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Abstract

"Green accounting" refers to the incorporation of changes in wealth, in particular natural resource wealth, into a country's national accounts. Despite a large body of theoretical work and considerable promotional efforts by international and national organizations, there is no firm evidence that greener national accounting measures provide better indicators of long-run economic possibilities. In this paper I construct per capita estimates of green net national product (NNP) and genuine savings for 13 countries in Latin America during 1973-86. I then test econometrically whether these measures are systematically related to consumption in subsequent years. I deal with possible nonstationarity in the data series by estimating models expressed in first-differences, in addition to models expressed in levels. Despite incomplete adjustments and crude data, my estimates of genuine savings are related to future consumption in a manner consistent with theoretical predictions. In particular, all the coefficients on the individual components of genuine savings have the correct signs and are highly statistically significant in both the models with levels and the models with first-differences. Results are more mixed for green NNP. An irony of my results is that physical capital, not natural capital, appears to be the greater source of data problems for green accounting.

Keywords: National Accounts, Green Accounting, Sustainability, Natural Resources, Latin America.

JEL Codes: E2, O1, Q0

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The idea that conventional measures of national income and wealth can provide misleading signals about a country's long-run economic possibilities has been in the economics literature for decades (Martin L. Weitzman 1976, John M. Hartwick 1977, Partha S. Dasgupta and Geoffrey M. Heal 1979). It has spawned a large body of theoretical work.[1] Most of the studies have focused on the divergence between gross and net income, and gross and net investment, in countries with large natural resource sectors. This focus is not surprising, given long-standing concerns about a "resource curse" in developing countries (Alan Gelb and Associates 1988) and econometric evidence that resource-rich countries have grown more slowly than their resource-poor counterparts (Jeffrey D. Sachs and Andrew M. Warner 1995). Indeed, the best-known "green accounting" study, by the World Resources Institute (Robert Repetto et al. 1989), estimated that the unsustainable liquidation of natural resource wealth accounted for nearly half of the increase in gross domestic product in Indonesia during 1971-84.

Green accounting is increasingly accepted and promoted by high-profile international and national organizations. In 1993, the United Nations' Department for Economic and Social Information and Policy Analysis, which coordinates international standards for national accounts, published guidelines for adjustments related to natural resource depletion and environmental degradation (United Nations 1993). Since then, it has organized regular meetings to refine the guidelines and has sponsored pilot tests in selected countries. The World Bank recently began including estimates of "genuine savings"—national savings net of resource depletion—in its *World Development Indicators* database, which is the most widely used source of international macroeconomic data. In 1999, the U.S. National Academy of Sciences issued a report on the greening of the United States' national accounts (William D. Nordhaus and Edward C. Kokkelenberg 1999).

Given all this attention, one would expect that there is by now firm evidence that greener national accounting measures are indeed better long-run economic indicators. In fact, no such evidence exists. Coming closest is a suggestive figure in a report by the World Bank (1997, Figure 2.2), which indicates that genuine savings rates were highest during 1970-93 in East Asia and the Pacific, followed by Latin America and the Caribbean and then sub-Saharan Africa. This ranking mirrors the relative economic growth rates among the three regions during that period. But this "evidence" is simply a visual correlation. Moreover, the correlation is essentially contemporaneous. Hence, it does not demonstrate that genuine savings estimates for earlier periods predict what happens in subsequent periods.

The lack of a serious effort to assess the predictive power of greener national accounting measures is troubling, because the adjustments made in constructing these measures are always incomplete and crude. The adjustments involve estimating changes in the values of a country's capital stocks. In principle, these stocks should include *all* forms of capital: not only physical (human-made) capital like equipment, structures, and infrastructure, but also human capital (including knowledge), stocks of natural resources (e.g., minerals, timber, land, fish, freshwater), and environmental quality (e.g., air and water quality). In practice, green accounting studies make partial adjustments using very incomplete data. Regarding natural capital, they typically include only a few of the commercially most important natural resource commodities in a

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[1] A book by Thomas Aronsson et al. (1997) and articles in a special issue of the journal *Environment and*

country, and they usually ignore environmental quality altogether. Limited data on the revenues and costs of natural resource extraction lead to the ample use of "guesstimates." For example, studies might assume, on the basis of a single data point (perhaps from another country!), that extraction costs are a constant proportion of resource revenues. They then insert these "data" into short-cut valuation formulas that rely on assumptions that are obviously, and grossly, violated in the real world (e.g., natural resources are managed optimally, and commodity prices or extraction cost curves do not change).[2] Although "capital" is inherently a forward-looking concept, green accounting studies typically estimate physical capital stocks by using the recursive, "perpetual inventory model." Lant Pritchett (2000) has argued that this model can yield wildly inaccurate estimates of capital stocks in developing countries, where a substantial portion of so-called "investment" is public expenditure that frequently does not generate future returns. Finally, the studies typically ignore human capital altogether, despite its obvious importance to economic growth.[3]

In this paper I formally test the predictive power of green accounting measures. I use panel data for 1973-97 to develop per capita estimates of green net national product (NNP) and genuine savings for 13 countries in Latin America: all countries in mainland South America except French Guiana, plus Mexico. As in previous studies, my estimates are rough. I ignore human capital, I estimate physical capital using the perpetual inventory model, and, although I include most of the major natural resource commodities produced in the region, I exclude agricultural land, marine resources, freshwater, and environmental quality.

Development Economics (vol. 5, nos. 1 & 2, February & May 2000) provide recent surveys of this literature.
[2] Eric Neumayer (2000) provides a critique of several of these methods.
[3] The World Bank (1997) included educational expenditures as a proxy for investment in human capital in its genuine savings estimates.

To test the predictive power of green NNP and genuine savings, I use regression models to determine the relationship between these variables in earlier periods and aggregate consumption expenditures in later periods. According to green accounting theory, if the accounting system is complete and its entries are measured accurately, then green NNP should equal the "stationary equivalent" of future consumption. This is a specific kind of moving average, which I will explain later. Genuine savings should equal the difference between the stationary equivalent and current consumption.

As a preview and to illustrate why testing these propositions is not entirely straightforward, Figures 1 and 2 show my estimates of these variables pooled across the countries and years in my dataset.[4] The figures also include the ordinary least squares (OLS) regression lines. A positive relationship between the stationary equivalent and green NNP is immediately obvious from Figure 1. Although there is much more scatter in Figure 2, the regression line is upward-sloping. Hence, it appears that the greener accounting measures, especially green NNP, do indeed predict average future consumption outcomes.

These apparent relationships might be illusory, however, for at least two reasons. First, familiar macroeconomic identities might explain the correlations in Figures 1 and 2. Consider green NNP. In constructing this variable, one starts with ordinary gross national product (GNP) and then makes a series of adjustments. Consumption is the major component of GNP, and it tends to evolve gradually over time. The presence of conventional GNP in green NNP, and the former's correlation with consumption, might therefore explain the relationship in Figure 1.

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[4] The sample period in these figures is 1973-86, not 1973-97, because I estimated the stationary equivalent and natural capital using a 10-year time horizon. I explain this point in section III.A.

A second reason follows from Robert E. Hall's (1978) famous observation that consumption expenditure in the United States has a unit root (i.e., follows a random walk): $\lambda_t = 1$ in the autoregressive reduced-form equation,[5]

$$E_t = \lambda E_{t-1} + \mu_t \, . \tag{1}$$

Because the dependent variables in the OLS regressions in Figures 1 and 2 involve linear combinations of consumption expenditure, they too might have unit roots if the Latin American consumption data do. Moreover, many studies have presented evidence that other macroeconomic time series, including per capita GNP, also have unit roots.[6] Unit roots in dependent and explanatory variables can violate the asymptotic properties of least-squares estimators and test statistics (e.g., *t* statistics). The correlations in Figures 1 and 2 might therefore be spurious, and statistical inferences based on the OLS results might be misleading.

I addressed the first issue, macroeconomic identities, by estimating not only aggregate models like those depicted in Figures 1 and 2 but also disaggregated models in which I included the individual components of green NNP and genuine savings as separate regressors. Hence, I investigated whether the individual green accounting adjustments add any information. I addressed the second issue, unit roots, by estimating not only models that included the levels of variables, as in Figures 1 and 2, but also models in which the variables were expressed in first-differences. My data series were far too short to deal more thoroughly with unit roots by testing for cointegration and developing error-correction models. I also estimated cross-sectional models, which avoid unit root problems by removing the time dimension.

[5] Although Hall found that adding lagged values of other variables, such as income and wealth, to (1) had a negligible impact on the equation's explanatory power, he emphasized that this does not imply the nonexistence of a long-term, structural relationship involving consumption, income, and wealth. Green accounting highlights the role of natural capital in this relationship.

I begin the paper by reviewing essential green accounting theory, highlighting the derivation of the relationships stated above and the valuation of changes in wealth, especially natural wealth. Next, I develop econometric models for testing these hypotheses for both green NNP and genuine savings. I then describe the data that I used to construct the variables in these models. I point out the many limitations in the data. After that I present the regression results, starting with the panel models involving levels of variables, followed by the panel models involving first-differences, and finishing with the cross-sectional models. Finally, I conclude by summarizing the main findings and discussing their implications for the interpretation of green accounting measures.

I. Green Accounting Theory

A. *Wealth and Income in Utility and Consumption Terms*

Define a country's long-run welfare, W_t, as the discounted sum of the utility of consumption,

$$W_t \equiv \int_t^\infty U(C_s)e^{-\rho(s-t)}ds \,. \qquad (2)$$

C is a single, homogeneous consumption good. C_s in (2) refers the country's actual consumption path, which is not necessarily optimal. Being a discounted sum, welfare defined in this fashion is essentially a measure of the country's wealth, expressed in utils rather than money (Dasgupta and Karl-Göran Mäler 2000). Differentiating (2) with respect to time, we obtain the change in welfare,

$$\dot{W}_t = \rho W_t - U(C_t) \,.$$

[6] The best-known early study was by C.R. Nelson and C.I. Plosser (1982). Pierre Perron (1989) challenged its conclusions, arguing that the apparent nonstationarity in Nelson and Plosser's data was caused by structural breaks,

Reorganizing, we obtain

$$\rho W_t = U(C_t) + \dot{W}_t . \tag{3}$$

The right-hand side of (3) can be termed "utility NNP": it is the sum of the utility value of current consumption and the change in wealth, also in utility terms.[7]

It will be useful below to express the left-hand side in a different form. First, implicitly define the stationary equivalent of utility, $U(\overline{C}_t)$:

$$\int_t^\infty U(\overline{C}_t) e^{-\rho(s-t)} ds \equiv \int_t^\infty U(C_s) e^{-\rho(s-t)} ds . \tag{4}$$

$\overline{C}_t$ is the hypothetical amount which, if consumed indefinitely, would yield the same discounted sum of utility as the actual consumption path from period *t* forward. Solving for $U(\overline{C}_t)$, we obtain

$$U(\overline{C}_t) = \left[\int_t^\infty U(C_s) e^{-\rho(s-t)} ds\right] \Big/ \left[\int_t^\infty e^{-\rho(s-t)} ds\right],$$

which simplifies to

$$U(\overline{C}_t) = \rho W_t . \tag{5}$$

Substituting (5) into (3), we obtain

$$U(\overline{C}_t) = U(C_t) + \dot{W}_t . \tag{6}$$

Utility NNP equals the stationary equivalent of utility, a result first demonstrated by Weitzman (1970).[8]

If we could measure utility, then (6) would provide the basis for an econometric test: we would investigate whether the stationary equivalent of utility is indeed positively and

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not unit roots.

[7] In an optimal control jargon, the right-hand side of (2) is the Hamiltonian.

[8] Weitzman (1976) is the most frequently cited source of this result, but that paper considered a special case, *U(C) = C*.

significantly related to utility NNP. But we instead measure consumption, NNP, and other national accounting measures in monetary terms. To develop a testable hypothesis expressed in non-utility terms, begin with a first-order approximation to W_t:

$$W_t \cong \int_t^\infty U'(C_s) C_s e^{-\rho(s-t)} ds \,. \tag{7}$$

We can convert to a consumption numeraire by dividing through by the current marginal utility of consumption, $U'(C_t)$:

$$\widetilde{W}_t = \int_t^\infty \frac{U'(C_s)}{U'(C_t)} C_s e^{-\rho(s-t)} ds \,. \tag{8}$$

Denoting the ratio of marginal utilities by P_s—the real price of consumption, with t as the base year—we can rewrite this as

$$\widetilde{W}_t = \int_t^\infty P_s C_s e^{-\rho(s-t)} ds \,. \tag{9}$$

In national accounting terms, we can think of $P_s C_s$ as aggregate consumption expenditure.[9] For this reason I will denote it below by E_s, but to save on words I will refer to it simply as "consumption."

Through derivations similar to those in (3)-(6), we obtain as an analogue to (6)

$$\overline{E}_t = E_t + \dot{\widetilde{W}}_t, \tag{10}$$

where

$$\overline{E}_t \equiv \left(\rho - \frac{U''(C_t)}{U'(C_t)} \dot{C}_t \right) \widetilde{W}_t \,. \tag{11}$$

The term in parentheses is the consumption discount rate, which I will denote below by r_t.[10] Note the difference compared to (5), where W_t is multiplied by the *utility* discount rate. Note also that r_t is not necessarily constant over time.

Equation (10) provides the theoretical basis for my empirical analysis. Its implications can be expressed in the form of two equivalent hypotheses:

1. Green NNP, calculated as the sum of current consumption (E_t) and change in wealth ($\dot{\tilde{W}}_t$), should predict the stationary equivalent of consumption ($\overline{E}_t$).
2. The change in wealth, or genuine savings, should predict the difference between the stationary equivalent of consumption and current consumption (i.e., $\overline{E}_t - E_t$).

The second hypothesis follows from subtracting E_t from each side of (10).

B. *Changes in Wealth*

Although $\dot{\tilde{W}}_t$ in (10) should include all forms of capital that directly or indirectly finance consumption, as mentioned in the introduction I assumed simply that

$$\dot{\tilde{W}}_t = \dot{V}_t + \dot{K}_t , \qquad (12)$$

where $\dot{V}_t$ is the change in value of natural capital and $\dot{K}_t$ is the change in value of physical capital. For natural resources that yield marketable commodities, the value of natural capital is defined as

$$V_t \equiv \int_t^{\infty} R_s e^{-r(s-t)} ds , \qquad (13)$$

where R_s is aggregate resource rent in period s: the difference between the total revenues and total costs of resource extraction. This is natural capital in consumption, not utility, terms. For simplicity, I am assuming here that the consumption discount rate is constant over time.

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[9] See Weitzman (2000) for a model that includes multiple consumption goods.
[10] In effect, long-term consumption is the return on wealth, in accordance with life cycle-permanent income theory.

Differentiating (13), the change in value of natural capital is

$$\dot{V}_t = rV_t - R_t\ . \tag{14}$$

The change reflects the offsetting influences of two forces: (i) appreciation of the remaining resource stock as time passes and future rent flows are discounted less heavily (the first term on the right-hand side), and (ii) depletion due to extraction in the current period (the second term). Most applied green accounting studies, including those by Repetto et al. (1989) and World Bank (1997), have ignored stock appreciation and thus have been biased toward predicting that natural capital is declining.

I estimated natural capital values using the following discrete-time versions of (13) and (14):

$$V_t = \sum_{s=t}^{t+T} R_s (1+r)^{-(s-t)} \tag{13a}$$

$$\dot{V}_t = V_{t+1} - V_t \tag{14a}$$

As (13a) implies, V_t refers to asset values at the beginning of period t. I combined (14) and (14a) to calculate stock appreciation, rV_t, as $\dot{V}_t + R_t$. I will discuss the choice of the discount rate (r) and the time horizon (T) in section III.

Although changes in physical capital should also be estimated using a forward-looking expression like (13),[11] they are instead typically estimated using the perpetual inventory model,

$$\dot{K}_t = I_t - \delta_t K_t, \tag{15}$$

where I_t is investment and δ_t is the depreciation rate. I used a discrete-time version of this model in the empirical analysis,

[11] Which equals the market prices of capital goods if markets are dynamically efficient.

$$K_t - K_{t-1} = I_{t-1} + \delta_{t-1} K_{t-1} . \tag{15a}$$

As in the case of V_t, K_t refers to values at the beginning of period t.

II. Econometric Issues

A. *Specification of Models for Green NNP*

Substituting (15) into (12) and the resulting expression into (10), and denoting $E_t + I_t$ by GNP_t, we obtain the following expression for green NNP:

$$\widetilde{Y}_t \equiv GNP_t - \delta_t K_t + \dot{V}_t . \tag{16}$$

I investigated the predictive power of this measure by estimating both aggregated and disaggregated models. The aggregated model was

<u>Green NNP: aggregated model, levels of variables</u>

$$\overline{E}_{it} = \beta_0 + \beta_1 \widetilde{Y}_{it} + \varepsilon_{it} . \tag{17a}$$

As I used panel data, i denotes country. From (10), we hypothesize that $\beta_0 = 0$ and $\beta_1 = 1$. In the disaggregated model, I separated green NNP into its constituent terms:

<u>Green NNP: disaggregated model, levels of variables</u>

$$\overline{E}_{it} = \beta_0 + \beta_{11} GNP_{it} + \beta_{12}(\delta_{it} K_{it}) + \beta_{13}(\dot{V}_{it} + R_{it}) + \beta_{14} R_{it} + \varepsilon_{it} . \tag{17b}$$

The third variable on the right-hand side, $\dot{V}_{it} + R_{it}$, is the appreciation of the resource stock (see (14)). Now, the hypotheses are $\beta_0 = 0$ and $\beta_{11} = -\beta_{12} = \beta_{13} = -\beta_{14} = 1$.

For each country i, I defined $\overline{E}_{it}$ using the discrete, consumption-based analogue to (4),

$$\sum_{s=t+1}^{t+T} \overline{E}_{it} (1+r)^{-(s-t)} \equiv \sum_{s=t+1}^{t+T} E_{is} (1+r)^{-(s-t)} .$$

Solving for $\overline{E}_{it}$, we obtain

$$\overline{E}_{it} = \left[\sum_{s=t+1}^{t+T} E_{is} (1+r)^{-(s-t)} \right] \Big/ \left[\sum_{s=t+1}^{t+T} (1+r)^{-(s-t)} \right]. \tag{18}$$

As this expression indicates, I used the same, constant discount rate in the numerator and denominator. This is a useful simplification, but it is not theoretically correct. Equations (9) and (11) imply that the numerator should include the utility discount rate and the denominator the consumption discount rate. Moreover, as noted earlier, the consumption discount rate is not necessarily constant over time. Given that consumption levels differ among countries, it is not necessarily constant across countries, either.

Equation (18) also indicates that I calculated the stationary equivalent for period t using consumption data starting with period $t+1$. Hence, there is no simultaneity between the left- and right-hand sides of (17a-b). On the other hand, simultaneity might occur between $\overline{E}_{it}$ and the stock appreciation variable in (17b), whose calculation involves V_{it} and thus future resource rents. An aggregate demand shock could conceivably induce a country to modify its production of natural resources to finance the increase or decrease in desired consumption. I used international price series for copper, iron ore, and oil as instruments for the stock appreciation variable.[12] Regression results differed very little between models that used the original stock appreciation variables and models that used the instrumented versions.

Given that the data are for different countries, the variance of the error terms might be heteroscedastic; given that the countries are in the same region, the covariances might be nonzero. For these reasons, I estimated (17a-b) using both OLS and generalized least squares (GLS), and I applied standard tests of the sphericality of the covariance matrix. I also tested for the presence of first-order serial correlation, allowing for country-specific serial correlation coefficients, and I made corrections as needed. As discussed in section II.C below, I also explored the implications of nonstationarity of the data series.

A final point is that I controlled for population by dividing the dependent and independent variables by each country's total population in a given year. Hence, the models test the ability of green NNP to predict the future consumption of the *average citizen* in the countries. The genuine savings models discussed in the next section are also per capita models.

B. *Specification of Models for Genuine Savings*

Subtracting E_t from each side of (16) yields an expression for genuine savings,

$$\widetilde{I}_t \equiv I_t - \delta_t K_t + \dot{V}_t \,. \tag{19}$$

The models corresponding to (17a-b) are thus

<u>Genuine savings: aggregated model, levels of variables</u>

$$\overline{E}_{it} - E_{it} = \beta_0 + \beta_1 \widetilde{I}_{it} + \varepsilon_{it} \tag{20a}$$

<u>Genuine savings: disaggregated model, levels of variables</u>

$$\overline{E}_{it} - E_{it} = \beta_0 + \beta_{11} I_{it} + \beta_{12}(\delta_{it} K_{it}) + \beta_{13}(\dot{V}_{it} - R_{it}) + \beta_{14} R_{it} + \varepsilon_{it} \,. \tag{20b}$$

The same hypotheses apply to the coefficients in these models as in the green NNP models. As in the green NNP models, I used instrumental variables for the stock appreciation variable, and I allowed for non-i.i.d. error terms.

[12] The data were the IMF commodity price series for copper and iron ore on the London Metals Exchange and oil on the world spot market.

C. *Estimation in the Presence of Unit Roots*

The development of unit root tests for panel data has been an active area of econometric research in recent years.[13] The IPS test, named after Kyung So Im, M. Hashem Pesaran, and Yongcheol Shin (1997), has emerged as the most popular test. As in most unit root tests, the null hypothesis is that unit roots are present. This creates a substantial risk of Type II error—falsely concluding that a unit root is present—if the power of the test is low. Unfortunately, unit root tests have notoriously low power in small samples,[14] and the IPS test is no exception (see Tables 5-7 in Im, Pesaran, and Shin). For data that do not have a time trend or serially correlated errors, the probability of rejecting a false null hypothesis is only 9.0-11.3 percent if there are 10 time periods and 10 groups (e.g., countries). It rises to only 47.9-54.9 percent if the number of time periods and groups is each 25. Power tends to be even less if the data have trends or serially correlated errors. A simpler test advocated by G.S. Maddala and Shaowen Wu (1999), Fisher's p_λ test, has even less power than the IPS test in small samples (see Tables 1 and 2 in their paper).[15]

From these findings, I concluded that the power of panel unit root tests in my sample, which contains just 13 countries and 14 years, was so low as to render the tests meaningless. I therefore pursued the alternative approach of assuming that unit roots were present in one or

[13] See the special issue of the *Oxford Bulletin of Economics and Statistics* (vol. 61, no. 5, 1999), especially the introductory essay by Anindya Banerjee, and pp. 133-39 in the 1998 book by G.S. Maddala and In-Moo Kim.
[14] In Monte Carlo studies of unit root tests, "small samples" sometimes include as many as 100 time periods (e.g., Graham Elliott, Thomas J. Rothenberg, and James H. Stock 1996). This is many times longer than my sample period.
[15] The IPS and Fisher tests also depend on an assumption that error terms are not correlated across countries (Maddala and Kim 1998). As noted in section IV.A, my data violate this assumption.

more data series and eliminating the unit roots by first-differencing the data: $\Delta x_t = x_t - x_{t-1}$.[16]

Expressed in first differences, the models of green NNP (17a-b) and genuine savings (20a-b) are:

Green NNP: aggregated model, first-differences of variables

$$\Delta \overline{E}_{it} = \beta_1 \Delta \widetilde{Y}_{it} + \Delta \varepsilon_{it} . \tag{21a}$$

Green NNP: disaggregated model, first-differences of variables

$$\Delta \overline{E}_{it} = \beta_{11} \Delta GNP_{it} + \beta_{12} \Delta(\delta K_{it}) + \beta_{13} \Delta(\dot{V}_{it} + R_{it}) + \beta_{14} \Delta R_{it} + \Delta \varepsilon_{it} . \tag{21b}$$

Genuine savings: aggregated model, first-differences of variables

$$\Delta\left(\overline{E}_{it} - E_{it}\right) = \beta_1 \Delta \widetilde{I}_{it} + \Delta \varepsilon_{it} \tag{22a}$$

Genuine savings: disaggregated model, first-differences of variables

$$\Delta\left(\overline{E}_{it} - E_{it}\right) = \beta_{11} \Delta I_{it} + \beta_{12} \Delta(\delta K_{it}) + \beta_{13} \Delta(\dot{V}_{it} - R_{it}) + \beta_{14} \Delta R_{it} + \Delta \varepsilon_{it} . \tag{22b}$$

If the data series do indeed have unit roots, then estimation results for these models should differ from results for models with levels of variables, with the former being less biased.

There is reason to expect the green NNP models to be more susceptible to unit root problems. Suppose consumption has a unit root: $E_{it} = E_{i,t-1} + \mu_{it}$. Substituting this expression into (18), we can show that

$$\overline{E}_{it} = \overline{E}_{i,t-1} + \sum_{k=1}^{T} \phi_k \mu_{i,t+k} , \tag{23}$$

where

$$\phi_k = \frac{(1+r)^{-k}}{\sum_{k=1}^{T} (1+r)^{-k}} . \tag{24}$$

Hence, the stationary equivalent, which is the dependent variable in (17a-b), is not stationary in a statistical sense if consumption has a unit root.[17]

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[16] Some evidence of unit roots in Latin American macroeconomic data comes from studies by Eliezer Diniz (2000), who concluded that real GDP in Brazil has a unit root, and David Canning and Peter Pedroni (1999), who concluded from IPS tests that real GDP per worker had a unit root in a panel of 51 countries, which included some Latin American countries.

We can also express the right-hand side of (23) in terms of consumption, not the stationary equivalent thereof:

$$\overline{E}_{it} = E_{it} + \sum_{k=1}^{T} \phi_k \left(\sum_{s=t+1}^{t+k} \mu_s \right).$$

Subtracting current consumption from each side yields

$$\overline{E}_{it} - E_{it} = \sum_{k=1}^{T} \phi_k \left(\sum_{s=t+1}^{t+k} \mu_s \right). \qquad (25)$$

The right-hand side is white noise. Hence, the dependent variable in the genuine savings models does not have a unit root, even if consumption does.

As stated in the introduction, I also avoided unit roots by eliminating the time dimension and estimating individual cross-sectional models for each year in the sample period. This is a more drastic approach, as it greatly reduces the sample size and relies solely on the variation that occurs between countries at a given point in time.

III. Data

A. *Sample Period, Time Horizon, and the Discount Rate*

I used annual data for 1973-97 to construct the dependent and explanatory variables in the green NNP and genuine savings models. Incomplete natural resource data, especially data on resource extraction costs, dissuaded me from selecting an earlier starting point. The 1973-74 oil shock induced national and international organizations to expand the collection of natural

[17] Equation (23) indicates another, more mechanical reason I did not apply unit root tests. From (23) we can see that the error terms for the stationary equivalent are correlated over 10 years. To test for unit roots using a standard test like the augmented Dickey-Fuller test, I would have had to include a 10-year lag structure. But as I had only 14 years of data, this would not have left enough degrees of freedom for meaningful testing. I encountered the same lack of degrees of freedom in testing the natural resource stock appreciation variable.

resource data. Consequently, data are markedly more complete from that point forward.[18] On the other end of the time range, 1997 was the most recent year with complete data for both macroeconomic and natural resource variables.

In calculating natural capital values and the stationary equivalent, I set the time horizon, T, in (13a) and (18) equal to 10 years.[19] Although this is an arbitrary number, it is a relatively long period from the standpoint of macroeconomic planning. Development plans in developing countries typically span five years. This 10-year time horizon reduced the sample period for the econometric analysis to 1973-86.[20]

I used the same discount rate, r, for all countries and all years in calculating the natural capital values and the stationary equivalent. I selected 2 percent as the baseline value. This corresponds approximately to the median value of the fairly spotty data on the real deposit rate in the 13 countries during 1973-97.[21] I also performed sensitivity analysis using a 5-percent rate, which corresponds approximately to the median real lending rate.[22] This range includes the rate that the World Bank (1997) used in constructing its wealth estimates, 4 percent.[23]

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[18] The choice of starting date depends on one's confidence in estimates constructed by extrapolating backwards from data for later periods. The World Bank (1997), for example, constructed genuine savings estimates from 1970 forward. I chose to be more conservative.

[19] The estimates of V_t and $\overline{E}_t$ were within-sample estimates: I did not project R_s and E_s beyond 1997.

[20] The end date is 1986 instead of 1987 due to the discrete nature of the data: one year is "lost" because $\dot{V}_t$ is the change in value over the course of a year.

[21] The series FR.INR.DPST in the World Bank's *World Development Indicators 2000* CD-ROM, deflated by the consumer price index in each country (base year = 1987).

[22] The series in FR.INR.LEND in the *World Development Indicators 2000*.

[23] As is well known from the project appraisal literature, transactions costs, taxes, and other distortions drive a wedge between the consumption discount rate and the rate of return on investment, thus causing the prices of capital goods to deviate from prices expressed in consumption terms. The market interest rate on deposits typically exceeds the consumption discount rate, while the market lending rate typically is smaller than the rate of return on investment. Ideally, I would have calculated country-specific estimates of consumption discount rates from data on deposit rates and tax rates, and calculated consumption-based shadow prices for investment flows. While such adjustments are feasible when appraising an individual investment project, the available national data were either too aggregate (investment) or too spotty (deposit rates, tax rates) to support these adjustments at a country level.

B. *Stationary Equivalent of Consumption, Green NNP, and Genuine Savings*

To calculate the stationary equivalent, I set E_{is} in (18) equal to total consumption: the sum of private and government consumption. I obtained data on total consumption from the World Bank's *World Development Indicators 2000* CD-ROM (hereafter, WDI 2000). I selected the series NE.CON.TETC.CN, which is expressed in local currencies at current prices. I deflated by the consumer price index in each country (the series FP.CPI.TOTL), which I first rescaled to a base year of 1987. I then converted to U.S. dollars by using the 1987 official exchange rate (the series PA.NUS.FCRF). I converted to dollars to scale the variables in roughly comparable terms: when expressed in constant local currencies, the variables differed by several orders of magnitude between some countries. Finally, I divided by the country's total population (the series SP.POP.TOTL).

I calculated green NNP and genuine savings using (16) and (19). I obtained data on GNP from the WDI 2000, selecting the series NY.GNP.MKTP.CN. Like the consumption series, it is expressed in local currencies at current prices. I followed the steps described in the previous paragraph to convert it to a per capita value in 1987 U.S. dollars. I set ordinary savings, I_{is} , equal to the difference between GNP and consumption. This is a broad measure of savings that implicitly accounts for trade imbalances.

C. *Depreciation of Physical Capital*

Vikram Nehru and Ashok Dhareshwar (1993) used the perpetual inventory model to estimate values of physical capital stocks (K) and depreciation (δK) for a large sample of developing countries during 1950-90.[24] Their estimates were in local currencies at 1987 prices. They set investment equal to gross domestic fixed investment and assumed a depreciation rate of 4 percent for all countries and all years. Their sample included all the countries in my sample except Suriname. I used their estimates for 1973-80 for all other countries. I generated updated estimates for 1981-90, and new estimates for 1991-97, by running (15a) forward with more recent data on gross domestic fixed investment from the WDI 2000 (the series NE.GDI.FTOT.KN).

For Suriname, I assumed that the *I/K* ratio in 1960 equaled that in Guyana. I then used (15a) and data on gross domestic fixed investment to construct the capital stock and depreciation series.

I converted all the estimates to per capita values expressed in U.S. dollars using the procedures described in section III.A.

D. *Change in Natural Capital*

As (13a) and (14a) indicate, calculating the change in natural capital requires annual estimates of resource rents. I defined rent as $R_s = q_s(p_s - c_s)$, where q is resource output, p is price of the extracted resource, and c is average total cost. Resource output refers to production quantities actually used by humans. It excludes unused portions of production, such as roundwood that is damaged during logging or natural gas that is flared or reinjected. It includes some noncommercial uses, however, such as household consumption of fuelwood. I obtained data on roundwood output from the U.N. Food and Agriculture Organization's website (www.fao.org). I obtained data on fossil fuel output from the websites of the U.S. Energy

[24] The estimates of capital stocks by Nehru and Dhareshwar are for the end of a year, not the beginning as in (15a). I was careful to assign their estimates to the correct years in constructing my variables.

Information Administration (www.eia.doe.gov), the International Energy Information Agency (www.iea.org), and BP Amoco (www.bpamoco.com/worldenergy). I supplemented the online data with data from various yearbooks of the same organizations. I obtained data on production of metal ores from the U.S. Geological Service's website (www.usgs.gov), yearbooks of the same agency and the now-defunct U.S. Bureau of Mines, and the UNCTAD *Yearbook of International Commodity Statistics*.

I set natural resource price, *p*, equal to the unit value of a country's exports of that resource. If data were not available for a particular country, I set price equal to the unit value for exports by other Latin American countries. The sources listed in the previous paragraph provided most of the data on export values and quantities. Two additional useful sources were the UNCTAD *Commodity Yearbook 1989* (for the years 1983-87) and the UNCTAD *Handbook of World Mineral Trade Statistics* (for the years 1992-97).

I defined average total cost as variable cost plus a normal return to capital. I excluded depreciation of capital used in resource extraction, because the estimates of economy-wide depreciation (δK) implicitly include it along with depreciation of other physical capital. Like previous green accounting researchers, I faced considerable difficulty obtaining data on average total cost and its components. I began my search with the data sources listed in Appendix B of Arundhati Kunte et al. (1998). I augmented these sources with various other information, including point estimates for the 1990s from several published and unpublished studies on logging costs in individual countries or regions[25]; estimates of production and development costs

[25] Principal studies included Andew J. Ewing and J.G. Devitt (1986), L.A.J. Hunter (1987), Charles Peters et al. (1989), Adalbérto Veríssimo et al. (1992), Douglas Southgate et al. (1993), Jan van Tongeren et al. (1993), Lorene Flaming (1995), John V. Kellenberg (1995), Nigel Sizer and Richard Rice (1995), Fernando Montenegro S. (1996), Steven Stone (1997, 1998), Paulo Barreto et al. (1998), Thomas P. Holmes et al. (1999), Adrian Whiteman (1999a, 1999b), Marcel Claude and Rodrigo Pizarro (undated), and Rigoberto Stewart et al. (undated).

for oil during 1973-85 from Morris Adelman and Manoj Shahi (1989)[26]; a cross-country study by the Copper Commission of Chile (Aldo Picozzi B. 1996); and production cost estimates for individual mines in the 1990s kindly provided by the World Mine Cost Data Exchange.[27]

Even with this additional information, cost estimates were not available for many years for many countries and resources. For all resources except oil, I filled in the missing data by assuming that the ratio of average total cost to price in the missing year equaled the median value of the available estimates for that country and resource. The available data indicated that these ratios were fairly constant over time. If a country lacked cost data entirely, I set the ratio equal to the median value for countries with data. Data were more complete for oil. I assumed that the average production cost in years without data equaled the mean of the values in the preceding and succeeding years, in real terms.

Sources typically reported price and cost data in current U.S. dollars. I used the official exchange rates for each year to convert to local currencies, deflated using the countries' consumer price indices, and then reconverted to dollars using 1987 exchange rates. I summed rents across resources before calculating the value of natural capital. That is, I used an aggregate R_s in (13a) and thus calculated a single natural capital estimate for each country in each year.

E. *Data Limitations*

It is evident from sections III.A-D that my estimates of the dependent and explanatory variables are crude, especially the estimates for resource-related variables. To illustrate just how crude they are, consider copper, which is one of the resources with the *best* data. Eight countries, led by Chile, produced this mineral during 1973-97. Complete data series on annual

[26] Adelman and Shahi provide estimates back to 1960, but they note that these estimates are likely to be less accurate than the ones for the 1970s and 1980s.

output were available for all eight. Complete data series on total export value and quantity, and thus complete data on export unit values, were available for just Chile and Peru. Data were reasonably complete for Bolivia and Mexico, but no data were available for Argentina, and data were spotty for the remaining three countries. I filled in the missing price data using a weighted-average of the estimates that were available across the countries in a given year. Complete data on average total cost were not available for any country, although Chile (1975-97) and Peru (1980-97) came close. Cost estimates were available in five or fewer years for Argentina and Mexico, and none were available for the other countries. For Chile, Peru, Argentina, and Mexico, I calculated country-specific median ratios of average total cost to price and multiplied the ratios times price to calculate average total cost in the missing years. I followed a similar procedure for the other countries but used the median ratio across the four countries with data.

The data suffer from many other inaccuracies. Export unit values typically overstate domestic prices in the case of heterogeneous commodities like oil, coal, and industrial roundwood, but I used export unit values to value a country's entire output. The estimates of consumption expenditure exclude consumption of services from durable goods and include an unknown amount of government expenditures that are more properly considered investment. Relative consumption levels across countries are distorted by the conversion into U.S. dollars using official exchange rates.[28] Consumption discount rates surely vary across countries and over time, but I used the same, constant rates, which were loosely based on quite spotty data on deposit and lending rates, which themselves are distorted in ways I did not correct. I calculated the stationary equivalent using the consumption discount rate in both the numerator and the denominator of (18) instead of using the utility discount rate in the former. I mentioned

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[27] I am grateful to Michael Farrell for providing mining cost models at a deeply discounted price.

Pritchett's (2000) criticism of the perpetual inventory model of capital formation in the introduction. The estimates by Nehru and Dhareshwar (1993) are especially subject to criticism because they lump all types of physical capital together and apply the same depreciation rate in every country and every year.[29] Finally, the theory in section I.A refers to an infinite time horizon, but I truncated my estimates of the stationary equivalent and natural capital at 10 years.

For these and other reasons, one should indeed regard my green accounting adjustments as crude. They are also incomplete. I noted in the introduction and in section I.B that I ignored human and social capital, and the discussion in section III.D indicates that I ignored all forms of natural capital associated with nonmarket environmental services like clean (or polluted!) air and water. Given all these shortcomings in the variables, one might be skeptical about the possibility of detecting systematic relationships between long-run consumption and green accounting measures.

F. *Characteristics of the Data*

Although the data are crude and incomplete, Figures 1 and 2 indicate that they do have one desirable property for regression analysis: they exhibit a lot of variation. Table 1 presents summary statistics for the data pooled across countries and years. The statistics for the dependent variables and the aggregated explanatory variables simply quantify what can be observed in the figures. The new information in the table concerns the components of the green accounting measures. All show a great deal of variation, especially the resource-related

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[28] I considered using purchasing-power parity (PPP) estimates of the variables, but the WDI 2000 does not include PPP data before 1975 for any country in the sample, before 1988 for a few countries, and for Suriname at all.

[29] The United Nations Economic Commission for Latin America and the Caribbean recently began reporting investment data separately for equipment and structures on its website (www.eclac.cl/estadisticas), but it does not provide corresponding data on depreciation. Donald F. Larson et al. (2000) recently reported sector-specific estimates of capital stocks, investment, and depreciation for 62 countries during 1967-92, but they included only 7 of the countries in my sample.

components, whose standard deviations exceed their means. Depreciation of physical capital is, on average, the largest adjustment to conventional national accounting measures. Its mean is more than 10 percent of mean GNP and nearly 60 percent of mean savings. The resource-related adjustments are about half as large. Given that the mean of current rent is greater than the mean of stock appreciation, the value of natural capital stocks fell, on average, in the region during the sample period.

Table 2 shows the distribution of the variation in these variables between countries and within countries. Nearly all of the variation in the stationary equivalent is between countries, which is not surprising given that it is a moving average of consumption. The difference between the stationary equivalent and current consumption shows the opposite pattern: most of the variation is within countries. The aggregate explanatory variables show parallel patterns, with green NNP having much more variation between countries (even more than does the stationary equivalent) and genuine savings having more variation within countries (although not as much as its corresponding dependent variable). All of the components of these measures show more variation between countries, especially depreciation of physical capital.

Table 3 shows pair-wise correlations among the explanatory variables. Correlations among several variables—in particular, depreciation of physical capital with GNP and savings, and current resource rent with appreciation of the resource stock—are large and highly significant. This suggests that coefficient estimates might be unstable for these variables. This turns out to be the case more for depreciation of physical capital than for the others.

Table 4 brings out the policy relevance of the variation in the data. This table shows the number of years during the first and second halves of the sample period when my estimates of each country's genuine savings were negative (equivalently, when its current consumption exceeded its green NNP). From equation (10), we expect this to be a signal of unsustainability: future consumption will, on average, be less than current consumption. Two countries appear to have been following predominantly unsustainable paths during both halves (Brazil, Guyana), while four countries appear to have been following predominantly sustainable development paths (Argentina, Mexico, Paraguay, Venezuela).[30] Evidence is mixed for the seven other countries. Consumption apparently became less sustainable in nearly all countries during the second half.

These differences suggest a need to understand why particular countries have evidently tended to overconsume in particular years and, based on this understanding, to develop policy responses that would discourage overconsumption. First, however, ought to know whether we should have any confidence in the apparent signals of unsustainability: did consumption indeed tend to decline in countries with negative genuine savings? The numbers in Table 4 suggest that the Latin American data set includes the variation across countries and over time that is desirable for answering this question.

IV. Analysis of Panel Data: Models with Levels of Variables

In this section I present results from estimating (17a-b) and (20a-b) using the full panel data set.

A. *Green NNP*

Table 5 shows results for the aggregated model using a series of estimators that progressively relax assumptions about the covariance matrix of the error terms. Estimates of the

[30] Using a dynamic computable general-equilibrium model, Francisco Rodríguez and Jeffrey D. Sachs (1999) forecast declining GDP per worker in Venezuela during 1994-2005. This result does not necessarily conflict with my estimates of positive genuine savings rates for this country, because there is little overlap between my sample period and their forecast period. Moreover, their forecast is for GDP, not consumption. They do not present

coefficient on green NNP are quite similar across Models I-IV, ranging approximately from 0.6 to 0.7. All of the estimates are highly significantly different from both 0 and 1. All of the estimated intercepts are also highly significantly different from 0 and, with the exception of the intercept in Model IV, are quite similar in magnitude. The aggregated model therefore offers evidence that the stationary equivalent is systematically related to green NNP, but not in a one-to-one manner. It also has considerable explanatory power, accounting for about 90 percent of the variation in the stationary equivalent.

As the notes in Table 5 explain, statistical tests reject the null hypotheses of homoscedasticity, zero covariances, and no serial correlation. These results indicate that the GLS estimator used in Model IV provides the most efficient coefficient estimates and the least biased standard error estimates. I used this same estimator for the disaggregated models in Table 6. Model V is the same as Model IV except that it includes the four components of green NNP as separate regressors. The coefficients on three of the components—GNP and the two resource-related variables—have the correct signs and are highly significantly different from both 0 and 1. They are also comparable in magnitude, with absolute values ranging approximately from 0.3 to 0.4. This range is much smaller than the magnitude of the coefficient on green NNP in Model IV. The coefficient on depreciation of physical capital is also highly significantly different from 0, but it has the wrong sign. The results for Model V are thus largely, but not completely, in line with theory.

In Model VI, I investigated the incompleteness of the accounting system by adding a time trend expressed as calendar year. The coefficient on this new variable is highly significantly different from 0, suggesting that the adjustments for depreciation of physical capital and changes

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forecasts of consumption, but it probably does not decline during the projection period, because the investment share in natural capital do not fully capture changes in the countries' total wealth. The addition of this variable reverses the sign on the depreciation of physical capital, so that all four variables now have the correct signs. They are also all highly significantly different from 0 and 1. The addition of the trend also increases the coefficients on GNP and the resource-related variables, which remain comparable in magnitude but are now closer to 1, ranging between approximately 0.75 and 0.85.

As a final variation, in Model VII I allowed the intercept to vary across countries by estimating a fixed-effects model.[31] The addition of the country-specific intercepts has an enormous impact on the results: it reverses the sign of the coefficient on current resource rent, shrinks the coefficients on GNP and appreciation of natural resource stocks to values barely above 0, and inflates the coefficient on depreciation of physical capital by a factor of six. This impact is not surprising. Recall from Table 2 that more than 90 percent of the variation in the stationary equivalent occurs between countries. The country-specific intercepts eliminate much of the variation that statistical methods need to detect a relationship between levels of dependent and independent variables.

B. *Genuine Savings*

Table 7 presents results for the aggregated genuine savings models. The results are broadly similar to the ones for the green NNP models in Table 5: the coefficients on genuine savings are positive, less than 1, and highly significantly different from both 0 and 1. With one

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of GDP appears to declines in parallel with GDP.

[31] I also estimated a standard random-effects version of Model VI, not allowing for heteroscedasticity, nonzero covariances, or serial correlation. As in Model VI in Table 6, the coefficients all had the correct signs and were significantly different from 0 at the 1-percent level; even better, with the exception of the coefficient on GNP, they were not significantly different from 1 at the 5-percent level. The Hausman test statistic ($\chi^2(5) = 144$) had a *p*-value of <0.0001, however, suggesting that the model was misspecified. The nonspherical covariance matrix is the likely cause.

exception (Model II), the intercepts are also highly significantly different from 0. The coefficients on genuine savings are, however, less stable than the coefficients on green NNP, ranging approximately from 0.2 to 0.8, and the regressions explain much less of the variation in the dependent variable, around 5-10 percent. Considering that the difference between the stationary equivalent and consumption is much more variable than the stationary equivalent (compare the means and standard deviations in Table 1), this reduced explanatory power is not surprising.

Results for the disaggregated models in Table 8 are even better. The coefficients on all four components of genuine savings have the correct signs and are highly significantly different from 0 in all three models. Although they are also highly significantly different from 1, most are closer to 1 than are the coefficients on genuine savings in Table 7. The exception is the coefficient on depreciation of physical capital, whose absolute value is much larger than 1, as in Model VII in Table 5 for the green NNP model. The results are more robust than those for green NNP in that the addition of the trend variable and the country-specific intercepts affects the coefficient estimates less.[32]

V. Analysis of Panel Data: Models with First-Differences of Variables

Table 9 presents estimation results for both the green NNP and genuine savings models expressed in first-differences, i.e. (21a-b) and (22a-b). I corrected for heteroscedasticity and nonzero covariances in both cases but serial correlation only in the green NNP models, as the *t*

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[32] Estimation of Model VI using a standard random-effects model yielded results similar to those for Model VI in Table 8. As in the case of green NNP (see the previous note), however, the Hausman test statistic ($\chi^2(5) = 35.5$) had a *p*-value of <0.0001.

statistics on the lagged error terms were not significantly different from zero in the genuine savings models.[33]

The coefficient estimates for both the aggregated and disaggregated models of green NNP are quite different from the results for the closest corresponding models with levels of variables, which are Model IV in Table 5 and Model VI in Table 6.[34] The coefficients on green NNP in the aggregated model and on GNP and current resource rent in the disaggregated model have the wrong signs, and the coefficient on the appreciation of the natural resource stock in the disaggregated model is very small, although it does have the right sign. Ironically, results are best for the coefficient on depreciation of physical capital, which is negative and near one.

In contrast, results for the genuine savings models are very similar to those from the earlier analyses. All the coefficients have the correct signs and are highly significantly different from 0. The 95-percent confidence intervals for the coefficients on genuine savings in the third column of Table 9 and Model IV in Table 7 overlap,[35] as do the coefficients on savings and current resource rent in the fourth column of Table 9 and Model VI in Table 8. The coefficient on appreciation of the natural resource stock changes, but for the better: it is now much closer to 1, and it is not significantly different from the coefficient on current resource rent. Even the intercept is statistically indistinguishable from the coefficient on the time trend in Model VI in Table 8. Only the coefficient on depreciation of physical capital continues to be problematic in that it grossly exceeds the other coefficients.

[33] The coefficients on the explanatory variables in the genuine savings models were not affected much by the inclusion or exclusion of lagged error terms.

[34] Model IV in Table 5 is not strictly comparable to the model in the first column of Table 10, because it does not include a time trend. The intercept in the latter is implicitly the coefficient on a trend variable.

[35] Model IV in Table 7 and the model in the third column of Table 10 are not strictly comparable. See the previous note.

In section II.C, I argued that if consumption has a unit root, then the estimation results for the models with levels and the models with first-differences should be more similar in the case of genuine savings than in the case of green NNP. My results might appear to be consistent with this expectation, but in fact they are not. If the presence of unit roots in the models with levels causes bigger problems in the case of green NNP, then we would expect the first-differencing of the data to cause the results of the green NNP and genuine savings models to become more similar. In fact, the opposite occurs. One explanation might be that first-differencing does not entirely eliminate unit roots in the stationary equivalent. The continuing presence of serial correlation in the green NNP models could be evidence of this. Another explanation might be the elimination of between-country variation in the stationary equivalent. Only about a third of the variation in the first-difference of this variable occurs between countries, compared to the more than 90 percent in the original data series. This could explain the small magnitudes of the coefficients on GNP and the resource-related variables in both the second column of Table 9 and the fixed-effects model in Table 6.

VI. Analysis of Cross-Sectional Data

The cross-sectional analyses provide additional evidence that changes in wealth affect future consumption in the expected ways, especially changes in natural capital. Tables 10a-b provide summary results for the disaggregated green NNP and genuine savings models, respectively. The coefficients on stock appreciation and current resource rent had the correct signs in 12 years and 11 years, respectively, out of the 14 years for the green NNP model, and 10 years each for the genuine savings model. Results were mixed for the other variables, with depreciation of physical capital having the correct sign more often in the genuine savings model

(10 years vs. 3 years) and GNP having the correct sign more often than savings (14 years vs. 6 years). The weaker results for the savings variable are not surprising, given that most of the variation in this variable occurs within, not between, countries (Table 2). Because they lack a time dimension, the cross-sectional analyses include no "within" variation. In contrast, most of the variation in GNP, depreciation of physical capital, and the two resource-related variables occurs between countries, as noted in section III.F.

Although the signs of the coefficients are therefore correct in most cases for most variables, most of the coefficients are not significantly different from 0, even at a 10-percent level. The sole exception is GNP in the green NNP model. Given that each cross-section includes only 13 countries and each model includes 5 regressors (including the intercept), the power of the estimators is very low. In the case of the genuine savings model, this problem is exacerbated by the limited variation in the dependent variable. As Table 2 shows, less than 20 percent of the variation in the difference between the stationary equivalent and current consumption occurs between countries.

VII. Effects of Changing the Discount Rate

Increasing the discount rate from 2 percent to 5 percent did not substantially affect the results. None of the coefficient estimates changed sign, none of their significance levels changed, and hardly any changed in magnitude more than a few decimal places. The coefficients on the stock appreciation variable in some models were an exception to the last point. For example, in the green NNP models, the coefficient estimates for this variable in the 5-percent versions of Models V, VI, and VII were 0.703, 0.855, and 0.248, which are all larger than the corresponding estimates from the 2-percent versions in Table 6. If any coefficient were to change, we would expect it to be the one on this variable, which is the sole component of green NNP and genuine savings constructed using the discount rate. The discount rate also enters the construction of the stationary equivalent, but the structure of (18) suggests that the latter is unlikely to be very sensitive to the former: the discount rate occurs in both the numerator and the denominator. Indeed, the correlation coefficient between the 2-percent and 5-percent versions of the stationary equivalent is 0.9998.

VIII. Conclusions

Despite incomplete adjustments made using crude data, my estimates of genuine savings are systematically related to consumption outcomes in subsequent years in the Latin American countries. All the coefficients on the individual components of genuine savings have the correct signs and are highly statistically significant in both the models with levels of variables and the models with first-differences of variables. The coefficients on ordinary savings and the two resource-related variables are similar between the models with levels and first-differences, and most are relatively near to 1. Although few of the coefficient estimates are significantly different from 0 in the cross-sectional regressions, a result that is probably due to the few degrees of freedom, most of the estimates for the resource-related variables have the correct signs. The positive relationship between genuine savings and the difference between the stationary equivalent and current consumption is therefore not simply an artifact of macroeconomic identities or spurious correlations between nonstationary data series.

In contrast, the evidence is much more mixed for green NNP. Although the cross-sectional results are better than for genuine savings, fewer of the coefficients in the panel regressions have the correct signs, especially in the model with first-differences. The coefficients on GNP and the resource-related variables are nearly 0 in that model. Until and unless more convincing evidence emerges for green NNP, genuine savings should be the preferred green accounting measure.

These findings indicate that resource-related green accounting adjustments add value to the national accounts even if natural resource data are far from perfect. National accountants in individual countries have access to more and better data than I did and so should be able to construct more accurate estimates of resource rents. They already collect data on the variable costs of resource-based industries to estimate ordinary value-added in those sectors. I did not have access to any of these data. On the other hand, national accountants constructing current estimates of genuine savings do not know, as I did in this retrospective study, what resource production levels, prices, and costs will be during the next 10 years. I was able to use *ex post* data to estimate changes in natural capital, but national accountants will need to project resource rents in order to estimate these changes. The statistically significant coefficients on both the stock appreciation variables and the current resource rent variables indicate that both components of the change in natural capital affect future consumption possibilities. Genuine savings estimates that include only the depletion-related component are wrong from a theoretical standpoint, and this mistake is empirically significant.

An irony is that my results suggest that physical capital, not natural capital, might be the greater source of data problems for green accounting. The coefficient on depreciation of physical capital in the genuine savings regressions has the correct sign and is highly significant in all the panel models and has the correct sign in most of the cross-sectional models, but its absolute value is many times larger than 1. Although collinearity with savings and other explanatory variables might be partly to blame (Table 3), mismeasurement of physical capital is probably a more fundamental cause. Pritchett (2000) estimates that the actual rate of physical capital accumulation in Latin America during 1960-90 was only three-fourths as large as the rate predicted by the perpetual inventory model if one assumes zero growth in total factor productivity (TFP). It is only a quarter as large if one assumes 1-percent TFP growth. Better estimates of physical capital might have yielded more reasonable estimates of the coefficient on the depreciation variable in the genuine savings regressions. More important, they would make genuine savings estimates more reliable.

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Figure 1. Scatter plot: Stationary equivalent of consumption vs. Green NNP (panel data: 13 countries, 1973-86; per capita values at 1987 prices)

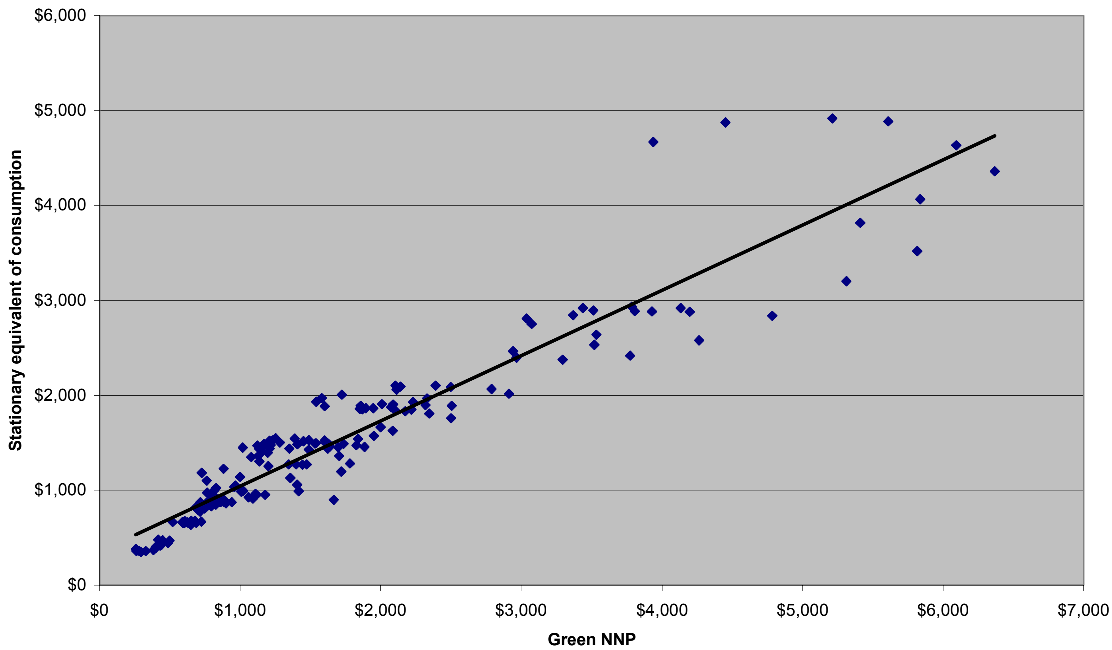

Figure 2. Scatter plot: Stationary equivalent *minus* current consumption vs. Genuine savings (panel data: 13 countries, 1973-86; per capita values at 1987 prices)

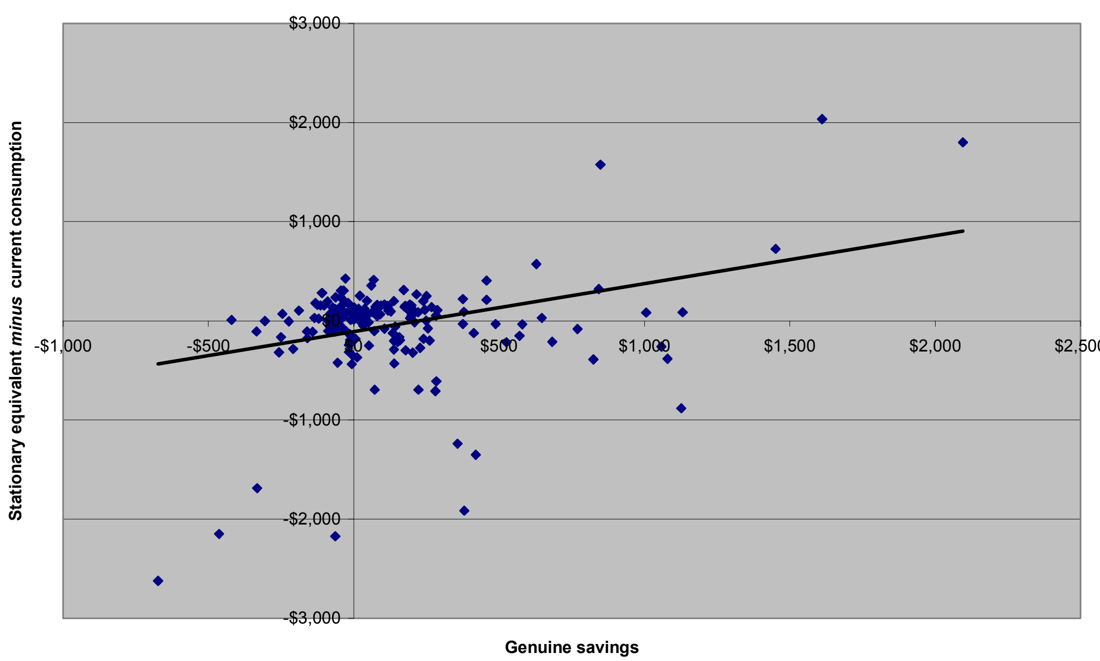

Table 1. Basic characteristics of the data. Note: in this tables and Tables 2-3, data are pooled across 13 countries for the period 1973-86 and are expressed in U.S. dollars at 1987 prices and exchange rates and in per capita terms.

Variable	Mean	Standard deviation	Minimum	Maximum
Dependent variables:				
• Stationary equivalent	1520	936	349	4917
• Stationary equivalent *minus* Current consumption	-41	495	-2622	2035
Explanatory variables (aggregated):				
• Green NNP	1696	1292	259	6367
• Genuine savings	135	348	-673	2096
Explanatory variables (disaggregated):				
• GNP	1977	1463	367	7218
• Savings	415	456	-54	2845
• Physical capital: Depreciation	244	171	45	724
• Natural resource: Stock appreciation	102	120	2	722
• Natural resource: Current rent	138	188	6	1113

Table 2. Analysis of variance.

Variable	Sum of squares		
	Between countries	Within countries	Total
Dependent variables:			
• Stationary equivalent	144,447,228	14,106,059	158,553,287
• Stationary equivalent *minus* Current consumption	7,955,299	36,480,077	44,435,376
Explanatory variables (aggregated):			
• Green NNP	284,013,982	18,126,291	302,140,273
• Genuine savings	9,048,451	12,864,459	21,912,911
Explanatory variables (disaggregated):			
• GNP	365,867,839	21,393,544	387,261,383
• Savings	26,242,705	11,440,354	37,683,059
• Physical capital: depreciation	4,906,675	371,638	5,278,313
• Natural resource: stock appreciation	2,037,448	578,116	2,615,564
• Natural resource: current rent	5,306,851	1,116,495	6,423,346

Table 3. Correlations among explanatory variables.

a. Disaggregated green NNP model.

	GNP	Physical capital: depreciation	Natural resource: stock appreciation	Natural resource: current rent
GNP	1			
Physical capital: depreciation	0.793***	1		
Natural resource: stock appreciation	0.185**	0.162**	1	
Natural resource: current rent	0.363***	0.304***	0.696***	1

*, **, *** Significantly different from 0 for $p \leq 0.10, 0.05, 0.01$.

b. Disaggregated genuine savings NNP model.

	Savings	Physical capital: depreciation	Natural resource: stock appreciation	Natural resource: current rent
Savings	1			
Physical capital: depreciation	0.590***	1		
Natural resource: stock appreciation	0.300***	0.162**	1	
Natural resource: current rent	0.515***	0.304***	0.696***	1

*, **, *** Significantly different from 0 for $p \leq 0.10, 0.05, 0.01$.

Table 4. Number of years that each country's per capita genuine savings was negative.

Country	Time period	
	1973-79	**1980-86**
Argentina	0	0
Bolivia	2	7
Brazil	6	7
Chile	2	5
Colombia	3	5
Ecuador	0	5
Guyana	5	7
Mexico	0	2
Paraguay	0	0
Peru	3	3
Suriname	0	4
Uruguay	0	5
Venezuela	0	1

Table 5. Green NNP: panel data, aggregated models, levels of variables.

	I	II	III	IV
Estimator	OLS	GLS	GLS	GLS
Variance matrix				
• Heteroscedastic?	No	Yes[a]	Yes	Yes
• Nonzero covariances?	No	No	Yes[b]	Yes
• Serial correlation?	No	No	No	Yes[c]
Explanatory variables:				
• Green NNP	0.688 (0.0168)***,†††	0.708 (0.0140)***,†††	0.688 (0.00126)***,†††	0.609 (0.00891)***,†††
• Intercept	353 (35.8)***	310 (17.0)***	353 (2.31)***	558 (27.7)***
R^2	0.903	0.902	0.903	0.886

*, **, *** Significantly different from 0 for $p \leq 0.10, 0.05, 0.01$.

†, ††, ††† For coefficient on green NNP: significantly different from 1 for $p \leq 0.10, 0.05, 0.01$.

[a] Cook-Weisberg test of hypothesis that variance is identical across countries in Model I: $\chi^2(12) = 367$ ($p < 0.0001$).

[b] Breusch-Pagan test of hypothesis that covariances equal zero across countries in Model II: $\chi^2(78) = 278$ ($p < 0.0001$).

[c] *t* tests of hypothesis that coefficients on lagged error term equal zero: reject hypothesis for $p < 0.01$ in 12 countries and $p < 0.05$ in the remaining country.

Table 6. Green NNP: panel data, disaggregated models, levels of variables. Note: in all cases, variance differs across countries (heteroscedasticity), covariances between countries are nonzero, and errors are serially correlated.

	V	VI	VII
Estimator	GLS	GLS	GLS
Explanatory variables:			
• GNP	0.429 (0.00883)***, †††	0.751 (0.00357)***, †††	0.140 (0.00646)***, †††
• Physical capital: depreciation	1.09 (0.0472)***, †	-0.425 (0.0292)***, †††	-2.43 (0.0837)***, †††
• Natural resource: stock appreciation	0.309 (0.0186)***, †††	0.775 (0.00578)***, †††	0.0793 (0.0223)***, †††
• Natural resource: current rent	-0.367 (0.0166)***, †††	-0.871 (0.00671)***, †††	0.0461 (0.00996)***, †††
• Year		-15.5 (0.868)***	4.99 (0.389)***
• Intercept	592 (12.2)***	30,800 (1710)***	(Country-specific)[a]
R^2	0.823	0.889	0.617

*, **, *** Significantly different from 0 for $p \leq 0.10, 0.05, 0.01$.

†, ††, ††† For coefficients on variables other than constant and year that are significantly different from 0: significantly different from 1 for $p \leq 0.10, 0.05, 0.01$.

[a] Test of hypothesis that dummy variables for individual countries (except Argentina) are identical: $\chi^2(11) = 7280$ ($p < 0.0001$).

Table 7. Genuine savings: panel data, aggregated models, levels of variables.

	I	II	III	IV
Estimator	OLS	GLS	GLS	GLS
Variance matrix				
• Heteroscedastic?	No	Yes[a]	Yes	Yes
• Nonzero covariances?	No	No	Yes[b]	Yes
• Serial correlation?	No	No	No	Yes[c]
Explanatory variables:				
• Genuine savings	0.492 (0.0990)***,†††	0.204 (0.0820)**,†††	0.494 (0.0113)***,†††	0.830 (0.0345)***,†††
• Intercept	-108 (37.0)***	5.49 (15.2)	-107 (1.81)***	-193 (22.8)***
R^2	0.120	0.0566	0.121	0.0571

*, **, *** Significantly different from 0 for $p \leq 0.10, 0.05, 0.01$.

†, ††, ††† For coefficient on green NNP: significantly different from 1 for $p \leq 0.10, 0.05, 0.01$.

[a] Cook-Weisberg test of hypothesis that variance is identical across countries in Model I: $\chi^2(12) = 576$ ($p < 0.0001$).

[b] Breusch-Pagan test of hypothesis that covariances equal zero across countries in Model II: $\chi^2(78) = 490$ ($p < 0.0001$).

[c] *t* tests of hypothesis that coefficients on lagged error term equal zero: reject hypothesis for $p < 0.01$ in all 13 countries.

Table 8. Genuine savings: panel data, disaggregated models, levels of variables. Note: in all cases, variance differs across countries (heteroscedasticity), covariances between countries are nonzero, and errors are serially correlated.

	V	VI	VII
Estimator	GLS	GLS	GLS
Explanatory variables:			
• Savings	1.12 (0.0118)$^{***, \dagger\dagger\dagger}$	0.899 (0.0196)$^{***, \dagger\dagger\dagger}$	0.849 (0.0204)$^{***, \dagger\dagger\dagger}$
• Physical capital: depreciation	-2.62 (0.0680)$^{***, \dagger\dagger\dagger}$	-3.20 (0.0757)$^{***, \dagger\dagger\dagger}$	-7.17 (0.416)$^{***, \dagger\dagger\dagger}$
• Natural resource: stock appreciation	1.77 (0.0169)$^{***, \dagger\dagger\dagger}$	1.65 (0.0349)$^{***, \dagger\dagger\dagger}$	1.09 (0.0285)$^{***, \dagger\dagger\dagger}$
• Natural resource: current rent	-1.17 (0.0168)$^{***, \dagger\dagger\dagger}$	-1.06 (0.0260)$^{***, \dagger\dagger}$	-0.909 (0.0245)$^{***, \dagger\dagger\dagger}$
• Year		18.6 (0.420)***	36.0 (2.70)***
• Intercept	299 (2.16)***	-36,500 (832)***	(Country-specific)[a]
R^2	0.0842	0.257	0.723

$^{*, **, ***}$ Significantly different from 0 for $p \leq 0.10, 0.05, 0.01$.

$^{\dagger, \dagger\dagger, \dagger\dagger\dagger}$ For coefficients on variables other than constant and year that are significantly different from 0: significantly different from 1 for $p \leq 0.10, 0.05, 0.01$.

[a] Test of hypothesis that dummy variables for individual countries (except Argentina) are identical: $\chi^2(11) = 361$ ($p < 0.0001$).

Table 9. Green NNP and genuine savings: panel data, aggregated and disaggregated models, first-differences of variables. Note: in all models, variance differs across countries (heteroscedasticity) and covariances between countries are nonzero. Errors are serially correlated in the green NNP models.

	Model			
	Green NNP[a]		Genuine savings[b]	
	Aggregated	Disaggregated	Aggregated	Disaggregated
Estimator	GLS	GLS	GLS	GLS
Explanatory variables:				
• ΔGreen NNP	-0.0493 (0.000481)***,†††			
• ΔGNP		-0.0393 (0.00229)***,†††		
• ΔGenuine savings			0.693 (0.0452)***,†††	
• ΔSavings				0.806 (0.0342)***,†††
• ΔPhysical capital: depreciation		-0.719 (0.105)***,††		-4.92 (0.528)***,†††
• ΔNatural resource: stock appreciation		0.0552 (0.00648)***,†††		0.800 (0.0561)***,†††
• ΔNatural resource: current rent		0.0569 (0.00434)***,†††		-0.936 (0.0499)***
• Intercept	18.1 (0.457)***	-7.18 (1.72)***	-6.97 (4.67)	16.0 (1.70)***

[a] Dependent variable = Δ(Stationary equivalent).

[b] Dependent variable = Δ(Stationary equivalent *minus* Consumption).

Table 10. Green NNP and genuine savings: cross-sectional data, disaggregated models, levels of variables.

a. Green NNP

Explanatory variable	Correctly signed estimates				
	Number	Significantly different from 0			Significantly different from 1*
		$p = 0.01$	$p = 0.05$	$p = 0.10$	$p = 0.05$
GNP	14	13	1	0	12
Physical capital: depreciation	3	0	0	0	0
Natural resource: stock appreciation	12	1	2	2	1
Natural resource: current rent	11	2	3	1	1

* If also significantly different from 0.

b. Genuine savings

Explanatory variable	Correctly signed estimates				
	Number	Significantly different from 0			Significantly different from 1*
		$p = 0.01$	$p = 0.05$	$p = 0.10$	$p = 0.05$
Savings	6	0	0	2	0
Physical capital: depreciation	10	0	0	1	0
Natural resource: stock appreciation	10	0	1	2	0
Natural resource: current rent	10	0	1	0	0

* If also significantly different from 0.