Determinants of Economic Growth Across Embedded Economies: A Transformational Analogy of Mining Population for Human Capital[1]

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Emerging evidence shows a strong correlation between institutions and economic growth, and explains the recent research shift from focus on resources and resource productivity to institutions as determinants of economic growth. The positive correlation is read by some as indication that economies with similar institutions should perform approximately the same, and by extension embedded economies should perform like their host(s). However, observation shows that some embedded economies, such as some U.S. Native economies, perform worse than their host(s) sometimes. There are two reason for the difference: (a) host-embedded interactions are weak; and (b) the institutions of embedded- and host economies are similar only at the infrastructure level, but very dissimilar at the supestructure level. Within general host economies infrastructural and supperstructural elements of institutions work together to stimulate and sustain economic growth, while within embedded economies they may pull in opposing directions thereby slowing, preventing, or even reversing economic growth.

This paper first sets up a practical model of host-embedded interactions assumed to take place via the states of the host economy (Y_j) and technology (A_j) - both of which affect local production (Y_i), where Y_j affects Y_i directly and A_j affects Y_i indirectly through human capital. Second, the paper introduces geo-engineering quantity-quality models that would allow assessment of the separate effects on the growth of embedded economies of infrastructural and superstructural aspects of institutions. An obvious weakness of the paper is that it leaves empirical estimations and tests for a separate study.

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Keywords: growth of embedded economies, mining for human capital, host-embedded interactions, infrastructural versus superstructural determinants of growth.

JEL Classification: O3, O4, P51, O57, J15

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[1]I borrowed the concept of "transformational analogy" in the subtitle of this paper from Rich and Knight (1991:480).

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0. Introduction

THOUGH with varying degrees of emphasis almost all conventional economic growth theories argue that differences in economic performance across economies are due to differences in factor endowment, factor productivity, technology, a combination of any two, or all the above. Human capital, and the scientific knowledge it implies, attracts considerable research attention because it is a *special* endowment that affects technology and the productivity of other factors and forces of production. It is not surprising that many extensions of the growth theories predict significant positive externalities from cross-economy interactions via human capital and trade. *Prima facie*, such predictions suggest that different parts of one economy would perform approximately the same, *ceteris paribus*. But if these predictions are correct, then what explains the observed differences in economic growth across embedded economies such as U.S. Native American economies vis-a-vis the general U.S. economy of which they are a part?

The objective of this paper is to contribute to the various attempts seeking answers to this question. Section 1 starts with a brief literature scan. Section 2 builds a practical model of economic growth across embedded economies, and specifies their relationship to the host economy. The interrelationship is assumed to be of two kinds: one is *static* via the effect of the state of the host economy on embedded economies, and the other is *dynamic* through technological spill-overs passing through human capital. The third section extends the model to explain how one may "mine" population for human capital. Based on the concepts developed in Section 3, Section 4 briefly shows that, measured conventionally, human capital is too narrow a concept and too dependent on infrastructural aspects of institutions, and that it can, perhaps must, be broadened to reflect superstructural elements of institutions. The paper makes concluding remarks in the final section.

1. Scanning the Literature

Following Solow's (1957) stunning finding that capital contributes less than expected to observed economic growth, leaving unexplained a surprisingly large residual, even after accounting for the share of "effective labor", progress in explaining economic growth slowed down significantly.[3] During the slow-down some economists questioned the appropriateness of the aggregate production function Solow employed, while others turned their attention to finding an explanation of why the effect of exogenous technical change (the Solow residual) deviates considerably from the theoretical prediction.[4] With "learning-by-

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[3]Solow attributed the discrepancy to exogenous technical change, and Abramovitz (1979) called the Solow residual the "measure of our ignorance" (Choi, 1983, Chapter 3). What is now called the "*1/3-rule*" came out of research on the Solow residual, and indicates that "our ignorance" is an enduring problem as well as a prospect for research, depending on one's perspective.

[4]Prior to Solow the conventional wisdom of dominant models, such as the Harrod-Domar model, was that long-run economic growth depended mainly on capital. So it was natural that in attacking Solow some critics pointed to model specification error (wrong functional form), while others saw the problem as mis-specification error (wrong variables included or correct variables excluded). The latter set of criticism has not gone away to-date; the former is

doing" Arrow (1962), among the latter group of researchers, succeeded in upgrading Solow *originale* to the neo-Solow status. In hindsight Solow (1997) points out that in re-reading Arrow he was struck again by how phenomenal a breakthrough learning-by-doing was, and the significance level of that was Arrow's and Hicks's receipt of the Nobel Prize in Economics, other things considered.[5] Like Solow *originale*, the first generation of neo-Solow models including Arrow's raised important questions about the causes of economic growth, measures of growth, and why growth rates differ across economies, see, e.g., Denison (1962) and Temple (1999). The second generation sought to illustrate the interplay between the factors and forces of production on one side and policy on the other, but got little traction outside the research community, see, e.g., Abramovitz (1979), Kendrick (1961), Jorgenson and Grilliches (1967, 1992), Kaldor (1961, 1966), Hicks (1961, 1966) and many others.[6] Within the research community the wheels of theory moved significantly into two directions. In one direction Lewis (1954) introduced the concept of a dual economy which is characterized by the coexistence of a modern sector and a backward sector whose economic growth depends on a surplus supply of labor. [7] While models of economic dualism are informative, they are inappropriate for application here, because the distinction between the embedded economies and their host economy is not as sharp as between the modern and backward sector of one economy.

Those who took the second direction of explaining why growth rates differ focused on the political economy of comparative growth rates. Here growth rate differences are due to the interactions of political and economic factors (Mueller, 1983). This work provided impetus to the third generation of neo-Solow growth models, like those by Romer (1989), Mankiw, Romer, and Weil (1992), Barro (1991, 1994), and Barro and Salai Martin (1995). However, these efforts went mainly into adjusting labor for quality and contributed to the momentum that led to the emergence of various new growth models, collectively called post-Solow or neo-Schumpeter (see Romer, 1990, 1994, Solow, 1994, Pack, 1994). According to this group of models, economic growth is a function of "objects" and "ideas", to borrow Paul Romer's lingo. The distinction between ideas and objects as factors of production is not trivial; while objects are subject to the initial conditions of the economy and subsequent diminishing returns, ideas are not (cf. Young, 1928). Relative resource scarcity gives incentives that motivate innovations such that, given similar growth preconditions and policies,

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not peculiar to Solow because it has been raised with respect to the restrictiveness of the original Cobb-Douglas production function (Douglas, 1948). To join the debate, the interested reader may want to review a recent retrospective and a reply on the "Cambridge capital controversies" by Cohen and Harcourt (2003a, 2003b) and the comments it provoked from Pasinetti (2003), Fisher (2003), Filipe and McCombie (2003), and Greenfield (2003). Maurice Scott (1991) offers another perspective on how to deal with the investment function in the production function framework, and Haavelmo (1960) and Lester Taylor (2002) give others.

[5]Kenneth Arrow and Sir JR Hicks shared the Nobel Prize in Economic Science for 1972 for their many contributions to the theories of general equilibrium and welfare, and the Arrow learning-by doing model was no less significant a part of that.

[6]In this line of work the Nobel Prize Committee missed honoring Nick Kaldor and Zvi Grilliches; one wishes it will not miss Jorgenson - but that is an uncalled for personal opinion.

[7]See Choi (1983: 167-180) and Thirlwall (1978: 129-142) for an extensive review of the literature.

different economies would still grow at different rates even if their objects and object productivities are the same. Thus, despite Pack's (1994) critical appraissal, one of the strongest contributions of the new growth models is bringing to renewed attention that the factors and forces of production can, perhaps must, be treated as endogenous determinants of economic growth (Lucas, 1988, 1993, Grossman and Helpman, 1991, Romer, 1990, 1993, 1994).

All these models show that quantitative and qualitative differences in factor productivities explain growth differences across economies. Unfortunately the sources of factor productivity differences have remained largely unexplained until the return to Adam Smith's original thesis that institutions are central to economic growth. The slow return has been coming for a while; Smith's reincarnations, like Sir W. Arthur Lewis (1965), Gary S. Becker (1964), and T.W. Schultz (1981) to list three, agree with the conventional wisdom that economic growth depends on resources, but they add that basic to the factors and forces of production are the historical and philosophical bases, and social structures that motivate and sustain, what Lewis (ib.) appropriately called "the will to economize". By *the will to economize* Lewis was clearly acknowledging resource scarcity; but scarcity that is not necessarily a bad thing because it gives rise to institutions that are capable of organizing resources into productive uses, and promote economic freedom and specialization on the basis of comparative advantages, all of which would then increase factor productivity and subsequently enhance the gains from the exchange of comparative advantages.[8] There are thus sufficient grounds for inferring that Lewis and other new classicals were well aware of the roles in economic growth of both economic preconditions and policies.

In "Why Do Some Countries Produce So Much More Output per Worker Than Others?" Hall and Jones (1998, 1999) attribute differences in average labor productivity across countries to institutions, broadly speaking, and social infrastructure particularly. The quantitative aspect of their research effort is refreshingly new, the positive association alleged between strong economic performance and "good" institutions, however, is not new as careful reading finds evidence of this assertion in Polanyi (1957), Barham (1989), North (1990) and others. In fact, Hall and Jones's finding is consistent with the results by Acemoglu, Johnson, and Robinson (2001), and Lee (2002), to mention just a couple, and suits snugly the model in which Smith sought the creation of institutions that would lead to "social order, liberty, and economic growth" (Angresano, 1992).

In Smith's model of a market economy institutions place first, because they define the modes of action and social relationships which allow people to engage in purposeful activities that have a [defensible] philosophical justification, and are governed by common rules - institutions think (cf. Douglas,1986). For example, market institutions and the property rights they engender enable economic agents to pursue their self-interests. The pursuit of self-interests enhances socio-economic progress and is anchored securely in Smith's two familiar laws of economic growth: "the law of accumulation and the

[8]See Lewis (1965), especially Chapter 2, pp.23-56. Lewis's book, first published in 1953, remains the best book on economic growth based on its coverage of theory, policy, and methodology. In some sense Paul Romer's objects-versus-ideas version of the new growth model is a re-interpretation of Lewis.

law of population" (Smith, 1957, 1974).[9] *Now, whether the material economy and its associated institutional processes (infrastructure), or the ideological referent of the material economy and its supporting institutional processes (superstructure), is fundamental to socio-economic progress is hard to discern from current literature on this topic*. However, it is abundantly clear from Temple (1998, 1999), Hall and Jones (1998, 1999), and others in this line of work, that the differences in factor productivity across countries, and hence in economic growth rates, come from differences in institutions. But again the problem is that this conclusion predicts that economies with similar institutions should perform approximately the same. Is this conclusion sustainable in the context of the special kind of dual economies, here referred to as embedded economies?[10]

2. Modeling Economic Growth across Embedded Economies

Let Y_i be a measure of the economic performance of the ith embedded economy produced using local resources (X_i), external resources (Z_j), and everything else (the random error, $\mu \sim N[0, \sigma^2]$), i.e.,

$$Y_i = f(X_i, Z_j) + \mu_i, \ i \subset j, \tag{1}$$

where X_i includes non-human resources such as physical capital (K_i), land (R_i), and technology (A_i), as well as human resources like the *socio-economically capable population* (N_i)[11], i.e., $Y_i = f(K_i, R_i, A_i, N_i)$. On the other hand, local production is not entirely independent of the host economy; the general condition (Y_j) and the state of technology (A_j) of the host economy both affect Y_i so that $Y_i = f(K_i, R_i, A_i, N_i, Y_j, A_j)$. Assuming that A_i augments L_i , that the effect on Y_i of Y_j is direct, and that the impact of A_j on Y_i is indirect through N_i, then giving (1) a multiplicative functional form results in

$$Y_i = [(A_i N_i)^{\alpha} K_i^{\beta} R_i^{\rho} (A_j N_i)^{\gamma} Y_j^{\delta}] e^{\mu_i}, \tag{2}$$

where A_iN_i is effective local N_i, and A_jN_i is effective N_i relative to the state of the host economy, and

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[9]Smith had argued under the guidance of the "Invisible Hand", but the point here is not about whether or not the Invisible Hand is invincible, as he was well aware that selfish pursuit of self-interest will occasionally fail, yet he believed that such failures would be either self-correcting or government would come to the rescue. I recommend Book II.

[10]A embedded economy is a relatively autonomous sub-economy of a larger (host) economy. U.S. Native American economies are good examples; they are neither dual nor enclaves with respect to the general U.S. economy of which they are a part.

[11]I define *socio-economically capable population* (N_i) as that part of total population that is capable of productive use whether in or out of the labor force. Professor T.W. Schultz would have probably termed "socio-economically capable population" "quality population".

$\alpha + \beta + \rho = 1$ locally, but globally $\alpha + \beta + \rho + \delta \geq 1$, $\alpha + \beta + \rho + \delta + \gamma \geq 1$, or $\alpha + \beta + \rho + \delta + \gamma \leq 1$.

From (2) one can follow Jones (1997, 1999) and Hall and Jones (1998, 2000) in treating N_i as decomposable into raw labor (L_i) and human capital (H_i), where human capital is the equivalent of the quality-enhanced component of total labor given by $H_i = e^{\varphi S_i} L_i$, and S_i is a measure that refines L_i into H_i such as schooling and the like. In that case $N_i \equiv L_i + H_i$ is the resource constraint, such that (2) becomes

$$Y_i = [(A_i L_i)^{\alpha} K_i^{\beta} R_i^{\rho} (A_j H_i)^{\gamma} Y_j^{\delta}] e^{\mu_i} = [(A_i L_i)^{\alpha} K_i^{\beta} R_i^{\rho} (A_j e^{\phi S_i} L_i)^{\gamma} Y_j^{\delta}] e^{\mu_i}. \qquad (3)$$

Alternatively, one can also argue that (3) underutilizes a “good” theory; the rate of diffusion, and hence the impact, of technological spillover is a function of the capacity rate of the embedded economy to soak up A_j. The soaking-up capacity rate in turn depends on the rate of acceptance of or resistence (adoption) to A_j by N_i.[12] Rogers (1983) makes a similar point in asserting that the key variables in determining the rate of adoption of innovations fall into five groups: “perceived attributes of innovations, types of innovation-decision, communication channels, nature of the social system, and extent of change agents’ promotion efforts” (p.233). The implication of that “paradigm” is that while a skilled labor would probably add more to production on average than an unskilled labor, social welfare is little enhanced by increased productivity if N_i is resistant to A_j. To appreciate the importance of N_i as a more reasonable basis for measuring H_i than L_i , take one hypothetical, but nonetheless illustrative, example. Assume a full-time working single parent of a teenage child. Let the child work part-time. The two (parent and child) live rent-free with a relative, say a retired school principal, who drops off and picks up the child from school/work everyday and often helps the child with homework. By helping in this way the relative (host) contributes to the work productivity of both the parent and child, as well as the accumulation of human capital by the child. Conventional theory in this circumstance would argue that the value of both human capital and raw labor is zero at retirement, and that children do not own human capital before the legal working age, about 14 years in the USA. This argument is simply shaky, and I am not the first to say it. Concepts such as the *social development index* (Adelman and Morris,1967), *social capability* (Temple and Johnson, 1998), *social capital* (Coleman,1990), and *cultural capital* (Fryer, 2003) - all speak to the same problem.[13] What

[12]This is an old idea on how cultural factors can aid or inhibit technical change, see, e.g., Bury (1932), Mead (1953), [Cipolla,1965 cf. Diamond, 1998], Volti (1992), Rogers (1983), Pytlik, Lauda, and Johnson (1985), and Nisbett (1980). The term “institutional sclerosis” has also been used to make this very same point, see, e.g., Choi (1983: Chapters 3 and 9), and Mueller (1983:57-78).

[13]Castle (2003) speaks of a social capital paradigm and I am not surprised; a while back I attended a lecture by Dr. Irma Adelman (1988) upon invitation by Emery Castle at Oregon State University in which she stressed alternative measures of economic development. By honoring J. Bhagwati, T.N. Srinivasan, and her for their many contributions at its 2004 Annual Meeting in San Diego, The American Economic Association did economic growth

they all suggest is that once accumulated, human capital retains some of its "scrap value"; in other words, human-capitalized people continue to add value to economic performance even when they are not directly employed in production, mainly because they allow the flow of technological improvements, as well as add to the productivity of those employed. The Mincerian approaches, such as those by Sianesi and Van Reenan (2003), and Harnom, Oosterbeek, and Waltker (2003), which measure returns to H_i only as returns to education, are insufficient.

Another important point is that models of diffusion, as in Hall and Khan (2003), Stoneman (2001), Scherer (1984), and Geroski (2000), show that diffusion rates differ across economies depending upon how prevailing market conditions affect demand and supply of innovations and their surroundings. Clearly the rate of diffusion of A_j through medium H_i is not hard to conceptualize, since if N_i is the quality population, and $f(H_i)$ is the number of people who have already adopted A_j, then $N_i - f(H_i)$ is the number of those who have not yet adopted A_j. Hence, the rate of diffusion is

$$dA_j/dH_i = k[N_i - f(H_i)] = k[\zeta_i] \quad (\zeta_i = N_i - f(H_i)). \tag{4}$$

However, for A_j to diffuse to all potential N_i is a different story, because each N_i^* has a certain capacity (Ξ_i) for "carrying" A_j. If $\xi_i > \Xi_i$, then

$$\xi_i = -\psi_i \Xi_i. \tag{5}$$

If ν_i is the rate of "infusion or mapping" of A_j into i from j, then

$$\xi_i' = \nu_i - \psi_i \Xi_i, \tag{6}$$

so that letting $M_i = \nu_i / \psi_i$ leads to

$$dA_j/dH_i \equiv \xi_i' = \psi_i(M_i - \Xi_i) \Rightarrow \Xi_i = M_i(1 - e^{-\psi_i}) = \nu_i/\psi_i(1 - e^{-\psi_i}) \Rightarrow \xi_i' < k(\zeta_i), \tag{7}$$

which is not unlike what Caselli and Coleman (2001) describe in the case of computers. Hence, for $N_i > L_i$, instead of $H_i = e^{\varphi s_i} L_i$, it makes sense to say that $H_i = e^{\varphi S_i} N_i$ such that

$$Y_i = [(A_i L_i)^\alpha K_i^\beta R_i^\rho (A_j H_i)^\gamma Y_j^\delta] e^{\mu_i} = [(A_i L_i)^\alpha K_i^\beta R_i^\rho (A_j e^{\phi S_i} N_i)^\gamma Y_j^\delta] e^{\mu_i}. \tag{8}$$

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and development a great service.

Normalizing by L_i and taking the natural logarithms of both sides of (8) we obtain

$$lny_i \;=\; \alpha_0+\beta\ln k_i+\rho\ln r_i+\phi S_i+\delta\ln y_j+\mu_i, \quad (\alpha_0=\alpha\ln A_i+\gamma\ln A_j), \tag{9}$$

where $k_i = K_i/L_i$, $r_i = R_i/L_i$ and $y_j = Y_j/L_i$. Similarly, using N_i as the numeraire and logging naturally both sides we get

$$\ln y_i \;=\; \alpha\ln \ell_i+\beta\ln k_i^{*}+\rho\ln r_i^{*}+\phi S_i+\delta\ln y_j^{*}+\mu_i, \tag{10}$$

where $\ell_i= L_i/N_i$ is the local physical labor intensity of N_i, $k^*_i = K_i/N_i$ is the physical capital intensity of N_i, $r_i^* = R_i/N_i$ is intensity of land use by N_i, and $y^*_j = Y_j/N_i$ is the host's output relative to N_i. Note that y^*_j can be read either as a spill-over effect of the host economy on the local economy or as a measure that equalizes local and host labor productivities. In other words, it is what national labor productivity would be if all national output were produced by local labor alone.

From Klenow and Rodriquez-Clare (1997)[14], an increase in A_i is likely to increase K_i, and since A_j and Y_j also affect Y_i

$$Y_i \;=\; [(A_iL_i)^{\alpha/\gamma}(K_i/Y_i)^{\beta/\gamma}R_i^{\rho/\gamma}(A_je^{\phi S_i}L_i)Y_j^{\delta/\gamma}]e^{\mu_i}, \tag{11}$$

which after taking into account L_i and logging both sides yields

$$lny_i^{*} \;=\; \frac{\alpha}{\gamma}\ln A_i+\frac{\beta}{\gamma}\ln k_i^{**}+\frac{\rho}{\gamma}\ln r_i+lnA_j+\phi S_i+\frac{\delta}{\gamma}\ln y_j^{*}+\mu_i, \tag{12}$$

for $k_i^{**} = (K_i/Y_i)/L_i$, and where A_i and A_j are exogenous, $\alpha/\gamma\ln A_i + \ln A_j$ = constant.

Alternatively,

$$Y_i \;=\; [(A_iL_i)^{\alpha/\gamma}(K_i/Y_i)^{\beta/\gamma}R_i^{\rho/\gamma}(A_je^{\phi S_i}N_i)Y_j^{\delta/\gamma}]e^{\mu_i}. \tag{13}$$

Dividing (13) by N_i and taking the logs results in

[14] As indicated in Amavilah (2002), I first learned of Klenow and Rodriquez-Clare's paper through Frankel and Romer (1999); my interpretation may be influenced by theirs, but I alone am responsible for my errors.

$$lny_i^{/}=\frac{\alpha}{\gamma}\ln(A_i\ell_i)+\frac{\beta}{\gamma}\ln k_i^{/}+\frac{\rho}{\gamma}\ln r_i^{*}+\ln A_j+\phi S_i+\frac{\delta}{\gamma}\ln y_i^{*}+\mu_i, \tag{14}$$

where yi’ = Yi/Ni and ki ‘ = (Ki/Yi)/Ni.

In all the above technology is assumed to be exogenous. This need not be the case as we can let $A_i = K_i^{\eta}$ be Arrow (1962)[15], where η is cumulative learning-by-doing and $1\text{-}2^{\eta}$ is the rate of learning, such that

$$Y_i=[K_i^{\eta\alpha+\beta}L_i^{\alpha}R_i^{\rho}(A_je^{\phi S_i})^{\gamma}Y_j^{\delta}]e^{\mu_i}. \tag{15}$$

Removing the scale effect from (15), normalizing by L_i, and taking the natural logs leads to

$$lny_i^{**} = \frac{\eta\alpha+\beta}{\gamma}\ln k_i^{**}+\frac{\rho}{\gamma}\ln r_i+\ln A_j+\phi S_i+\frac{\delta}{\gamma}\ln y_j+\mu_i, \tag{16}$$

which considering N_i instead of L_i is similar to

$$lny_i^{/} = \frac{\alpha}{\gamma}\ln(A_i\ell_i)+\frac{\eta\alpha+\beta}{\gamma}\ln k_i^{**}+\frac{\rho}{\gamma}\ln r_i^{*}+\ln A_j+\phi S_i+\frac{\delta}{\gamma}\ln y_j+\mu_i. \tag{17}$$

One application of Arrow is technological change is Young (1991). Following Harris (ib) and others, Amavilah (1998, pp. 12-14 and 31-32) has suggested another scheme that shows that the efficiency of technological change can be both Arrow and Hicks.[16]

3. Extended Model Adaptations: Mining Population for Human Capital

A cogent review of different measures of H_i by Yang-Taek Lim and Joon-Suk Jung (2003) compared to studies like those by Harmon, Oosterbeek, and Walker (2003), and Sianesi and Van Reenen (2003) shows that the debate over the processes for generating, as well as measuring, H_i is ongoing. Still one can estimate (5), (8), and (11) assuming $H_i = e^{\varphi S_i} L_i$, or (6), (10) and (12) assuming $H_i = e^{\varphi S_i} N_i$.

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[15]For a brief overview of new growth models of this type see Rogers (2002).

[16]One is better off aware of the policy implications of net learning (net of system forgetfulness) and gross learning, see Amavilah (2002) and Benkard (1999).

But how would one measure N_i? To measure N_i I introduce a set of quantity-quality (Q-Q) models familiar to economic geology, mining and geological engineering, and mineral economics. In their original use these models illustrate the responsiveness of a stock (quantity) of resource, such as a mineral ore, to its average grade (quality) in one deposit or across deposits (Lasky, 1950).[17] By "transformational analogy" N_i can be thought of as a rich stock of an unknown average quality that can be "mined" for human capital, utilizing three mathematical forms of the Q-Q model: the Lasky, the quadratic, and the simple power.

3.1 The Lasky Adaptation

The Lasky adaptation represents an inverse relationship between the log of cumulative stock - the socio-econmically capable population (N_i) in this case - and its corresponding quality (q-bar), i.e.,

$$lnN_i=\theta_0+\theta_1\bar{q}_i \Rightarrow \bar{q}_i=\lambda_0+\lambda_1 \ln N_i, \quad [\lambda_0=\theta_0/\theta_1,\ \lambda_1=1/\theta_1], \tag{18}$$

Hence, for

$$N_i=e^{\theta_0+\theta_1\bar{q}_i},\ H_i=e^{\phi_i S_i}[N_i]=e^{\theta_0+\theta_1\bar{q}_i+\phi_i S_i}. \tag{19}$$

Alternatively,

$$H_i=N_i\bar{q}_i=[e^{\theta_0+\theta_1\bar{q}_i+\phi_i S_i}][\lambda_0-\lambda_1\theta_0-\lambda_1\theta_1\bar{q}_i]. \tag{20}$$

Eq. (20) suggests that the minimum average quality of N_i, and therefore the level of H_i, is associated with the lowest cut-off quality, and the maximum average grade is associated with the highest cut-off grade, suggesting that *S_i is not an adequate measure of H_i*. More later.

3.2 The Quadratic Adaptation

The Lasky model assumes a linear relationship between the quality and quantity of the population stock, but such a relationship may be of a (lognormally-distributed) quadratic form:

[17] I learned all I know about these group of models from my teacher Dr. Deverle Harris, formerly Director of the Mineral Economics Program in the Department of Mining and Geological Engineering, and now Professor of Geoscience, at the University of Arizona (see Harris, 1984, 1993, 1985, 1976). In his writings and classroom teachings Harris warns users of Q-Q models to be aware of the fact that the results of this models may be misleading if associated problems of economic translation and truncation are not born in mind in interpreting the results.

$$\bar{q}_i=\lambda_0+\lambda_1\ln N_i+\lambda_2(\ln N_i)^2 \Rightarrow \ln N_i=\theta_0+\theta_1\bar{q}_i+\theta_2\bar{q}_i^2, \tag{21}$$

which, upon substitution and simplification, gives

$$\bar{q}_i=q_i^{/}-\lambda_1-2\lambda_2\theta_0+2\lambda_2\theta_1\bar{q}_i+2\lambda_2\theta_0\theta_2\bar{q}_i^2. \tag{22}$$

For $H_i = N_i\bar{q}_i$ the cut-off quality $q_i' = dH_i / dN_i$ so that subtracting q-bar from both sides of (22) above leads to

$$0=q_i^{/}-\lambda_i-2\lambda_2\theta_0-(1-2\lambda_2\theta_1)\bar{q}_i+2\lambda_2\theta_0\theta_2\bar{q}_i^2. \tag{23}$$

Solving (23) by the quadratic formula gives

$$\bar{q}_i=\frac{-(1-2\lambda_2\theta_1)\pm\sqrt{(1-2\lambda\theta_1)^2-4(2\lambda_2\theta_0\theta_1)[q_i^{/}-\lambda_1-2\lambda_2\theta_0])}}{2(2\lambda_2\theta_0\theta_1)} \tag{24}$$

Hence,

$$H_i=[e^{\theta_0+\theta_1\bar{q}_i+\theta_2\bar{q}_i^2}][\frac{-(1-2\lambda_2\theta_1)\pm\sqrt{(1-2\lambda_1\theta_1)^2-4(2\lambda_2\theta_0\theta_1)(q_i^{/}-\lambda_1-2\lambda_2\theta_0)}}{2(2\lambda_2\theta_0\theta_1)}]. \tag{25}$$

3.3 The Simple Power Adaptation

If the *N*-*q* relationship is of a simple power form, then

$$N_i=C\bar{q}_i^{\lambda_i} \Rightarrow (N_i/C)^{-1/\lambda_i}=\frac{q_i^{/}}{\lambda_i+1} \quad (C=constant). \tag{26}$$

Since $q_i^{\prime} = (1+\lambda_i)\bar{q}_i$, it is the case therefore that

$$H_{i\bar{q}_i(q_i^{\prime})} = \int_{\bar{q}_i(q^{\prime}_{\min})}^{\bar{q}_i(q^{\prime}_{\max})} f(\bar{q}_i(q_i^{\prime})d[\bar{q}_i(q_i^{\prime})], \tag{27}$$

which can be estimated as

$$H_i = (C\frac{q^{\prime}}{(1+\lambda_i)})^{\lambda_i} = \ln H_i = \ln C^{\lambda_i} + \frac{\lambda_i}{(1+\lambda_i)}\ln q_i^{\prime}. \tag{28}$$

From these three adaptations above, and many others in e.g. Thompson (1992), it is clear that

$$H_i = f(N_i(\bar{q}_i(q_i^{\prime}))). \tag{29}$$

One one can add in passing that while $N_i > L_i$, H_i conditional on N_i may be smaller, larger, or equal to H_i conditional on L_i - all depending on the average quality assumed of N_i. Having said that, it is still important, however, to stress that an embedded economy is like an island - it is surrounded by water on all sides, being a part of its surroundings and yet different from it. Incoming tides act as both positive and negative forces. As positive forces they enrich the island, not unlike A_j might do to Y_i through H_i; as negative forces they destroy and/or slow down the growth of the island - think of the effects on an island of a storm such as a hurricane. Receding tides on the other hand carry away elements of the island, including those the previous incoming tides helped to grow. They barely enrich the surrounding waters, while slowing down the performance of the island - a process not unlike the “braindrain” phenomenon. The following is an abbreviation of how it plays out.

According to the standard models, the desirable, not necessarily optimal or efficient, level of human capital (H_i^*) is

$$H_i^* = (1-\sigma)e^{\phi S_i}L_i = e^{\phi S_i}L_i,\ \ \sigma=0,\ \ 0<dlnH_i^*/dS_i = \phi<1, \tag{30}$$

implying that there is no human capital drain, either because L_i is all employed already, or because, since it is tied to local A_i, it is unemployable outside the embedded economy itself - nowhere to go (cf. Chevalier, 2003).

With nonzero human capital drain,

$$
\begin{aligned}
H_i^* &= (1-\sigma)e^{\phi S_i}N_i, \quad 0<\sigma<1 \quad (\textit{conventional if } N_i \equiv L_i) \\
&= (1-\sigma)e^{\theta_0+\theta_1\bar{q}_i+\phi S_i} \quad (\textit{Lasky}) \\
&= (1-\sigma)e^{\theta_0+\theta_1\bar{q}_i+\theta_2\bar{q}_i^2+\phi S_i} \quad (\textit{Quadratic}) \\
&= (1-\sigma)C[\frac{q_i^{/}}{1+\lambda_i}]^{\lambda_i} \quad (\textit{Power}).
\end{aligned} \tag{31}
$$

From (31) it is clear that

$$
\frac{dlnH_i^*}{d\bar{q}_i} = \theta_1 \ (\textit{Lasky}), \frac{dlnH_i^*}{d\bar{q}_i} = \theta_1 + 2\theta_2\bar{q}_i \ (\textit{Quadratic}), \ \frac{dlnH_i^*}{d\bar{q}_i} = \lambda_i(1-\sigma)C[\bar{q}_i]^{\lambda_i - 1} \ (\textit{Power}). \tag{32}
$$

What this means is that A_j *transforms* N_i *into* H^*_i *that can be employed on and off the embedded economy*, and hence $\sigma \neq 0$ implies a sort of human capital drain, and in that case γ would also be nonzero. Hence, $H_i^* < H_i$ in this case. Note that H_i is either net of depreciation, or depreciation is zero; in fact H_i depreciates slower with old age than it appreciates with youth age.

4. Are Institutional Determinants of Economic Growth Infrastructural or Superstructural?

While I am still thinking through this question, and the best way of presenting the idea that follows, I am aware of an old but helpful Marxian dichotomy that institutional determinants of economic growth can be either infrastructural or superstructural. This, distinction can be exploited profitably without one becoming a Marxist. Marx is praised by some and criticized by others for according supremacy to the role of the economy in society. But he was aware of the dynamics underlying production forces and social relations, and argued that the factors of production are responsible for the transformation of material (economic) conditions - the basic structure or infrastructure of the economy. Changing the infrastructure tends to alter the social relations of production. And that is not all there is to it because if it were infrastructural change would always lead to progress. That is obviously not the usual case. The infrastructure without the superstructure (ideological/philosophical underpinning) would be the equivalent of a body skeleton without any flesh on it. In other words, changing infrastructure changes the social relations of production, thereby motivating the superstructure to respond adversely favor of the status quo. The result is cosmetic institutional change (Marx, 1906, 1973, Cornforth, 1962, cf Rosenberg, 1982:34-51. Thus a modest contribution from Q-Q models is that they permit one to consider S_i to be a proxy for infrastructural elements of institutions, while q-bar would represent the superstructural components of institutions. Moreover, the appropriate human capital for growth, with the possibility of H_i^* drain, is,

$$H_i^{**} = (1-\sigma)e^{\omega R}(N_i - L_i), \tag{33}$$

where ω is a vector of parameters θ and ϕ, and R is a vector of variables S_i and q-bar_i. Clearly $H_i^{**} < H_i^* < H_i$ for $\sigma \neq 0$, so that after accounting for H_i^* drain, (33) combines infrastructural and superstructural factors in its first term; and infrastrutural elements as in Hall and Jones in its second term, with the difference standing for purely superstructural factors. I extend this argument further in a separate empirical companion of this paper.

5. Concluding Remarks

A seemingly simple relationship between embedded economies and their host economy is important in explaining the economic growth of the former. The interactions between the two economies take place via Y_j and A_j, where Y_j affects Y_i directly, while A_j goes through Hi, and that raises a number of issues, no less important to economic growth than traditional factors and forces of production, and their corresponding productivities. Conventionally measured H_i is a function of total labor; i.e., it is the enriched part of the total labor force - where labor enrichment occurs through cumulative investment in education, training, experience, and health and nutrition, among well-know avenues. Investment in education and health is nothing more than investment in the infrastructural aspects of institutions (school buildings, teachers, hospital, doctors, etc.). This current measure of H_i is seriously wanting in that it is far too narrow. As a result it captures mainly infrastructural properties of institutions and misses or subsumes superstructural elements. This means that L_i is limiting as a sole source of H_i for two points: (a) it claims that when retirement comes, apparently H_i depreciates to zero; and (b) it also supposes that H_i is zero before the legal working age, say 14 years. Both points are simply unacceptable even within the infrastructure-based model. For example, health, nutrition, and medical care extends the life expectancy, which in turn slows the rate of H_i depreciation and making the lecvel of H_i accumulation last longer than before. With rapid technological change H_i accumulates faster and earlier in life than before.[18] *The net joint effect: the productive life-cycle increases as H_i propagates backwards and forwards*. The Q-Q models utilized help us sort through the host-embedded economic interactions to find the determinants of economic growth, and whether or not they have foundations in the infrastructural or superstructural elements of institutions. Successful sorting adds to the debate about how [and why] economies with seemingly similar institutions would still grow at different rates. The paper is obviously incomplete without its empirical component, but that is a different project.

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[18] Here I am reminded of William Thomson's (2001) observation that nowadays knowledge of information and communications technologies flows from the young to the old. The implication of this observation to learning is a forward "propagation mechanism" as in Chang, Gomes, and Schorfheide (2002), as well as a backward one. The difference is that the backward horizon is shorter than the forward horizon.

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