Comprehensive Wealth and Future Consumption: Accounting for Population Growth

Susana Ferreira, Kirk Hamilton, and Jeffrey R. Vincent

Economic theory predicts that the current change in national wealth, broadly defined to include natural and human capital as well as produced capital ("genuine savings"), determines whether the present value of future changes in consumption is positive or negative. Theoretical research has focused on the effects of population growth on this relation, but no rigorous empirical investigation has been conducted. Panel data for 64 developing countries during 1970–82 are used to test the effects of three adjustments for population growth, including one that controls for omitted wealth. Although the adjustments have substantial impacts on estimates of genuine savings, they lead to only limited improvements in the relation between those estimates and subsequent consumption changes. Even without adjustments for population growth, adjustments for natural resource depletion improve the relation significantly. Policymakers and economists can interpret published estimates of genuine savings as signals of future consumption paths if and only if the estimates include adjustments for natural resource depletion. But better estimates of capital stocks are needed before it can be confidently said that adjustments for population growth significantly improve the accuracy of those signals. JEL codes: O40, Q01, C33.

A well-established body of economic theory indicates that the current change in a country’s wealth—broadly defined to include natural and human capital as well as produced capital—determines whether the country’s stream of future consumption will lie above or below its current consumption level.1 This comprehensive measure of the net change in national wealth is commonly referred...
to as “genuine savings” (Hamilton and Clemens 1999). An implication is that current levels of consumption are unsustainable in countries in which genuine saving rates are negative. An example is a country in which natural resource depletion is outstripping investment in more reproducible forms of capital.

This theory—and evidence of a lack of sustained economic growth in many resource-rich developing countries—prompted the World Bank, the United Nations, and other international and national organizations to launch initiatives aimed at creating more-comprehensive national wealth accounts (United Nations 1993; World Bank 1997, 2006). The World Bank’s (various years) widely used World Development Indicators now includes data on net national saving rates adjusted for depreciation of produced capital and depletion of natural resources, in addition to conventional savings measures, which account only for gross investment in produced capital.

The proposition that changes in capital stocks have an impact on future economic performance is neither new nor surprising. One of the few consistent findings in the extensive cross-country growth literature is that gross investment in produced capital is significantly correlated with growth in gross domestic product (GDP). An early review by Levine and Renelt (1992), which characterized most of the conclusions from initial growth studies as “fragile,” reported a robust, positive correlation between gross investment and GDP growth. Sala-i-Martin (1997) subsequently argued that Levine and Renelt’s extreme-bounds analysis constituted an overly stringent test of significance. Sala-i-Martin based his analysis on complete distributions of the regression coefficients, but he, too, found that gross investment was significantly correlated with GDP growth.

The genuine savings literature differs from the growth literature in two principal ways. One is that it focuses on changes in consumption rather than GDP growth, which makes it more welfare oriented. The other is that it emphasizes net savings measures that are broader than ordinary gross investment. It draws particular attention to changes in natural resource stocks.

Ferreira and Vincent (2005) analyze the performance of the broader net savings measures published in the World Development Indicators (World Bank various years). Using panel data for 1970–2001 they test whether measures adjusted for the depreciation of produced capital and the depletion of natural capital were correlated with subsequent changes in countries’ consumption levels. They find that these measures are correlated in non–Organisation for

2. Evidence of a “resource curse” comes from both case studies (for example, Gelb and Associates 1988) and cross-country econometric studies (for example, Sachs and Warner 1995).

3. Since Burnside and Dollar’s (2000) study, the empirical growth literature has focused largely on the effectiveness of foreign aid, but it has continued to provide evidence that gross investment contributes positively to GDP growth. These results refer to long-run growth; Easterly (1999) shows that there is no evidence of a link between investment and growth in the short run. Easterly and Levine (2001) emphasize the role of total factor productivity growth, rather than factor accumulation, in explaining differences in income and growth across countries.
Economic Co-operation and Development (OECD) countries: adjusted net savings in a given year had a positive and significant impact on consumption changes during the subsequent decade. They find no evidence of a similar relation in OECD countries, a result they attribute to the fact that the World Development Indicators measures refer purely to factor accumulation and exclude technical change.

The effects of population growth have been a recent focus of theoretical research on genuine savings (Dasgupta 2001; Dasgupta and Mäler 2001; Hamilton 2002; Arrow, Dasgupta, and Mäler 2003; Asheim 2004). This research indicates that population growth can reduce per capita consumption possibilities by spreading existing capital stocks more thinly across a larger number of people and that empirical genuine savings estimates should account for this wealth-diluting (capital-widening) effect. Using data for a small sample of developing countries and regions, Dasgupta (2003) shows that this effect can be large enough to flip genuine savings estimates from positive to negative. Estimates that ignore this effect run the risk of exaggerating countries’ future consumption possibilities.

This article investigates whether current per capita savings is correlated with future changes in per capita consumption. It uses the formulas linking saving and future consumption derived from the underlying growth theory. It takes wealth dilution and several other effects of population growth into account, including the effects of changes in the population growth rate over time.

The sample is a panel that includes annual data on 64 developing countries for 1970–82, with additional data for 1983–2003 used to construct some of the variables. The analysis is limited to developing countries in view of Ferreira and Vincent’s (2005) results and because developing countries are the countries in which population growth rates are highest and thus affect genuine savings estimates the most. As by-products, additional evidence is generated suggesting that adjustments for natural resource depletion improve the performance of genuine savings measures. The analysis also generates econometric estimates of national wealth components not included in produced and natural capital.

The article is organized as follows. Section I summarizes pertinent economic theory, which leads into the specification of the econometric models in section II. Section III describes the data sources, the construction of key variables, and estimation issues. Section IV presents the results. The last section discusses the implications of the results for the construction and use of estimates of cross-country genuine savings.

### I. Theoretical Underpinnings

The test of savings measures used here builds on the result in Dasgupta (2001) that states that current genuine savings equals the present value of future changes in consumption. Hamilton and Hartwick (2005) derive this result as a corollary to a more general result that links growth in savings to growth in
consumption. They show that the following relation holds in a competitive economy:4

\[
(1) \quad \int_{t}^{\infty} \frac{dC(v)}{dv} e^{-\int_{t}^{v} \rho(\tau) d\tau} dv = G(t)
\]

where \( C \) is total (not per capita) consumption, \( G \) is total genuine savings, and \( \rho \) is the interest rate (the consumption discount rate, not the utility discount rate). This relation rests on less restrictive assumptions than the theoretical relation that provides the basis for Ferreira and Vincent’s (2005) econometric test. Following Weitzman (1976), they examine the relation between current genuine savings and the difference between average future consumption and current consumption, not the present value of future consumption changes.

Dasgupta (2001) shows that per capita genuine savings mirrors the change in social welfare (“dynamic average utilitarianism”) in an economy with a growing population under three conditions: the population grows at a constant rate, per capita consumption is independent of population size, and production has constant returns to scale. Under these assumptions the relation between current genuine per capita savings and future changes in per capita consumption is given by the following equation:

\[
(2) \quad \int_{t}^{\infty} \frac{dc(v)}{dv} e^{-\int_{t}^{v} (\rho(\tau) - \gamma) d\tau} dv = g(t).
\]

In this equation \( c \) is per capita consumption \((C/N, \text{where } N \text{ is population, assumed to equal the labor force})\); \( g \) is genuine per capita savings \((G/N)\); and \( \gamma \) is the constant population growth rate.

The inclusion of population growth leads to three differences between equations (1) and (2). Two are obvious: consumption and genuine savings are expressed in per capita terms in equation (2), and the discounting factor on per capita consumption is reduced by the population growth rate. The use of per capita consumption and genuine savings is the only population adjustment Ferreira and Vincent (2005) make.

The third difference is the wealth-dilution effect of population growth, embodied in \( g(t) \). Hamilton and Hartwick (2005) derive this effect as follows. Production in their model is based on the constant returns to scale technology \( F = F(K, R, N) \), where \( R \) is the current extraction of an exhaustible resource. Production yields a homogeneous good, which can be either invested in produced

4. See Dixit, Hammond, and Hoel (1980) for the definition of a competitive economy. Hamilton and Hartwick (2005) analyze an optimal Dasgupta–Heal economy, but their result requires only that the economy be competitive.
capital or consumed. Per capita production is \( f(k, r) = F/N = F_K k + F_R r \), where \( k = K/N \) and \( r = R/N \). Per capita wealth is \( w = k + F_K s \), where \( s = S/N \) and \( S \) is the resource stock. Genuine per capita savings is given by \( g = k + F_K s \), or

\[
g = \frac{\dot{K}}{N} - F_R r - \gamma w. \tag{3}
\]

The first two terms on the right side are per capita investment in produced capital and per capita depletion of natural capital. The third term, \(-\gamma w\), captures the wealth-dilution effect. It represents the reduction in per capita wealth that results from sharing existing wealth with the population increment.

The assumption of constant population growth in this model is restrictive. Population growth rates vary widely, even over short periods. The population growth rate in the sample used here, for example, had a within-country standard deviation equivalent to 10 percent of the mean. In supplemental appendix S.1 (available at http://wber.oxfordjournals.org) the following modified version of equation (2) is shown to hold when the population growth rate varies over time:

\[
\int_t^\infty \left( \frac{dc(v)}{dv} + \frac{d\gamma(v)}{dv} w(v) \right) e^{\int_t^v (\rho(\tau) - \gamma(\tau)) d\tau} dv = g(t). \tag{4}
\]

The extra term on the left side accounts for the change in the population growth rate. The wealth-dilution term in \( g(t) \) is now \(-\gamma(t)w\), because \( \gamma \) is no longer constant. Proposition 6 in Asheim (2004) implies that the sign of genuine per capita savings in this model indicates whether social welfare is increasing or decreasing under two different measures of social welfare: the present value of total utility (population times per capita utility) or the present value of per capita utility.\(^5\)

All of the preceding expressions are in continuous time for an infinite period. Empirical work requires expressions in discrete time over a finite interval. When the population growth rate is changing over time, the discrete-time approximation to equation (4) is given by the following equation:

\[
\sum_{t=1}^{t+T} \left( \frac{C_{t+1} - N_{t+1} - C_t}{N_t} \right) + (\gamma_{t+1} - \gamma_t) (W_{t+1} - W_t) = g_{it} \tag{5}
\]

where \( i \) denotes the country and \( \rho \) denotes the interest rate. The continuous-time result is interpreted as implying that savings at time \( t \) equals the present

\(^5\) Dasgupta (2001) shows that the ethics of maximizing per capita utility are questionable: the optimal allocation of a fixed quantity of a good across two groups of unequal size will lead to a smaller per capita allocation to the larger group if the utility function exhibits decreasing marginal returns.
value of future changes in consumption (beginning with period $t + 2$ minus period $t + 1$) plus the population growth-wealth interaction term. This can be written more compactly as follows:

\[ \text{PV} \Delta C_{it} + \text{PV}(\Delta \gamma_{it} w_{it}) = g_{it}. \]  

The first term on the left side stands for the present value of future changes in per capita consumption; the second term stands for the present value of per capita wealth, weighted by the change in the population growth rate. This equation provides the basis for the empirical tests.

**II. Econometric Models**

If population growth rates are constant over time, equation (6) implies that one should test the relation between per capita current genuine savings and per capita future consumption changes by estimating the following equation:

\[ \text{PV} \Delta C_{it} = \beta_0 + \beta_1 g_{it} + \varepsilon_{it}. \]  

If population growth rates vary over time, one should instead estimate the following equation:

\[ \text{PV} \Delta C_{it} + \text{PV}(\Delta \gamma_{it} w_{it}) = \beta_0 + \beta_1 g_{it} + \varepsilon_{it}. \]  

This equation differs from equation (7) in three ways: it includes $\text{PV}(\Delta \gamma_{it} w_{it})$ in the dependent variable, it includes the wealth-dilution term in $g_{it}$, and it includes adjustments for time-varying population growth rates in the discount rates in $\text{PV} \Delta C_{it}$, $\text{PV}(\Delta \gamma_{it} w_{it})$ and the wealth-dilution term. Both equations were estimated. Given that population growth rates varied over time in the countries in the sample, the expectation was that the results for equation (8) would be stronger than those for equation (7) in ways defined below.

Strictly interpreted, equation (6) implies the joint hypotheses $\beta_0 = 0$ and $\beta_1 = 1$: there is a one-to-one relation between genuine savings and consumption changes. A weaker hypothesis is simply $\beta_1 > 0$: genuine savings and consumption changes are positively correlated. The theory refers to a situation in which genuine savings include all changes in wealth. Any empirical estimates of genuine savings will inevitably be incomplete, which could bias the estimate of $\beta_1$ away from 1. This bias was expected to be smaller, and the estimates of $\beta_1$ therefore closer to 1, for more comprehensive savings measures. Equations (7) and (8) were estimated sequentially to test this hypothesis. Initially, $g$ was set equal to gross national savings. It was then adjusted sequentially, for the depreciation of produced capital, the depletion of natural capital, and the dilution of produced and natural capital. As discussed in the next section, these
adjustments are crude. The resulting measurement error could weaken the
convergence of the estimates of \( b_1 \) toward 1.

One might expect country fixed effects to be added to equations (7) and (8)
(changing the intercepts from \( b_0 \) to \( b_{0i} \)) to control for omitted wealth com-
ponents that are more or less constant over time. In fact, in the presence of
time-invariant total omitted wealth \( X \), equation (3) becomes

\[
\tilde{g} = \frac{\dot{K}}{N} - F_r \bar{r} - \gamma \left( w + \frac{X}{N} \right) = g - X \frac{\gamma}{N}
\]

where \( \tilde{g} \) is true (unobserved) genuine savings.\(^6\) As long as population \( N \) is
changing over time, an ordinary fixed effect will not solve the problem of the
omission of \( X \gamma/N \) from the genuine savings variable in equations (7) and (8).
The problem occurs even if the population growth rate is constant (and
nonzero). To solve this problem one must include the ratio of the population
growth rate to the total population as an additional explanatory variable.
Equations (7) and (8) thus become

\[
P V \Delta C_{it} = \beta_0 + \beta_1 g_{it} + \beta_2 \frac{\gamma}{N_{it}} + \epsilon_{it}
\]

and

\[
P V \Delta C_{it} + PV(\Delta \gamma_{it} \bar{w}_{it}) = \beta_0 + \beta_1 g_{it} + \beta_2 \frac{\gamma_{it}}{N_{it}} + \epsilon_{it}.
\]

From equation (9) one would expect \( \beta_{2i} \) to be negative if significant wealth
were omitted and zero otherwise. The absolute value of this coefficient pro-
vides an estimate of \( X_i \), the total omitted wealth for country \( i \). These two
equations and, for comparison, fixed-effects versions of equations (7) and (8)
are estimated.\(^7\)

**III. Data and Estimation Issues**

This section describes the data sources, the construction of key variables, and
estimation issues.

**Data**

Data for constructing the variables in equations (7), (8), (10), and (11) were
obtained from the *World Development Indicators* (World Bank various years).

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6. The authors are indebted to a referee for pointing this out.

7. Fixed effects were used instead of random effects, because the sample is not random: it includes
the population of developing countries. An F-test was used to test the null hypothesis that the fixed
effects were equal to zero. The hypothesis was rejected in all models.
All monetary variables are expressed in constant 2000 U.S. dollars. The final sample includes 64 non–OECD countries. Complete series for 1970–2003 were available for most countries, with missing values occurring mainly in 2003. Hence the panel is unbalanced but reasonably complete.

The time horizon, $T$, was set equal to 20 years in constructing the present value of future changes in per capita consumption. Although Ferreira and Vincent (2005) use 10 years in their benchmark model, they show that the econometric relation between genuine savings and their consumption measure improves when they extend the time horizon to 20 years. This improvement is not surprising: “green” accounting theory refers to an infinite time horizon. The 20-year time horizon reduced the sample in the econometric analysis to 1970–82: a test was run to determine whether genuine savings in year $t$ was positively correlated with the actual present value of consumption changes during the period $t + 1$ to $t + 21$.

Each equation was estimated sequentially for four comprehensive savings measures. In increasing order of completeness, the four measures are as follows:

1. **Gross savings.** This measure implicitly includes both gross investment in produced capital within the country’s borders and the current change in holdings of foreign assets.
2. **Net savings.** This measure equals gross savings minus depreciation of produced capital.
3. **Green savings.** This measure was constructed by subtracting estimates of the current depletion of subsoil assets and forest resources from net savings.
4. **Population-adjusted savings.** This measure equals green savings minus the wealth-dilution term.

Summary statistics for the 64 countries reveal that the means of $PV\Delta C$ and $PV\Delta C + PV(\Delta \eta \nu)$ are the same order of magnitude as the savings measures, suggesting that an empirical relation between current savings and future consumption changes is plausible (table 1). The means of the savings measures decrease sharply with the progressive adjustments for depreciation of produced capital (net savings), depletion of natural capital (green savings), and wealth dilution (population-adjusted savings). In line with Dasgupta’s (2003) findings, the mean of population-adjusted savings is negative, suggesting that on average...

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8. A reviewer pointed out that exchange rates in 2000 may not be representative, because countries were still recovering from the effects of the Asian financial crisis. Choosing a different base year would alter the relative size of the different variables in the model across countries (because of different base year exchange rates). With country fixed effects, however, it is within-country variation over time rather than variation across countries that determines the econometric results. The results are therefore invariant to the choice of base year.

9. Supplemental appendix S.2 provides detail on data sources and the procedures followed in constructing the variables. Supplemental appendix S.3 provides detail on individual countries.
the countries in the sample dissaved after accounting for the spreading of existing wealth across growing populations. The adjustment for wealth dilution also increases the variability of the savings measure, as indicated by the larger standard deviation for population-adjusted savings than for green savings.

**Estimation Issues**

There is a risk of endogeneity when population-adjusted savings is the savings measure. The estimates of natural capital in the wealth-dilution term are constructed using data on future resource rents. It is possible that a positive consumption shock in period $t + s$, which is reflected in $PV\Delta C_{it}$ on the left side of the regression equations, might induce a country to extract more resources to pay for the additional consumption. Because resource rents would also increase in period $t + s$, the dependent and explanatory variables would be simultaneously determined. This risk is greater when the adjustments for time-varying population growth rates are included, because future resource rents that appear in the current wealth-dilution term also appear in the $PV(\Delta \gamma_{it} w_{it})$ term on the left side of equations (8) and (11). Although this risk is reduced by the facts that current wealth was not used in constructing $PV(\Delta \gamma_{it} w_{it})$ (see equation (5)) and that future per capita wealth in $PV(\Delta \gamma_{it} w_{it})$ is weighted by the discount rate and the change in the population growth rate, it does not necessarily become negligible.

Equations that involved population-adjusted savings using instrumental variables were estimated using the generalized two-stage least squares fixed-effects estimator of Balestra and Varadharajan-Krishnakumar (1987) in

**Table 1. Descriptive Statistics for Key Variables**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Number of Observations</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>$PV\Delta C$</td>
<td>799</td>
<td>111.1</td>
<td>356.9</td>
<td>-2,201.3</td>
<td>1,414.9</td>
</tr>
<tr>
<td>$PV\Delta C + PV(\Delta \gamma w)$</td>
<td>790</td>
<td>50.2</td>
<td>379.3</td>
<td>-2,067.4</td>
<td>1,284.1</td>
</tr>
<tr>
<td>Gross savings</td>
<td>794</td>
<td>240.8</td>
<td>363.5</td>
<td>-86.8</td>
<td>2,516.3</td>
</tr>
<tr>
<td>Net savings</td>
<td>794</td>
<td>144.7</td>
<td>254.1</td>
<td>-221.3</td>
<td>2,124.0</td>
</tr>
<tr>
<td>Green savings</td>
<td>794</td>
<td>53.6</td>
<td>198.2</td>
<td>-1,591.3</td>
<td>1,489.1</td>
</tr>
<tr>
<td>Population-adjusted savings</td>
<td>793</td>
<td>-148.5</td>
<td>289.4</td>
<td>-2,321.1</td>
<td>1,028.2</td>
</tr>
<tr>
<td>Population growth rate (percent)</td>
<td>858</td>
<td>2.37</td>
<td>0.81</td>
<td>-0.13</td>
<td>4.37</td>
</tr>
<tr>
<td>Total population (millions)</td>
<td>858</td>
<td>41.5</td>
<td>136</td>
<td>0.120</td>
<td>1,010.0</td>
</tr>
</tbody>
</table>

*Note: All variables except population growth rate and total population are expressed in per capita terms in 2000 U.S. dollars. $PV\Delta C$ and population-adjusted savings are computed using country-specific constant interest and population growth rates, as in equation (7); $PV\Delta C + PV(\Delta \gamma w)$ is computed using country-specific constant interest rates but time-varying population growth rates, as in equation (8). The sample of 64 countries covers the period 1970–82.*

*Source: Authors’ analysis based on data from World Bank (various years).*
order to reduce the bias that could result. The set of instruments included lagged values of green savings, produced capital, the percentage of the population of working age, and the population growth rate, and a time trend. These variables were correlated with contemporaneous savings in the first-stage regressions (and were thus relevant instruments); lagging them ensured that they were exogenous. Standard errors were corrected in all models for serial correlation, and time dummy variables were included to control for unobserved global factors that affected consumption-savings decisions across all countries in a given year.

The risk of spurious correlation must be considered given that time-series data were used. Formal testing for stationarity and cointegration is not appropriate for the data, because time-series tests have little power in samples that cover as short a period as those used here (Banerjee 1999). There is ample evidence that consumption is nonstationary but cointegrated with income, so that savings is stationary (see, for example, Davidson and others 1978; Hamilton 1994). Although consumption is nonstationary, the dependent variable is constructed as the present value of future changes in per capita consumption. Examination of the autocorrelograms for these series confirms their stationarity. Ferreira and Vincent (2005) examine autocorrelograms for longer time series of similar variables, because the time horizon in their study was only 10 years. They, too, find that the series are stationary.

IV. Results

Estimates of $\beta_1$ were derived for the four model specifications and the four savings measures. Comparison of estimates in the last row (population-adjusted) of table 2 with those in the second from last row (green) indicates the impact of accounting for wealth dilution; comparison of estimates in column 3 with those in column 1 (and column 4 with column 2) indicates the impact of accounting for changes in the population growth rate through adjustment to the dependent variable; and comparison of the estimates in column 2 with those in column 1 (and column 4 with column 3) indicates the impact of controlling for time-invariant omitted wealth by including the ratio of the population growth rate to total population as an additional explanatory variable. For reference, column 5 shows results from a model with the dependent variable used by Ferreira and Vincent (2005) (that is, the difference between average future consumption and current consumption). That model includes no adjustments for population other than the variables expressed in per capita terms. A 20-year time horizon and country-specific (but time-invariant) interest rates were used instead of the 10-year horizon and the fixed 3.5 percent rate used by Ferreira and Vincent to make the results more directly comparable to those in the other columns.

Consider first the results in columns 1–4. The most striking result is the adjustment for natural resource depletion. The hypothesis $\beta_1 > 0$ is supported
<table>
<thead>
<tr>
<th>Variable</th>
<th>1 Equation (7)</th>
<th>2 Equation (10)</th>
<th>3 Equation (8)</th>
<th>4 Equation (11)</th>
<th>5 Ferreira and Vincent (2005)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent variable</td>
<td>$PV\Delta C$</td>
<td>$PV\Delta C$</td>
<td>$PV\Delta C + PV(\Delta \gamma w)$</td>
<td>$PV\Delta C + PV(\Delta \gamma w)$</td>
<td>$\bar{C} - C$</td>
</tr>
<tr>
<td>Time dummy variables?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Country fixed effects?</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Control for omitted wealth?</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Savings measure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross</td>
<td>$-0.642^*$</td>
<td>$-0.084$</td>
<td>$-0.764^*$</td>
<td>$-0.106$</td>
<td>$-0.597^{**}$</td>
</tr>
<tr>
<td></td>
<td>$(0.365)$</td>
<td>$(0.255)$</td>
<td>$(0.415)$</td>
<td>$(0.258)$</td>
<td>$(0.268)$</td>
</tr>
<tr>
<td>Net</td>
<td>$-0.610^*$</td>
<td>$-0.200$</td>
<td>$-0.729^*$</td>
<td>$-0.234$</td>
<td>$-0.533^{**}$</td>
</tr>
<tr>
<td></td>
<td>$(0.364)$</td>
<td>$(0.316)$</td>
<td>$(0.412)$</td>
<td>$(0.324)$</td>
<td>$(0.274)$</td>
</tr>
<tr>
<td>Green</td>
<td>$0.425^{**}$</td>
<td>$0.405^{**}$</td>
<td>$0.558^{**}$</td>
<td>$0.504^{**}$</td>
<td>$0.801^{**}$</td>
</tr>
<tr>
<td></td>
<td>$(0.203)$</td>
<td>$(0.178)$</td>
<td>$(0.274)$</td>
<td>$(0.197)$</td>
<td>$(0.362)$</td>
</tr>
<tr>
<td>Population-adjusted</td>
<td>$0.413^{**}$</td>
<td>$0.392^{**}$</td>
<td>$0.560^{**}$</td>
<td>$0.496^{***}$</td>
<td>$0.788^{***}$</td>
</tr>
<tr>
<td></td>
<td>$(0.163)$</td>
<td>$(0.165)$</td>
<td>$(0.213)$</td>
<td>$(0.182)$</td>
<td>$(0.287)$</td>
</tr>
</tbody>
</table>

***Significant at the 1 percent level; **significant at the 5 percent level; *significant at the 10 percent level.

Note: Numbers in parentheses are robust standard errors corrected for serial correlation. Two-stage least squares estimates are shown for population-adjusted savings. Fixed-effects estimates are shown for equations (7) and (8). Pooled ordinary least squares estimates are shown for equations (10) and (11). The sample of 64 countries and 788 observations covers the period 1970–82.

Source: Authors’ analysis based on data from World Bank (various years).
only for the two savings measures that include this adjustment, green savings and population-adjusted savings. The estimates for gross savings and net savings are negative; although none is significantly different from zero at the 5 percent significance level, the estimates for equations (7) and (8) are significant at the 10 percent level and have very large negative values. The expected positive correlation between current savings and future consumption changes occurs only when the savings measure is expanded to include natural capital.

The sign change between net and green savings is consistent with the expectation that estimates of $\beta_1$ should be closer to 1 for savings measures that are more comprehensive. The estimates on green and population-adjusted savings remain significantly below 1 in all four equations, however. In addition, the estimates for population-adjusted savings are virtually identical to those for green savings rather than being closer to 1. One would expect the coefficient on population-adjusted savings to be biased upward if the instrumental variables did not completely purge that saving measure of endogeneity. In fact, the adjustment for wealth dilution does not substantially improve the empirical relation between current savings and future consumption changes.

The adjustment to the dependent variable increases the absolute value of the estimates, with the estimates for green and population-adjusted savings in columns 3 and 4 about one-fifth to one-third larger than the corresponding estimates in columns 1 and 2 and reaching values of 0.5 or more. Although these increases are not statistically significant, they are nonetheless substantial. There is thus some evidence that the adjustment moves the estimates closer to 1.

The control for omitted wealth affects only the coefficients on gross and net savings, which rise toward zero and become less significant (compare column 2 with column 1 and column 4 with column 3). It makes sense that omitted variables bias should be greater for these measures than for the more comprehensive ones. Although the coefficients on green and population-adjusted savings barely change, the estimates of $\beta_{2i}$, the country-specific coefficients on the ratio of population growth rate to total population, are significantly different from zero for many countries when they are the savings measures.

Consider the results for population-adjusted savings in equation (11), the model that includes all three population adjustments. Estimation of this model generated estimates of $\beta_{2i}$ for 62 countries (estimates for China and India were not possible, because of the low estimates of the omitted-wealth control variables for these countries).\(^{10}\) Fifty-one of the estimates—four-fifths of the total—were nonpositive (either significantly negative or not significantly different from zero), as theory predicts they should be. (Recall that a negative $\beta_{2i}$ indicates a positive amount of omitted wealth.) Forty-five were negative, with half of those (22) significantly different from zero. There is thus econometric

\(^{10}\) For China and India, figures in hundredths (population growth) are divided by figures in billions (population). The resulting variables are close enough to zero to make the matrix of explanatory variables singular when they are included in it.
evidence that the estimates of produced and natural capital failed to account for significant amounts of time-invariant national wealth in about half of the countries.

The plausibility of the 51 nonpositive estimates of $\beta_{2i}$ can be gauged by comparing them with the difference between the present value of future consumption flows, capitalized over a 20-year time horizon, and the sum of the values of produced and natural capital. The present value of consumption is a broad measure of a country’s total wealth (Hamilton and Hartwick 2005; World Bank 2006); this procedure identifies the residual amount of the consumption stream that must be generated by some form of capital other than produced and natural capital. These variables need to be in total, not per capita, terms to be compared properly, because $-\beta_{2i}$ provides an estimate of total, not per capita, omitted wealth. A simple ordinary least squares regression was run with the 51 nonpositive estimates as the dependent variable and the corresponding residual amounts (means for 1970–82) as the explanatory variable. Although the fit was not tight ($R^2 = 0.101$), the slope parameter ($-0.151$) was significantly different from zero ($P = 0.023$). The magnitude of the slope parameter implies that the omitted wealth components determined by the estimation of equation (11) accounted for about one-sixth of the wealth omitted from the estimates of produced and natural capital.

Comparison of the results in column 5 with those in column 1 indicates that differences between the definition of the dependent variable in the study by Ferreira and Vincent (2005) and this study have the greatest impact when the savings measures incorporate adjustments for natural capital. The more restrictive theoretical basis of the model used by Ferreira and Vincent, which draws on Weitzman (1976) rather than Dasgupta (2001), causes it to exaggerate the correlation between current savings and future consumption: the coefficients on green and population-adjusted savings in column 5 are not significantly different from 1, whereas those in column 1 are.

**V. Discussion**

The econometric results indicate that there is a positive correlation in developing countries between current per capita savings and the present discounted value of changes in future per capita consumption when the measure of savings is expanded to incorporate natural resource wealth. This result holds when additional adjustments for wealth dilution linked to population growth and the effects of changing population growth rates are taken into account. Conventional savings measures are negatively related with the present value of changes in consumption; adding adjustments for natural capital reverses the relation and makes it positive, as theory predicts it should be. The improved performance of savings measures after making this adjustment is consistent with the results from the more restrictive model used by Ferreira and Vincent (2005). The results presented here imply that policymakers and economists
should interpret the net national savings rates for developing countries published in the *World Development Indicators* (World Bank various years) as signals of future consumption paths if and only if the rates include this adjustment for natural capital.

The three population-related adjustments evaluated lead to only minor improvements in the relation between current saving and changes in future consumption. The coefficients on green and population-adjusted savings increase by a third when the dependent variable is adjusted for changes in the population growth rate over time, but the increases are not statistically significant. Controlling for time-invariant omitted wealth by including the ratio of population growth rate to total population improves the relation in the sense that the coefficients on gross and net savings are no longer significantly less than zero; it does not affect the coefficients on green and population-adjusted savings. This suggests that the most important unobserved time-invariant components of total wealth are related to natural wealth and that the estimates of natural wealth, crude though they are, account for them surprisingly well.

The lack of significant impact of the adjustment for wealth dilution is surprising. The adjustment has a substantial impact on the savings estimates, as shown in table 1 and supplemental appendix S.3. Measurement error may well be to blame. The estimates of the stocks of produced and natural capital are crude, especially for produced capital (Pritchett 2000). Measurement error could also explain the lack of significance of the increases in the coefficients on green and population-adjusted savings when the dependent variable is adjusted for changes in the population growth rate over time, as this adjustment involves the capital stock estimates. Adjusting genuine savings for wealth dilution is justified theoretically, and the estimates presented here and those of Dasgupta (2003) and Hamilton and Atkinson (2006) indicate that it has a potentially large impact on estimates of genuine savings. Better estimates of capital stocks are needed, however, before it can confidently be stated that this adjustment significantly improves the performance of genuine savings as an indicator of future consumption changes.

The data provided in national accounts in developing countries are of questionable quality. The analysis suggests three priorities for producing better data: strengthening basic national accounts data, including data on gross savings and depreciation; updating and refining estimates of natural resource extraction and harvest costs, as well as constructing time series of resource lifetimes; and extending the coverage of natural resource data, particularly for agricultural soils, fisheries, and diamonds.

**References**


