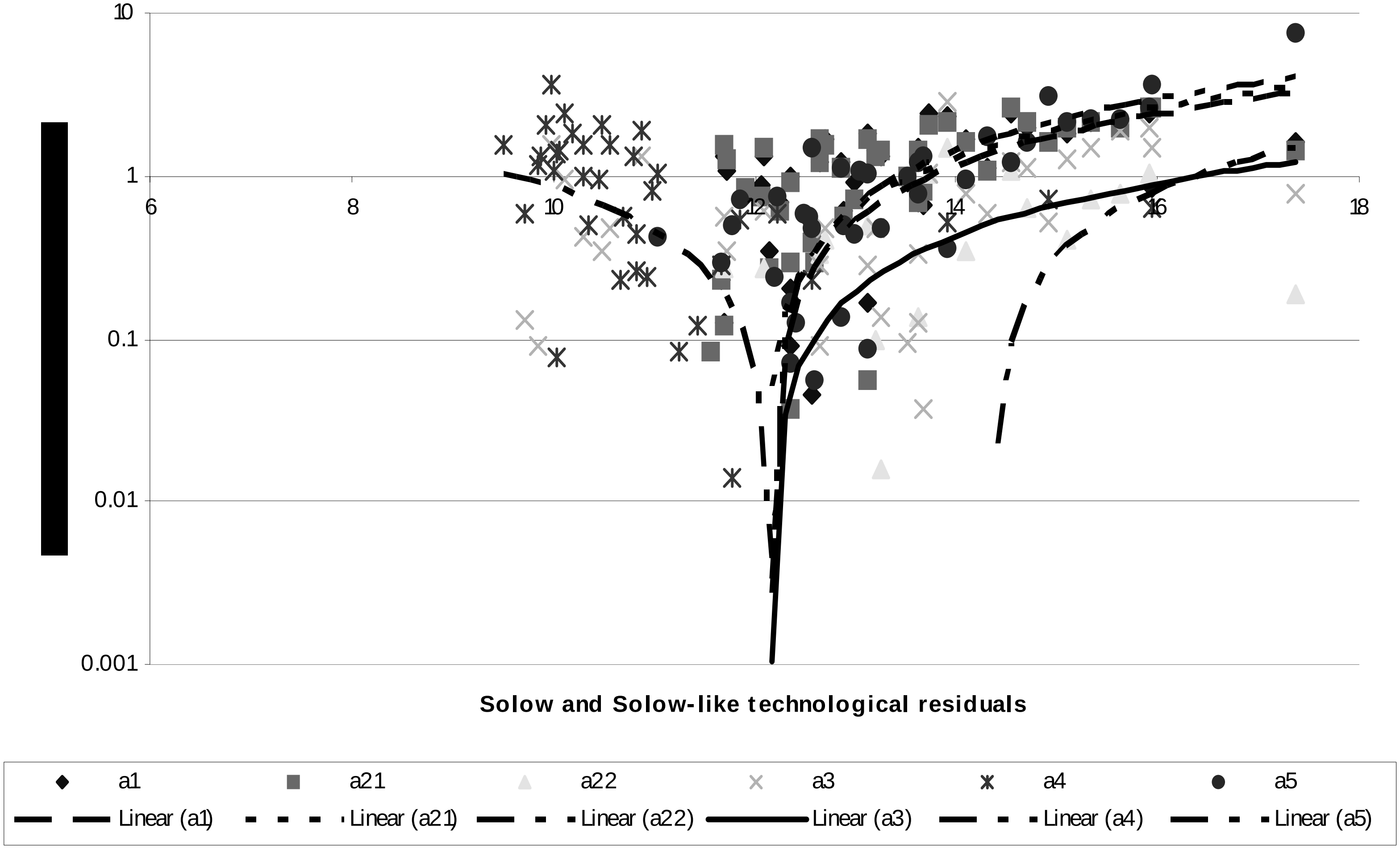


Figure 4 - Solow and Solow-like technological residuals across US NAEs given the economic conditions of U.S. states

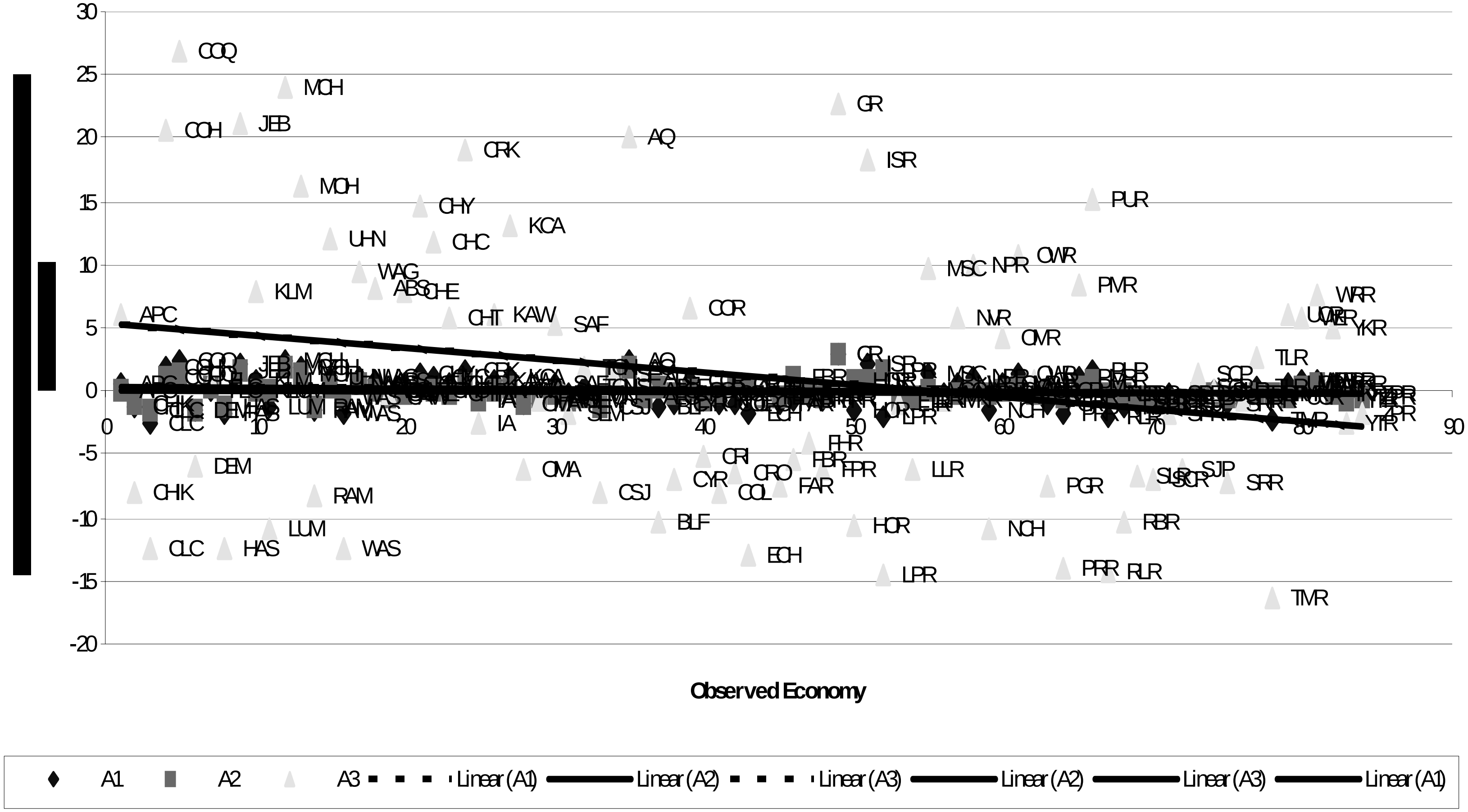


Figure 5- Solow and Solow-like technological residuals across USNAEs given the economic condition of the USA as a whole

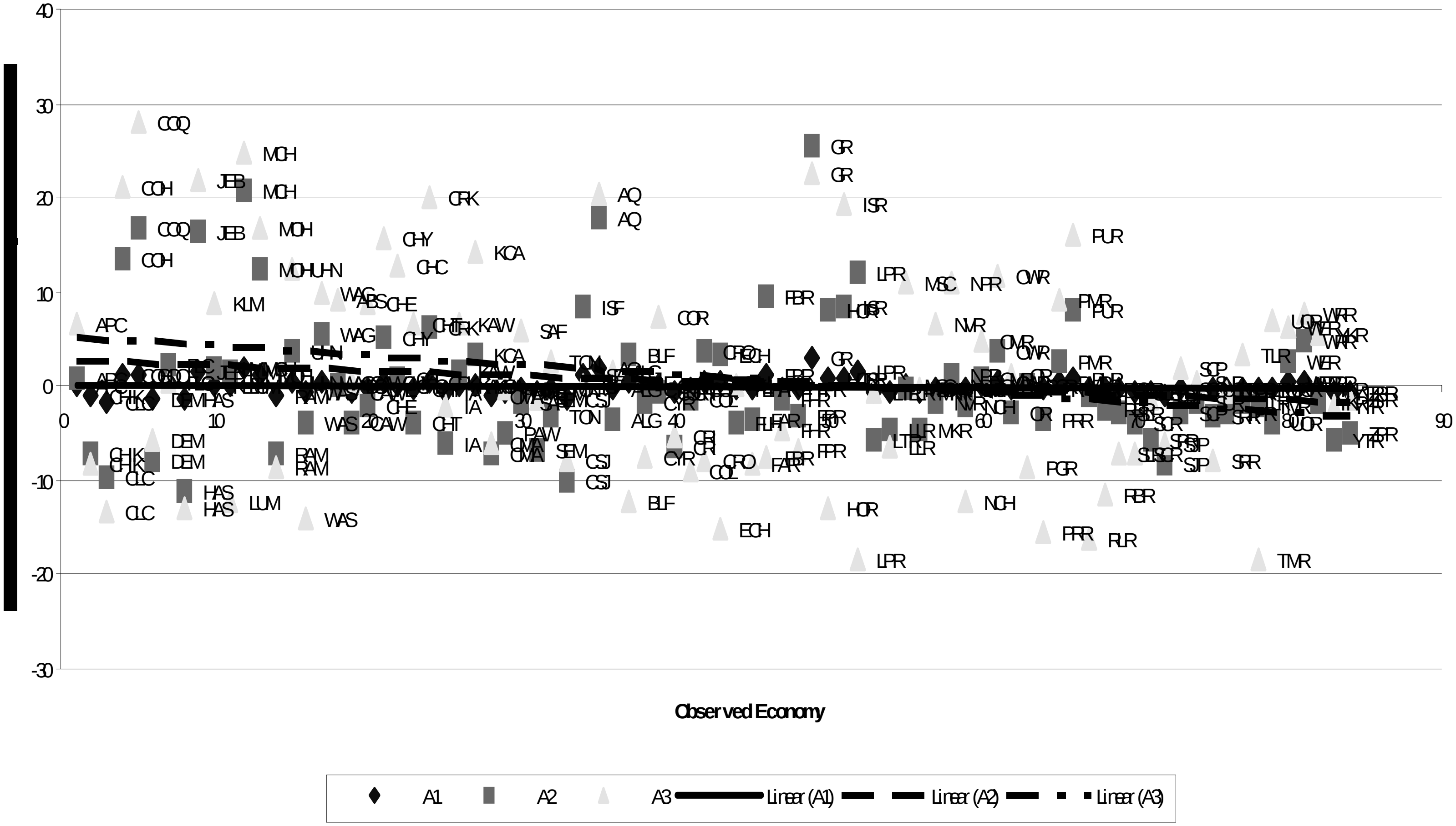


Figure 6 - Solow and Solow-like technological residuals across USNAEs given the economic conditions of host economies

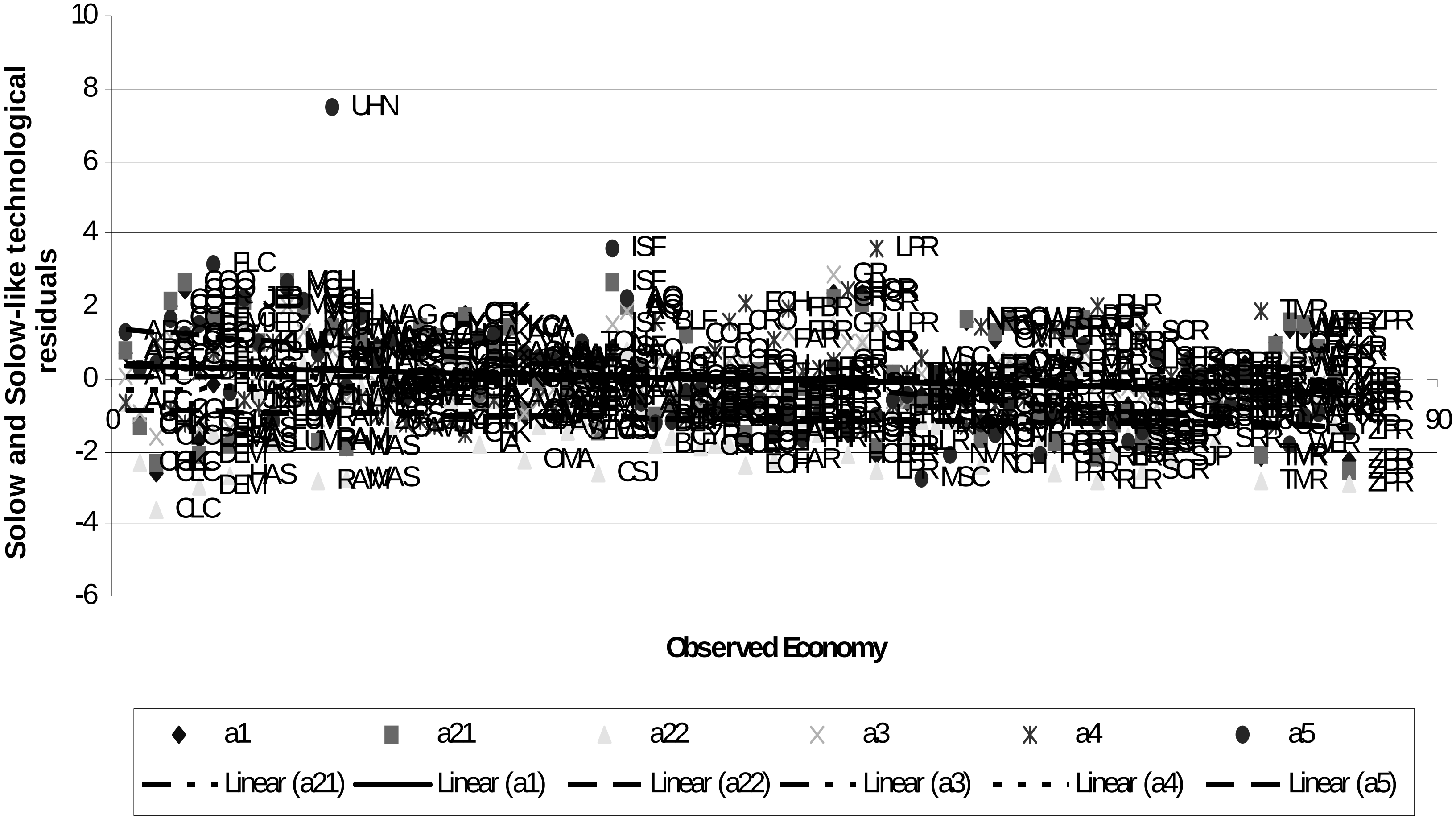


Table 0.0 Codes and Full Names of U.S. Native American Economies[a]

No. Code	Full Name
1. APC	Apache Choctaw
2. CHIK	Chickahominy
3. CLC	Clifton Choctaw
4. COH	Coharie
5. COQ	Coquille
6. DEM	Delaware-Muncie
7. FLC	Florida Tribe, Eastern Creek
8. HAS	Haliwa-Saponi
9. JEB	Jena Band, Choctaw
10. KLM	Klemath
11. LUM	Lumbee
12. MCH	Meherrin
13. MOH	Mohegan
14. RAM	Ramapough
15. UHN	United Houma Nation(s)
16. WAS	Waccamaw Siouan
17. WAG	Wampanong Gay Head
18. ABS	Absentee Shawnee
19. CAW	Caddo-Wihita-Delaware
20. CHE	Cherokee
21. CHY	Cheyenne-Arapaho
22. CHC	Chickasaw

---

[a] 1-17 are Tribal Designed Statistical Areas; 18-34 are Tribal Jurisdiction Statistical Areas; and 35-84 are Reservations and Trust Lands.

No. Code	Full Name
23. CHT	Choctaw
24. CRK	Creek
25. IA	Iowa
26. KAW	Kaw
27. KCA	Kiowa-Comanche-Apache
28. OMA	Otoe-Missouria
29. PAW	Pawnee
30. SAF	Sac-Fox
31. SEM	Seminole
32. TON	Tonkawa
33. CSJ	Creek-Seminole, Joint
34. ISF	Iowa-Sac-Fox, Joint
35. AQ	Agua Caliente
36. ALG	Allegany
37. BLF	Blackfeet
38. CYR	Cheyenne River
39. COR	Coeur d’Alene
40. CRI	Colorado River Indian
41. COL	Coville
42. CRO	Crow
43. ECH	Eastern Cherokee
44. FLH	Flathead
45. FAR	Fort Apache
46. FBR	Fort Berthold
47. FHR	Fort Hall
48. FPR	Fort Peck

No. Code	Full Name
49. GR	Gila River
50. HOR	Hopi
51. ISR	Isabella
52. LPR	Laguna Pueblo
53. LTR	Lake Traverse
54. LLR	Leech Lake
55. MSC	Mississippi Choctaw
56. MKR	Muckleshoot
57. NVR	Navajo
58. NPR	Nez Perce
59. NCH	Northern Cheyenne
60. OMR	Omaha
61. OWR	Oneida West
62. OR	Osage
63. PGR	Papago
64. PRR	Pine Ridge
65. PMR	Port Madison
66. PUR	Puyallip
67. RLR	Red Lake
68. RBR	Rosebud
69. SLR	Salt River
70. SCR	San Carlos
71. SPR	Sandia Pueblo
72. SJP	San Juan Pueblo
73. SCP	Santa Clara Pueblo
74. SUR	Southern Ute

No. Code	Full Name
75. SRR	Standing Rock
76. TPR	Taos Pueblo
77. TLR	Tulalip
78. TMR	Turtle Mountain
79. UOR	Uintah & Ouray
80. WER	White Earth
81. WRR	Wind River
82. YKR	Yakima
83. YTR	Yankton
84. ZPR	Zuni Pueblo