

Genuine Savings: Leading Indicator of Sustainable Development?

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I. Introduction

Interest in the relationships among national income, wealth, and welfare has revived in recent years, driven in large part by concern about the long-run consequences of natural resource depletion and environmental degradation.¹ A fundamental result in this “green accounting” literature is that a comprehensive measure of a country’s net investment across all forms of capital—produced, natural, human—should predict whether consumption will be higher or lower in the future compared to the present.

This result traces back to theoretical work in the late 1970s. In an influential paper,² Weitzman (1976) analyzed a simple optimizing economy in continuous time with a single consumption good (C), multiple capital goods (\mathbf{K}), stationary technology, and intertemporal welfare equal to the discounted sum of consumption. He defined net national product (NNP) in the usual way, as the sum of consumption and net investment:

$$Y(t) \equiv C(t) + \mathbf{p}(t)\mathbf{I}(t), \quad (1)$$

where $\mathbf{p}(t)$ is the competitive price vector for capital goods and $\mathbf{I}(t) \equiv \dot{\mathbf{K}}(t)$ is the vector of net changes in the stocks of those goods. Weitzman’s key

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¹ See Dasgupta (2003), Heal and Kriström (in press), and Weitzman (2003) for recent syntheses.

² Hartwick (1977) and Dasgupta and Heal (1979, chap. 8) are other seminal contributions.

contribution was to demonstrate that NNP in this model equals a weighted average of future consumption,

$$\bar{C}(t) = Y(t), \quad (2)$$

where the weights in $\bar{C}(t)$ involve the consumption discount rate, r :

$$\bar{C}(t) = \frac{\int_t^{\infty} C(s)e^{-r(s-t)}ds}{\int_t^{\infty} e^{-r(s-t)}ds}. \quad (3)$$

NNP thus provides a forward-looking measure of average future consumption. By subtracting $C(t)$ from each side of equation (2) we obtain

$$\bar{C}(t) - C(t) = \mathbf{p}(t)\mathbf{I}(t), \quad (4)$$

which indicates that average future consumption will be above (below) current consumption if and only if net investment is positive (negative). In this sense net investment is, in theory anyway, a leading indicator of sustainable development.³

As indicated, this result rests on several restrictive assumptions. Subsequent theoretical research has demonstrated that variants of it continue to hold even if those assumptions are relaxed.⁴ For example, it holds with multiple consumption goods if the utility function is linearly homogeneous and a Divisia index is used to convert prices to real terms (Asheim and Weitzman 2001). If technology is nonstationary—for example, a country is small and faces changing terms of trade—but production is efficient and exhibits constant returns to scale, then it holds if anticipated capital gains are added to the right-hand side of equation (4) (Asheim 1996; Vincent, Panayotou, and Hartwick 1997). It holds even if the economy is not on an optimal path and does not exhibit constant returns to scale, as long as technology is stationary and net investments are valued at appropriate shadow prices (Dasgupta and Mäler 2000; Arrow, Dasgupta, and Mäler 2002).⁵

Despite this long and rich history of theoretical research, the reliability of empirical estimates of comprehensive net investment as sustainability indicators has gone unexamined. Until recently, the reason was simple: data were insufficient to investigate the issue. Early efforts to construct comprehensive

³ Because it pertains to average future consumption, it is not an indicator of sustainability in the strict sense of consumption never declining from one period to the next.

⁴ See Asheim (2003) for a comprehensive and methodical summary of these advances.

⁵ See also Aronsson and Löfgren (1998).

measures of net investment focused on individual countries, most notably on Indonesia (Repetto et al. 1989) and Costa Rica (Solórzano et al. 1991). Pearce and Atkinson (1993) published the first cross-country estimates, but their estimates covered only 18 countries and a single year. During the past few years, however, the World Bank has begun including comprehensive estimates of net investment, or “genuine savings,” in its widely used cross-country database, the World Development Indicators (WDI; Hamilton and Clemens 1999).⁶ The Bank’s estimates are intended to reflect changes in not only produced capital but also natural and human capital. Understanding the reliability of these estimates is important given their now widespread availability. It is also important in view of a parallel effort by the United Nations (UN) to integrate such estimates into its official national accounting guidelines (UNSD 1993).⁷

In this article we conduct an empirical investigation of the Bank’s genuine savings estimates. Our objectives are to evaluate their consistency with green accounting theory and their accuracy as predictors of the difference between current and average future consumption. We begin by describing the estimates and discussing their limitations. Next, we present four hypotheses related to equation (4), and we discuss econometric issues that arise in testing them. We then present our results in two sections: the first focuses on consistency with theory, and the second focuses on predictive accuracy. We conclude by summarizing the implications of our analysis for the interpretation and use of the Bank’s estimates.

II. The World Bank’s Genuine Savings Estimates

The World Bank first published cross-country estimates of genuine savings in 1997 (World Bank 1997). It began including them in the WDI in 1999. The 2003 WDI contains estimates for 136 countries during 1970–2001 (partial series for some countries). The Bank constructs these estimates by making a series of adjustments to gross national savings. The principal adjustments are to subtract a depreciation allowance for produced capital stocks and depletion allowances for fossil fuels,⁸ minerals,⁹ and timber, and to add investment in human capital. Hamilton and Clemens (1999) and Bolt, Matete, and Clemens (2002) describe the methods used by the Bank to make these adjustments. The methods are similar across countries and rely on standard international

⁶ The estimates are labeled “adjusted savings” in the latest edition of the WDI.

⁷ See also the recommendations for the United States in a report for the U.S. National Academy of Science by Nordhaus and Kokkelenberg (1999).

⁸ Oil, natural gas, and coal.

⁹ Bauxite, copper, gold, iron, lead, nickel, phosphate, silver, tin, and zinc.

data sources. The WDI includes data on not only the “bottom-line” genuine savings estimates but also the individual adjustments.

The Bank’s estimates have several shortcomings. The most general is that they are not truly comprehensive: although the Bank has extended the measurement of investment to include much more than gross investment in produced capital, it has not captured changes in all capital stocks. For example, although it makes adjustments for an impressively wide range of natural resources, it omits some important ones: agricultural land, fresh water, and fisheries. So, although its timber adjustment reflects the depletion of timber stocks due to deforestation, the Bank does not account for the offsetting increase in natural capital that results from the conversion of forestland to cropland.

A second shortcoming is measurement error in the estimates the Bank does include. Regarding produced capital, the Bank derives the depreciation allowances from UN national accounts data on “capital consumption allowances.” Such allowances are typically imputed from a perpetual inventory model, which assumes that all investments are productive and that the depreciation rate is constant over time. Pritchett (2000) has sharply criticized both assumptions.

Regarding natural capital, the Bank equates the depletion of fossil fuels and minerals to current resource rent: quantity extracted times the difference between price and average total cost of extraction. This exaggerates the loss in value of reserves that results from extraction, because it ignores the appreciation of remaining reserves that occurs as time passes and future rents come closer to the present (El Serafy 1989; Hartwick and Hagemann 1993). Empirical work by Neumayer (2000) suggests that the degree of exaggeration can be enormous. This approach also ignores physical increases in reserves that result from discoveries and capital gains and losses on reserves that result from changes in resource commodity prices.¹⁰ Vincent et al. (1997) and Vincent (2002) found that these factors can swamp the effects of resource extraction.

In the case of timber, the Bank makes a one-sided adjustment: it reduces net investment if roundwood harvest exceeds forest growth but does not increase it if growth exceeds harvest. This exaggerates the loss of natural capital that results from forest harvesting. More appropriate accounting methods for forest resources have been developed by Vincent (1999) and applied to South Africa by Hassan (2000).

¹⁰ The Bank has undertaken research to address this shortcoming. See Hamilton and Bolt (2004).

The Bank's estimate of investment in human capital is the most questionable. It equals UNESCO estimates of current operating expenditures on education. One problem is that this is a purely gross measure, which makes no allowance for losses in human capital. More fundamentally, it assumes that a dollar of educational expenditure translates into a dollar increase in human capital. Studies in both rich countries (Jorgenson and Fraumeni 1992) and poor countries (Schultz 1988) indicate that this is a poor assumption.

Perhaps the most fundamental source of measurement error is that all of these adjustments are constructed using data based on market prices. They surely diverge from the shadow-priced estimates that are required for equation (4) to hold in imperfect, real-world economies.

The Bank is aware of these shortcomings. Its rationale for publishing such crude estimates is twofold. The first is that by publishing them, it hopes to prompt countries to report better data, which will enable it to produce better estimates. The second is that despite their shortcomings, the estimates provide a better measure of net capital accumulation, and thus a better predictor of future consumption prospects, than does gross national savings. That is, their comprehensiveness offsets their crudeness. The first rationale might well be true, but the second is our concern in this article.

III. Methods

Our analysis involved pooled (panel data) and individual-country analyses of the following model, which is based on equation (4):

$$\Delta_{it} = \beta_0 + \beta_1 S_{it} + \varepsilon_{it}, \quad (5)$$

where Δ_{it} is the difference between current and average future consumption in country i in year t (i.e., $\bar{C}(t) - C(t)$ in eq. [4]), S_{it} is net investment ($\mathbf{p}(t)\mathbf{I}(t)$ in eq. [4]), and ε_{it} is a randomly distributed error term. We expressed both Δ_{it} and S_{it} in inflation-adjusted, per capita terms.

We discuss the construction of these variables and associated econometric issues below. Before delving into these matters, we note that although equation (5) might resemble models in the enormous cross-country growth literature, it is in fact quite different. The most obvious difference is that the dependent variable is not the gross domestic product growth rate. The more fundamental difference is that our objective is not to identify which variables in a large set of potential explanatory variables are most significantly correlated with the dependent variable and explain most of the cross-country variation in it. Instead, our attention is focused on the performance of a single explanatory variable, net investment. Based on green accounting theory, the World Bank

has presented its comprehensive estimates of this variable as improved indicators of economic sustainability. Our objective is to evaluate the theoretical consistency and predictive accuracy of those estimates.

A. Construction of Δ and Definition of the Sample

To construct Δ_{it} , we first needed to construct average future consumption, \bar{C}_{it} . As a preliminary step we converted equation (3) to discrete time, because the WDI data are annual:¹¹

$$\bar{C}_{it} = \frac{\sum_{s=t+1}^{t+T} C_{is}(1+r)^{-(s-t)}}{\sum_{s=t+1}^{t+T} (1+r)^{-(s-t)}}. \quad (6)$$

We obtained data on final consumption expenditure, in constant 1995 U.S. dollars, from the WDI (series NE.CON.TOTL.KD). We divided by total population (SP.POP.TOTL) to obtain per capita estimates. We set C_{is} in equation (6) equal to these per capita estimates.

We set the time horizon, T , equal to 10 years in our benchmark analysis. This reduced the estimation period to 1970–91, because the construction of $\bar{C}_{i,1991}$ required consumption data through 2001. In estimating equation (5), we were in effect asking whether an estimate of net investment in, say, 1970 predicted the actual difference between weighted-average consumption during 1971–80 and consumption in 1970, and so on through 1991. Although 10 years is infinitely less than infinity, which is the time horizon for defining $\bar{C}(t)$ in equation (3), it is a relatively long period from a macroeconomic policy perspective. For example, many developing countries formulate development plans, in which they make major public investment decisions, on a 5-year cycle. From the standpoint of the lifetime of capital stocks, however, a 10-year time horizon may be considered too short. For example, the depletion of individual mineral deposits can take many decades. To address this concern, we also estimated the model using a 20-year time horizon. With $T = 10$ years, the sample included 93 countries; with $T = 20$ years, it shrank to 83 countries. In the former case, 20 countries had a complete set of 22 observations, and another 50 countries had more than 11.

For the discount rate, r , in the benchmark analysis we used a uniform value of 3.5% for all countries. This is the median of the lending and deposit interest rates (FR.INR.LEND and FR.INR.DPST) reported in the WDI for

¹¹ The conversion from continuous to discrete time explains why the sums on the right-hand side of eq. (6) begin with $t+1$ instead of t , as in eq. (3).

the 93 countries during 1970–2001, after converting to real terms using the consumer price index (FP.CPI.TOTL). We also estimated the model with country-specific discount rates, set equal to the median for each country during 1970–2001.¹²

B. Construction of S and Description of Hypotheses

To explore the effects of the Bank's adjustments, we sequentially set S_{it} equal to the following four, increasingly comprehensive investment measures drawn from the WDI. The first is the standard macroeconomic series that is the Bank's starting point, while the last three incorporate adjustments related to produced, natural, and human capital, respectively.

- a) *Conventional gross investment* (gross national savings; WDI series NY.GNS.ICTR.GN.ZS). The Bank defines this as gross domestic savings plus net income and net current transfers from abroad. This measure represents the gross increase in produced capital stocks within a country, net of current investment flows with the rest of the world.
- b) *Conventional net investment* (net national savings; NY.ADJ.NNAT.GN.ZS). The Bank defines this as conventional gross investment minus the depreciation of produced capital.
- c) *Green net investment*. This equals conventional net investment minus the WDI depletion allowances for fossil fuels (NY.ADJ.DNGY.GN.ZS), minerals (NY.ADJ.DMIN.GN.ZS), and timber (NY.ADJ.DFOR.GN.ZS).
- d) *Genuine investment*. This equals green net investment plus the WDI estimate of investment in human capital (NY.ADJ.AEDU.GN.ZS).¹³

The indicated WDI series are expressed as percentages of gross national income (GNI). We converted them to per capita terms by multiplying by GNI in constant 1995 U.S. dollars (constructed by deflating the GNI series

¹² The discount rate was constant over time in all analyses, which implies an assumption of a linearly homogeneous utility function. Dasgupta and Mäler (2000) criticize this assumption. In response, Weitzman (2000) cites evidence that interest rates have been trendless. We regressed the interest rate series for the countries in our sample on a constant and a time trend and found that the coefficient on the time trend was not significantly different from 0 for most countries.

¹³ The Bank labels its broadest measure "adjusted net savings" (NY.ADJ.SVNG.GN.ZS). In addition to the items that we included in genuine investment, it subtracts the global damage caused by a country's carbon dioxide emissions (NY.ADJ.DCO2.GN.ZS) and the local health damage caused by emissions of particulate air pollution (NY.ADJ.DPEM.GN.ZS). We excluded the former adjustment because it does not pertain to the environmental capital stock that determines the impact of climate change on a country's economy: the concentration of carbon dioxide in the atmosphere, which is a function of global emissions, not just an individual country's own emissions. We excluded the latter because the WDI includes data on it only for 2001.

in current U.S. dollars, NY.GNP.MKTP.CD) and dividing by total population (SP.POP.TOTL).

The availability of these four measures enabled us to test the following hypotheses, which are listed in decreasingly stringent order:

HYPOTHESIS 1. $\beta_0 = 0$ and $\beta_1 = 1$.

HYPOTHESIS 2. $\beta_1 > 0$, and $\beta_1 \rightarrow 1$ as S_{it} is extended to include more types of capital.

HYPOTHESIS 3. $\beta_1 > 0$.

HYPOTHESIS 4. Equation (5) predicts Δ_{it} more accurately when S_{it} includes more types of capital.

We used results from the pooled analysis to test the first three hypotheses and results from the individual-country analyses to test the fourth.

Hypothesis 1 is implied directly by equation (4): the difference between current and average future consumption exactly coincides with net investment. It is the most stringent test of the consistency of the World Bank's estimates with green accounting theory. In view of the various sources of measurement error discussed in Section II, one might expect this hypothesis to be rejected, as measurement error should bias the estimate of β_1 toward zero. This observation motivates hypothesis 2, which is weaker in that it merely requires the net investment estimates to become more consistent with theory as they are extended. A progressive reduction in omitted variables bias provides the rationale for $\beta_1 \rightarrow 1$. Omitted components of net investment are part of the error term ε_{it} , and there is reason to expect that they are correlated with the estimates of S_{it} . For example, a highly industrialized economy would be expected to have high levels of not only gross investment in produced capital but also depreciation of such capital: the larger the stock, the more depreciation. So, the estimate of β_1 should be less biased when S_{it} is defined as conventional net investment instead of as conventional gross investment.

Although the number of omitted components declines as S_{it} is extended from conventional gross investment to genuine investment, it does not go to zero. As discussed in Section II, the Bank's estimates do not include all types of capital, especially natural capital (e.g., agricultural land). For this reason, we expect $\beta_1 < 1$ even for the broadest estimates. There is also a more subtle source of omitted variables bias that could lead to this result. The net investment estimates we analyze refer to per capita changes in capital stocks, which are not the same as changes in per capita capital stocks (Dasgupta and Mäler 2001; Hamilton 2002; Arrow, Dasgupta, and Mäler 2003; Asheim 2004). Denoting a country's population by N_{it} , the change in a per capita

capital stock is given by

$$\frac{d}{dt} \left(\frac{K_t}{N_t} \right) = \frac{\dot{K}_t}{N_t} - \frac{\dot{N}_t K_t}{N_t N_t} \tag{7}$$

The Bank’s estimates reflect only the first term on the right-hand side. They exclude the second term, which represents the spreading of a country’s existing capital stocks over a larger number of people as population grows. The Bank does not report capital stocks in the WDI, and so we could not adjust its estimates of net investment to incorporate this term.

Hypothesis 3 is weaker still. It simply requires a correctly signed relationship between net investment and the difference between current and average future consumption: if S_{it} increases, Δ_{it} does too. The rationale for not expecting $\beta_1 \rightarrow 1$ is that measurement error likely increases as S_{it} is extended beyond produced capital to include natural and human capital. As discussed in Section II, the Bank’s estimate of investment in human capital is especially poor. If measurement error does indeed increase as S_{it} is extended, then the estimates of β_1 should be increasingly biased toward zero.

Finally, the rationale for hypothesis 4 is simply that broader estimates of net investment provide more information about changes in capital stocks and thus more information about future consumption prospects. We tested this hypothesis by calculating Theil inequality statistics for one-step-ahead forecasts based on individual-country analyses of equation (5). As noted earlier, with $T = 10$ years, the maximum sample period was 1970–91. For each country with more than 11 observations, we estimated equation (5) for the first half of this period (1970–80) and used it to forecast Δ_{1981} . We then extended the estimation period by 1 year (1970–81), reestimated the equation, and forecast Δ_{1982} . We repeated this process until we had formed forecasts through Δ_{1991} for each country. We then computed the Theil statistic for each country (Pindyck and Rubinfeld 1981, 364),

$$U_i = \frac{\sqrt{(1/n_i) \sum_{t=1981}^{1991} (\hat{\Delta}_t - \Delta_t)^2}}{\sqrt{(1/n_i) \sum_{t=1981}^{1991} (\hat{\Delta}_t)^2} + \sqrt{(1/n_i) \sum_{t=1981}^{1991} (\Delta_t)^2}}, \tag{8}$$

where n_i is the number of forecasts (11 for countries with complete data), $\hat{\Delta}_t$ is the forecast difference between current and average future consumption,

and Δ_i is the actual difference. A value of $U = 0$ indicates a perfect forecast, while $U = 1$ indicates the worst possible forecast.

To investigate whether this structural forecasting method yields predictions superior to those from time-series analysis, we also fit an autoregressive-integrated-moving-average (ARIMA) model to Δ_{it} for each country for the same sample period and calculated its Theil statistic. In fitting the ARIMA models, we placed more weight on a visual inspection of autocorrelograms (Box-Jenkins methodology) than on the results of unit root tests, which have extremely low power in such small samples.

C. Other Econometric Issues: Endogeneity, Stationarity, and Panel Estimators

Consumption and savings are two sides of the same dynamic decision-making process. Given that Δ_{it} includes C_{it} , this implies that equation (5) includes variables that are simultaneously determined on the left- and right-hand sides. Under these circumstances, the error term is not orthogonal to S_{it} . The solution to this endogeneity problem is to estimate equation (5) using instrumental variables. Any lagged, stationary variables are potentially valid instruments for S_{it} since they are orthogonal to ε_{it} . Good instruments must also be correlated with S_{it} . From a broad set of potential instruments we removed the ones that showed a weak correlation with S_{it} in first-stage regressions. Our initial set of instruments included lagged values of S_{it} , lagged values of GNI, lagged values of financial variables such as real interest rates and real exchange rates, the lagged proportion of the population of working age, and a time trend. Only lagged S_{it} and the lagged proportion of working-age population (SP.POP.1564.IN.ZS) showed significant partial correlations with savings,¹⁴ so we used just those two variables as instruments.

There is ample evidence that consumption is nonstationary but is cointegrated with income, so that savings is stationary (see, e.g., Davidson et al. 1978; Hamilton 1994, chap. 19). Although consumption is nonstationary, Δ_{it} is stationary because it is formed by subtracting current consumption from average future consumption.¹⁵ Examination of autocorrelograms for the Δ_{it} and S_{it} series confirmed their stationarity for nearly all the countries in the sample.

For pooled versions of equation (5), we first estimated an ordinary two-stage-least-squares (2SLS) model for a given investment measure. To investigate whether the mean of the error term varied across countries, we then estimated a random-effects model. We used Breusch and Pagan's Lagrangean multiplier

¹⁴ Moreover, the use of real interest rates or exchange rates as instruments reduced the number of observations by more than 50%, owing to missing values.

¹⁵ Demonstrating this is straightforward. Details are available from the authors.

TABLE 1
2SLS COEFFICIENT ESTIMATES FROM BENCHMARK SPECIFICATION OF POOLED MODEL,
WITH AND WITHOUT FIXED EFFECTS (FE)

Investment Measure	Observations	Without FE		With FE
		$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_1$
Conventional gross	1,295	90.2** (18.2)	.263**. $\dagger\dagger$ (.007)	-.002 (.025)
Conventional net	1,252	131.4** (19.9)	.551**. $\dagger\dagger$ (.015)	.128**. $\dagger\dagger$ (.035)
Green net	1,252	237.0** (19.3)	.534**. $\dagger\dagger$ (.016)	.129**. $\dagger\dagger$ (.034)
Genuine	1,197	152.2** (18.9)	.416**. $\dagger\dagger$ (.011)	.037 (.034)

Note. Standard errors are in parentheses. Ninety-three countries, sample period = 1970–91 (varies by country), $T = 10$ years, $r = 3.5\%$.

** Estimate is significantly different from 0 at 1% level.

$\dagger\dagger$ Estimate is significantly different from 1 at 1% level (applies only to $\hat{\beta}_1$, and reported only when the estimate is also significantly different from 0 at the 5% level).

test to test $\text{var}(\mu_i) = 0$, where μ_i is the random effect for country i . If we rejected this hypothesis, we used a Hausman test to determine whether the random effects were orthogonal to S_{it} . If we rejected that hypothesis as well, we reestimated the model using fixed effects.¹⁶

IV. Results: Hypotheses 1–3

A. Benchmark Specification

Table 1 presents results from estimating the benchmark specification of equation (5) with panel data: that is, the specification with $T = 10$ years, $r = 3.5\%$, and the complete sample of 93 countries.¹⁷ Consider the ordinary 2SLS results first. We reject hypothesis 1, $\beta_0 = 0$ and $\beta_1 = 1$, at the 1% level for all four investment measures. With respect to hypothesis 2, the estimates of β_1 increase as we broaden the measure from conventional gross investment to conventional net investment, suggesting that the decrease in omitted variable bias outweighs the increase in measurement error for the adjustment for depreciation of produced capital. The estimate falls slightly (but not significantly)

¹⁶ In principle, we could have obtained more efficient estimates if we corrected for possible heteroskedasticity and first-order autocorrelation. With 73 of the countries having fewer than 22 observations (and 23 having fewer than 11), however, the lack of degrees of freedom to perform the heteroskedasticity and autocorrelation tests and to estimate the variance matrix advised against applying these more information-demanding generalized least squares (GLS) estimators. One consequence of autocorrelation is that instrumental variables must be lagged an extra period. Using instruments lagged twice instead of once had a negligible impact on our estimation results.

¹⁷ The number of observations differs across the investment regressions, as indicated in the first column of table 1. The results did not change appreciably when we constrained the samples to be identical.

when we include the adjustments for natural resources and more markedly (and significantly) when we include the adjustment for human capital. Evidently, current educational expenditure provides such a poor proxy for the change in human capital that it substantially increases measurement error in the genuine investment variable. Finally, although the estimates of β_1 differ significantly from one for all four measures, they also differ significantly from zero at the 1% level and are positive in all four cases. Hence, we do not reject hypothesis 3, even for genuine investment.

For all four measures we rejected the null hypotheses that the random effects equaled zero and were orthogonal to the investment variables.¹⁸ The latter rejection is not surprising in view of the discussion of omitted-variables bias in Section III.B. The last column of table 1 shows the fixed-effects estimates of β_1 . Compared to ordinary 2SLS, 2SLS fixed-effects estimation is more attractive because it provides a way to control for omitted variables and thus to obtain consistent estimates, when the omitted variables are stable over time. The estimates continue to be significantly different from one and largest for the middle two investment measures. What is most striking is that all the estimates are greatly reduced compared to the ordinary 2SLS estimates, especially the coefficients on conventional gross and genuine investment, both of which are now insignificant.

In sum, both the ordinary and fixed-effects 2SLS estimates reject hypothesis 1: none of the investment measures coincides exactly with the difference between current and average future consumption. On the other hand, both sets of estimates offer partial support for hypotheses 2 and 3: broadening the measure of investment to account for reductions in produced and natural capital improves concordance with theory in terms of coefficient magnitude and significance. The benefits of comprehensiveness outweigh the costs of crudeness up to the point of green net investment, but not when investment is broadened further by including educational expenditure as a proxy for investment in human capital (recall that green net investment and genuine investment differ only by the addition of educational expenditure to the former). The much poorer performance of genuine investment compared to green net investment is a clear indication of the shortcomings of the human capital accumulation measure used by the World Bank.

Still, the estimates of β_1 are much less than one even for conventional net and green net investment. While this persistent discrepancy could be a sign of enormous inefficiencies in generating consumption streams from capital stocks, it could also be due to the incompleteness and inaccuracy of the Bank's

¹⁸ Details of these test results are available upon request.

TABLE 2
2SLS ESTIMATES OF β_i FROM ALTERNATE SPECIFICATIONS OF POOLED MODEL, WITH FIXED EFFECTS

Investment Measure	All Countries			
	<i>r</i> Varies across Countries,		OECD Countries	Non-OECD Countries
	<i>T</i> = 10 Years	<i>r</i> = 3.5%, <i>T</i> = 20 Years	<i>r</i> = 3.5%, <i>T</i> = 10 Years	<i>r</i> = 3.5%, <i>T</i> = 10 Years
Conventional gross	-.004 (.025)	.095 (.064)	-.274**. ^{††} (.067)	.169**. ^{††} (.018)
Conventional net	.132**. ^{††} (.036)	.214**. ^{††} (.068)	-.001 (.078)	.282**. ^{††} (.027)
Green net	.133**. ^{††} (.035)	.250**. ^{††} (.055)	-.029 (.073)	.349**. ^{††} (.028)
Genuine	.038 (.034)	.215**. ^{††} (.065)	-.274**. ^{††} (.078)	.322**. ^{††} (.026)

Note. Standard errors are in parentheses. Number of countries: all, 93; OECD, 22; Non-OECD, 71. Number of observations: for first column of results, same as in table 1; for second column, 464–96 (depending on investment measure); for third column, 360–92; for fourth column, 827–935.

** Estimate is significantly different from 0 at 1% level.

^{††} Estimate is significantly different from 1 at 1% level (reported only when the estimate is also significantly different from 0 at the 5% level).

estimates. In fact, the dramatic reduction in the estimates when fixed effects are added suggests that relatively stable components of net investment that are excluded from the Bank's measures are more important in explaining the evolution of consumption over time than the components those measures do include.

B. Alternate Specifications

The results in table 2 shed light on the sensitivity of these findings to the definition of average future consumption and the sample of countries. Given the evidence that the mean of the error term differs across countries, we present results for just the fixed-effects models.

We imposed two strong assumptions when we constructed \bar{C}_{it} in the benchmark analysis: the discount rate is constant across countries and over time, and the time horizon is finite. Economic theory indicates that the discount rate can vary along both dimensions (Dasgupta and Mäler 2000), and equation (3) involves an infinite time horizon. Relaxing the former assumption does not affect the results much. The results for the models with country-specific discount rates in table 2 are almost identical to the corresponding results in the last column of table 1. This lack of sensitivity to the discount rate probably results from the presence of the discount rate in both the numerator and the denominator of equation (6). Cross-country differences in the discount rate tend to cancel out. On the other hand, changing the time horizon to 20 years has a more noticeable and positive impact. The coefficient estimates increase—they move toward the theoretical value of 1—and the coefficient on genuine

investment now becomes significant. The estimates remain much less than one, however.

To investigate the influence of measurement error, we split the sample into two groups, OECD countries and non-OECD countries, and we estimated the models separately for each group. We hypothesized that measurement error was less, and therefore estimates of β_1 should be closer to one, for the richer countries. The results in table 2 do not show this pattern, however. In fact, results are worse for OECD countries than for non-OECD countries. All the estimates of β_1 are negative for OECD countries: even hypothesis 3 is rejected. In contrast, all the estimates for non-OECD countries are positive, significantly different from zero, and larger than the corresponding estimates in table 1, though still significantly less than one.¹⁹

We doubt that these results mean that the Bank's net investment estimates contain more measurement error for OECD countries. Instead, we believe they indicate that capital accumulation, even when expressed in net terms and extended beyond produced capital, offers a less powerful explanation for the increased consumption that occurred in OECD countries during the sample period than it does for the non-OECD countries. This is the old story of the Solow residual. It is consistent with Krugman's (1994) well-known argument that developing countries whose economies grew rapidly into the early 1990s (the end of our sample period) did so via factor accumulation instead of improvements in total factor productivity. It is also consistent with an observation by Weitzman and Löfgren (1997), that the omission of technological progress from empirical net investment measures causes NNP to understate average future consumption. The Bank's net investment estimates for OECD countries are evidently so incomplete—or put another way, technological progress is so much more important than factor accumulation in those countries—that the estimates do not even signal whether average future consumption will be higher or lower than current consumption.

V. Results: Hypothesis 4

The regression equations explained about half of the variation in Δ_{it} in the ordinary pooled 2SLS models and, owing to the addition of the country dummies, more in the fixed-effects models. The fit was worse for green net investment than for conventional gross investment, however. For example, the R^2 in the ordinary 2SLS model was 0.475 for the former and 0.558 for the latter. Although extending the measure of investment improves the models'

¹⁹ We also used Cook's (1977) distance statistic to identify outliers and influential data points for the non-OECD countries. Excluding such points had a minimal impact on the results.

TABLE 3
**MEDIAN VALUES OF THEIL INEQUALITY STATISTICS FOR ONE-STEP-
 AHEAD FORECASTS FROM INDIVIDUAL-COUNTRY INVESTMENT
 MODELS AND ARIMA MODELS**

Model	Median Value of Theil Statistics
Investment model:	
Conventional gross	.604
Conventional net	.564
Green net	.472
Genuine	.474
ARIMA model	.320

Note. Sample contains non-OECD countries with more than 11 observations (50 countries).

consistency with theory, at least for non-OECD countries, these results suggest that it does not improve their predictions of the difference between current and average future consumption.

As discussed in Section III.B, we investigated the predictive accuracy of the different investment measures more carefully by estimating equation (5) for individual countries and using the estimated equations to make out-of-sample forecasts. Table 3 shows median values of the Theil inequality statistics for countries in the non-OECD subsample. It also shows results for the ARIMA models. The median Theil statistics decline by nearly a quarter (predictive accuracy improves) as the investment measure broadens from conventional gross to green net investment. Predictions are even better for the ARIMA models, however: the median Theil statistic is a third lower than for green net investment. Time-series analysis thus provides more accurate forecasts of the difference between current and average future consumption than do structural net investment models based on WDI data.²⁰

VI. Conclusions

Results from our pooled analysis reject the hypothesis that even the broadest of the World Bank's net investment measures coincides with the difference between current and average future consumption. This rejection is robust to changes in the discount rate and the time horizon. The lack of support for our most stringent hypothesis is not surprising. The Bank's estimates are not fully comprehensive, and they suffer from various sources of measurement error. Of the various adjustments, the most error-ridden is probably the one for

²⁰ Although this finding resembles Hall's (1978) famous conclusion that consumption in the current quarter is the best predictor of consumption in the next quarter, there is an important difference. Hall's result stemmed from quarterly consumption's being a random walk, whereas the difference between current and average future (annual) consumption is, as discussed in Sec. III.B, stationary by construction.

human capital accumulation, and the especially poor performance of investment measures that incorporate this adjustment lends support to this view.

The Bank's estimates fare better with regard to our weaker hypotheses but only when the sample is limited to non-OECD countries. The estimated coefficients on the investment measures are positive and significantly different from zero for those countries and increase in magnitude when investment is extended to include depreciation of produced capital and depletion of natural capital.

Even for non-OECD countries, however, the broader net investment measures do not provide any forecasting advantage compared to a simple ARIMA model. The adjustments for depreciation of produced capital, depletion of natural capital, and investment in human capital do not add much predictive power.

In sum, we conclude that although the Bank's net investment estimates tend to move in the same direction as the difference between current and average future consumption in non-OECD countries, they have little value for predicting the magnitude of this difference. Economic policy makers in developing countries can use the Bank's estimates to predict whether average future consumption will be above or below current consumption under current policies, but not by how much. The Bank's estimates are of course initial ones, and their performance might well improve as the Bank refines them. The existing estimates published in the WDI must, however, be used with caution.

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