SOURCES OF GROWTH METHODOLOGY IN LOW-INCOME COUNTRIES: A CRITIQUE

ALLEN C. KELLEY
JEFFREY G. WILLIAMSON

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I. INTRODUCTION

The role of capital formation in economic growth is possibly the leading area of controversy in development theory. A major landmark has been Solow's 1957 article¹ in which he showed that technical change, and not capital formation, constituted the leading factor in American twentieth-century economic growth. Solow's contribution has inspired an extensive development of the "sources of growth" methodology as a technique for isolating the "determinants" of economic growth. Furthermore, many of these empirical studies have been concerned with low-income economies.² The typical conclusion of this research has been that when inputs are conventionally measured, a very large share of labor productivity growth is "accounted for" by the residual. A corollary is that capital formation explains very little of the observed improvements in productivity. Of course, refinements of the sources of growth methodology have been numerous. For example, by providing a more careful measurement of labor and capital inputs, Denison, Jorgenson, and Griliches have all but eliminated the residual.³

This note argues that while the residual is now much better understood, its measurement has brought us no closer to understanding the role of capital formation than we were fifteen years

1. Robert Solow, "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics*, XXXIX (Aug. 1957), 312-20.

2. For example, see Henry Bruton, "Productivity Growth in Latin America," *American Economic Review*, LVII (Dec. 1967), 1099-1116; Samuel Bowles, "Sources of Growth in the Greek Economy, 1951-61," Memorandum No. 27, Project for Quantitative Research in Economic Development, Harvard University (Nov. 1966), mimeo.; Jeffrey G. Williamson, "Dimensions of Postwar Philippine Economic Progress," this *Journal*, LXXXIII (Feb. 1969), 93-109.

3. Edward Denison, *The Sources of Economic Growth in the United States* (New York: Committee for Economic Development, 1962); Dale W. Jorgenson and Zvi Griliches, "The Explanation of Productivity Change," *Review of Economic Studies*, XXXIV (July 1967), 249-84.

ago. This is because the sources of growth methodology only provides a framework for descriptively examining ex post data drawn from complex, interdependent economic systems. The methodology is nothing more than a social accounting technique of decomposition. It cannot reveal the sources of growth since the technique provides no theory of endogenous factor growth, nor of potential interdependence in factor growth.

While this criticism of the sources of growth methodology is hardly unique, the present paper will provide a *quantitative dimension* to its importance. We use an historically relevant model of a low-income economy developed and analyzed in an earlier paper⁴ to evaluate quantitatively the role of capital formation on growth. It is shown that capital accumulation constitutes a very important element in output expansion. The standard sources of growth methodology is also applied to the modeled economy's simulated record. Ironically the sources of growth paradox is replicated — capital formation constitutes a relatively "unimportant" element in economic growth. We then offer a reconciliation between the growth-theoretic approach and the sources of growth approach in appraising the role of capital formation. This analysis justifies our highlighting an all too often overlooked qualification to the use of the sources of growth methodology. Even though history may usefully provide a record of economic events, the "lessons of history" cannot be revealed without the use of a descriptively relevant theory; the sources of growth methodology does not represent such a theory.

II. A GENERAL EQUILIBRIUM MODEL OF THE GROWING LOW-INCOME ECONOMY

The model under investigation has been examined extensively in a previous article in this *Journal*.⁵ In the tradition of Fei and Ranis and Jorgenson, a formal model of the low-income economy has been developed to include dualistic specifications in consumer demand and in demographic behavior, as well as in sector production functions. The result is a model of endogenously determined population growth, declining with industrialization, where the urban-industrial sector has the following attributes: highly capital-

4. Allen C. Kelley, Jeffrey G. Williamson, and Russell J. Cheetham, "Biased Technological Progress and Labor Force Growth in a Dualistic Economy," this *Journal*, LXXXVI (Aug. 1972), 426-47.

5. Kelley, Williamson, and Cheetham, *op. cit.*

TABLE I
AVERAGE ANNUAL GROWTH OF LABOR AND OUTPUT FROM THE SIMULATION MODEL

Decade	Labor force (1)	Aggregate output (2)	Agricultural output (valued) (3)	Industrial output (valued) (4)	Aggregate output per capita (5)	Agricultural output per laborer (6)	Industrial output per laborer (7)	(7) (6) (8)
1-10	0.0269	0.0346	0.0305	0.0399	0.0075	0.0047	0.0096	2.043
11-20	.0268	.0366	.0312	.0427	.0104	.0075	.0109	1.453
21-30	.0266	.0380	.0318	.0443	.0113	.0097	.0112	1.155
31-40	.0264	.0390	.0324	.0450	.0136	.0117	.0111	0.949
41-50	.0260	.0395	.0327	.0450	.0146	.0133	.0111	0.835
Average								
1-50	0.0265	0.0375	0.0317	0.0435	0.0107	0.0086	0.0099	1.151

intensive, labor-saving in technical change (in contrast to labor-using in agriculture), and a CES production function with lower substitution possibilities than agriculture. The modeled economy is then parameterized with quantitative features characteristic of contemporary Southeast Asia.

Given this "empirical" description of the modeled low-income economy, we consider in Section III the role of capital formation in explaining output performance over fifty simulation periods, using the sources of growth methodology. Sensitivity analysis is then applied to the modeled economy in Section IV by evaluating the impact of parametric variation in the savings rate on capital accumulation and per capita output expansion. The results contrast sharply.

III. THE SOURCES OF GROWTH PARADOX

Criticisms of the sources of growth methodology have taken several forms. Among them have been (i) the use of a Cobb-Douglas specification, (ii) the assumption of disembodied and neutral technical progress, and (iii) the assumption of competitive factor markets. We pose the following problem to illustrate the implications of this methodology. Given our model structure and its simulated growth experience, what would be the description of the economy's rate of technical progress had it been inferred using only the simulated historical data and the sources of growth methodology?

In our model competitive product and factor market conditions are satisfied by assumption. Moreover, we know precisely the "true" rate of technical change. The current rate or intensity of technical progress, $R_i(t)$, measures the output-raising effect of technical change holding inputs constant:

$$(1) \quad R_i(t) = \frac{\partial Q_i(t)}{\partial t} \cdot \frac{1}{Q_i(t)}.$$

The production function is written as

$$(2) \quad Q_i(t) = F^i[x(t)K_i(t), y(t)L_i(t)],$$

where $x(t) > 0$ and $y(t) > 0$ are the respective technical progress parameters augmenting physical input stocks. Differentiating (2) with respect to time and rearranging, we get

$$(3) \quad R_i(t) = \frac{F_K^i x(t) K_i(t)}{Q_i(t)} \frac{\partial x(t)}{\partial t} \frac{1}{x(t)} + \frac{F_L^i y(t) L_i(t)}{Q_i(t)} \frac{\partial y(t)}{\partial t} \frac{1}{y(t)},$$

where F_K^i and F_L^i are the marginal products of "efficiency" capital and labor, respectively. Since the current elasticity of output with respect to the capital input is

$$a_i(t) = \frac{F_K^i x(t) K_i(t)}{Q_i(t)},$$

expression (3) can be restated in more familiar terms:

$$(4) \quad R_i(t) = \lambda_K a_i(t) + \lambda_L [1 - a_i(t)],$$

where λ_K and λ_L are simply the constant rates of capital and labor augmentation through technical progress. Since it has little relevance in most low-income developing economies, we do *not* assume neutrality in technical progress. In summary, given estimates of λ_K and λ_L , and given the endogenously determined values of $a_i(t)$, then the "true" rate of technical progress is known with certainty in our model. The first three columns in Table II exhibit the $R(t)$ series.

Using the sources of growth methodology, to what extent do the residual calculations, $R'_i(t)$, diverge from the "true" rate of technical change, $R_i(t)$? Given the simulated data on factor shares (not reported here), physical input series, and deflated output growth, the residual can be readily calculated using the sources of growth methodology. Had we no knowledge of the true economy, we would *assume* neutral and disembodied technical progress and unitary elasticity of substitution, providing

$$R'(t) = dQ/Q - a_L dL/L - (1 - a_L) dK/K.$$

Table II reports these calculations for both industry and the economy as a whole. A comparison of the estimated $R'(t)$ and its "true" value reveals striking discrepancies. Columns 6 and 9 in Table II exhibit sharply declining $R'(t)$ over time while the true $R(t)$ is almost constant! In some cases the discrepancies are very large indeed: e.g., $R'_1(t)$ is less than one half of $R_1(t)$ by the fifth decade of development. Based on the conventional sources of growth calculation, we would erroneously conclude that this economy underwent a long-run decline in the rate of technical progress.

This result is consistent, of course, with Nelson's⁶ argument that output growth can be approximated in the CES case (in industry, say) to be

6. Richard R. Nelson, "Aggregate Production Functions and Medium-Range Growth Projections," *American Economic Review*, LIV (Sept. 1964), 575-606.

TABLE II
THE "TRUE" RATE OF TECHNICAL CHANGE AND SOURCES OF
GROWTH CALCULATIONS COMPARED

Decade	Economy-wide sources of growth					Industry sources of growth			
	Economy $R'(t)$ (1)	Industry $R'_i(t)$ (2)	Agriculture $R'_a(t)$ (3)	$\frac{dK}{dQ} \frac{dL}{dL} \frac{1-a_L}{K}$ (4)	$\frac{dL}{L}$ (5)	Residual = $R'(t)$ (6)	$\frac{dK_i}{(1-a_{i,L})} \frac{a_{i,L}}{K_i}$ (7)	$\frac{dL}{L}$ (8)	Residual = $R'_i(t)$ (9)
1-10	0.0066	0.0055	0.0075	0.013	0.014	0.0076	0.021	0.011	0.0069
11-20	0.0066	0.0054	0.0076	.016	.014	.0066	.024	.013	.0057
21-30	0.0065	0.0054	0.0076	.017	.014	.0070	.026	.013	.0053
31-40	0.0064	0.0054	0.0076	.020	.013	.0060	.028	.013	.0040
41-50	0.0064	0.0054	0.0076	.021	.013	.0055	.029	.014	.0020
Average									
1-50	0.0065	0.0054	0.0076	—	—				

Notes: Columns 6 and 9 are calculated under the assumption of Cobb-Douglas production functions. Thus, $R'_i(t) = \frac{Q}{dQ} \frac{dL}{dL} \frac{1-a_L}{K} - (1-a_L) \frac{dK}{K}$. Output growth rates are taken from

Table I. Factor shares are decade mid-point observations produced by the simulation model. Factor stock growth rates, also taken directly from the model's simulated figures, are average annual growth rates per decade. The simulated time series is reported in more detail in Kelley, Williamson, and Cheetham, *op. cit.*

$$\frac{dQ_1(t)}{Q_1(t)} = R'_1(t) + a_{1L}(0) \frac{dL_1(t)}{L_1(t)} + [1 - a_{1L}(0)] \frac{dK_1(t)}{K_1(t)} + \frac{1}{2a_{1L}(0)} [1 - a_{1L}(0)] \frac{\sigma_1 - 1}{\sigma_1} \left\{ \frac{dK_1(t)}{K_1(t)} - \frac{dL_1(t)}{L_1(t)} \right\}^2,$$

where $a_{1L}(0)$ is the initial labor share. If $\sigma_1 < 1$ and capital stock growth exceeds that of labor, both true of our simulated economy, then $R'(t)$ will be underestimated. In a rapidly developing economy, e.g., our fifth decade of simulation, the last term in Nelson's approximation is large.

An interesting and important issue remains. Average industrial labor productivity growth in our model is approximately 1 percent in the first decade of growth. The sources of growth residual "accounts for" about 0.7 percentage points. Thus, we have recaptured the fundamental paradox of the sources of growth literature: 70 percent of average labor productivity growth is "explained by" technical progress. Does it follow that capital formation is also unimportant in our description of a low-income economy?

IV. AN ANALYSIS OF THE SOURCES OF GROWTH PARADOX

This question involves two related issues. First, what is the contribution of increased aggregate savings rates to increased rates of capital formation? Second, what is the role of capital formation in economic growth?

4.1. Accumulation and the Savings Effort. A widely accepted premise among economic historians and development economists is that shifts in savings behavior are a necessary condition for improved growth performance. Although this hypothesis certainly appears reasonable, in historical fact increased savings may not have been the main source of accelerating rates of capital accumulation. Define gross national product by $G(t)$ and $a_K(t)$ as the non-labor income share. Since gross investment equals savings out of nonlabor income in our model, then

$$(5) \quad \frac{dK(t)}{K(t)} = \frac{I(t)}{K(t)} - \delta = a_K(t) s \left[\frac{K(t)P(t)}{G(t)} \right]^{-1} - \delta = s^*(t) \left[\frac{K(t)P(t)}{G(t)} \right]^{-1} - \delta,$$

where s is a savings parameter, $s^*(t)$ is the aggregate savings rate, δ is the depreciation parameter, and $P(t)$ is the relative price of industrial goods. Given CES production functions and a bias toward

labor-augmenting technical progress, our model is capable of producing both a rising nonlabor share and a falling economy-wide capital-output ratio. Rising rates of capital formation are thus consistent with a *fixed* savings parameter; moreover, accelerating rates of capital formation can be achieved even if the aggregate national savings rate is constant.

Table III presents some results on this point. The rate of capital accumulation accelerates over time in our simulated economy: it increases from 0.023 to 0.041 per annum. Of this increase, approximately two thirds is attributable to the declining capital-output ratio, while the remainder is due to increased gross savings rates.⁷

TABLE III
THE CAPITAL-OUTPUT RATIO, NET SAVINGS
RATES, AND ANNUAL RATES OF CAPITAL FORMATION

Period	Capital-output ratio (1)	Period	Net savings rates (2)	dK/K (3)
1	1.9	1-10	6.6%	2.3%
10	1.8	10-20	7.2	3.1
20	1.7	20-30	7.8	3.5
30	1.7	30-40	8.2	3.8
40	1.7	40-50	8.5	4.1
50	1.7			

In summary, impressive increases in the rate of accumulation are possible *without* increases in the aggregate savings rate. In any case, it can be achieved with fixed savings parameters.

4.2. *Accumulation and Economic Growth.* We turn now to the second question: what is the role of capital formation in economic growth? This question can best be answered by examining Table IV, which presents the structural elasticities showing the parameter change on several economic indicators of a 1 percent increase in the savings parameter. There we see that capital stock and $G(t)$ growth rates are profoundly affected by a 1 percent increase in the savings parameter. This result is in sharp contrast with the naive predictions of the sources of growth "model." In the first decade of de-

7. The total differential of (5) is

$$ds^*(t) \left[\frac{K(t)P(t)}{G(t)} \right]^{-1} + d \left[\frac{K(t)P(t)}{G(t)} \right]^{-1} s^*(t).$$

The gross savings rate increases from 0.151 to 0.161 over the five decades, while the average capital-output ratio is 1.8. It follows that changing aggregate gross savings accounts for only 30 percent of the rise in accumulation rates from 0.023 to 0.041 per annum.

TABLE IV
THE IMPACT OF THE SAVINGS RATE IN
THE SIMULATED ECONOMY

Variable	$\epsilon^*_t(s)$: Value of elasticity at year —				
	10	20	30	40	50
GNP growth rate	0.684	0.501	0.431	0.081	0.027
Per capita GNP growth rate	3.022	2.040	1.709	0.612	0.472
Capital stock growth	2.433	1.767	1.246	0.786	0.458

Note: $\epsilon^*_t(s)$ measures the elasticity of a variable's response to a once-over change in s . The elasticity is adjusted for the impact on initial conditions.

velopment, an initial 1 percent increase in the savings parameter produces a 2.4 percent increase in economy-wide capital stock growth rates. This result may at first seem puzzling. Should not a 1 percent increase in s produce a comparable effect on the rate of capital formation? No. The comparative static result need not conform to the comparative dynamic result: that is, it need not yield the same expansion in rates of capital formation at some future point in time (say, a decade hence). In fact, the initial rise in s generates an accelerated decline in labor's share, and thus even higher rates of accumulation at the end of the first decade of development. These cumulative effects are ignored in the sources of growth literature.

The impact on $G(t)$ growth, however, is almost 0.7 percent. This result is not entirely consistent with the sources of growth literature. Furthermore, note that per capita income growth is raised by 3 percent! Some time ago, Nelson⁸ cautioned us that the sources of growth methodology ignores the potential interaction between rates of factor augmentation and technical progress. The embodiment models are in part a response to that criticism. Our approach ignores the embodiment specification and instead considers another equally powerful interaction. What the sources of growth literature does not fully appreciate, even in its more sophisticated embodied technical change form, is precisely how increased savings rates foster industrialization-urbanization and thus a more rapid decline in population growth. These interaction effects may be ignored for a mature industrialized economy, but they can hardly be overlooked in the dualistic low-income economy. Our specification of these potential interaction effects through demo-

8. Nelson, *op. cit.*

graphic dualism is clearly one of many, but the experiment surely suggests that the application of the sources of growth methodology to low-income economies may be plagued with serious error.

V. CONCLUSION

A few years ago Sir John Hicks revealed a very negative reaction to Golden Age models and empirical work with aggregate production functions: "It is very wrong to give the impression to a poor country, which is very far from equilibrium even on a past technology, that capital accumulation . . . is a matter of minor importance."⁹ This note has shown just how wrong such applications may have been.

DUKE UNIVERSITY
THE UNIVERSITY OF WISCONSIN

9. John R. Hicks, *Capital and Growth* (Oxford: Oxford University Press, 1965), p. 304.

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