Testing comprehensive accounting theoretical predictions

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Abstract

The aim of this paper is to present a set of testable expressions of comprehensive accounting theory regarding local over-time welfare comparisons that have been scattered in the literature, and test them using the time series of genuine savings and green net national income for Portugal estimated in Mota et al. (2010). For the first time, the value of technological progress is included in the tests of comprehensive accounting predictions, as well as the effects of business cycles. Overall, our results indicate that we reject the hypothesis that the estimated comprehensive accounting measures coincide with the theoretical predictions. However, the results also suggest that the more comprehensive the measure of savings or income used the better it fits the theory. Generally, genuine savings present the best results. Excluding business cycles increases the accuracy of the regressions, whereas the terms that present most measurement errors are the education expenditure and, particularly to our case, mineral depletion. Both genuine savings and green net national income move in the same direction of changes in welfare.

Keywords: Comprehensive accounting tests; Mismatch; Portugal; Time series; Technological progress

JEL Classification: Q20, C51, C55

1. Introduction

The need to assess the sustainable development of countries with indicators firmly grounded in economic theory is widely recognized. The interest is in the relationships between national income, welfare and sustainability. The theory of comprehensive accounting (also known as green accounting) provides such an approach. The fundamental result in the comprehensive accounting literature was provided by Weitzman's (1976) seminal paper, where it was shown that a comprehensive measure of a country's net product equals

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a weighted average of future consumption. The current net national income, NNI, is proportional to the current maximum welfare attainable along the optimal path. This result is for a constant population, discounted utilitarian context with linear utility[2] and no technological progress, and suggests that welfare is improving if NNI is improving.

From this result it is easy to show that average future consumption will be above (below) current consumption if and only if a measure of comprehensive net investment is positive (negative) (Hamilton and Clemens, 1999). The comprehensive measure of net income is termed green net national income (GNNI), whereas the comprehensive measure of net investments is termed genuine savings (GS). These results are based on a set of somewhat restrictive assumptions. Subsequent theoretical developments have demonstrated that variants of these results still hold when some assumptions are relaxed. Asheim and Weitzman (2001) provided an important contribution towards empirical estimation of GNNI and GS in generalizing the Weitzman's (1976) results by proving that the welfare and sustainability interpretation of GNNI and GS holds even if utility is a non-linear function of a bundle of consumption goods, if GNNI is deflated by a Divisia consumer price index (CPI). The interpretations still hold even if welfare is not given by a discounted utilitarian welfare function (Asheim, 2007). In fact, by assuming only that society has a well-functioning resource allocation mechanism – by itself a very strong assumption – and identifying welfare improvement with the present value of future changes in consumption Asheim (2007) shows that the relation between welfare, GNNI and GS is verified.

The literature on comprehensive accounting is very rich in theoretical developments but its empirical application is both poorly developed and scarcely rigorous. Nonetheless, given the numerous efforts invested in estimating these indicators it is urgent to provide evidence that supports the use of the theory of comprehensive accounting to assess sustainability in real economies, or at least to indicate what should be included or corrected and where to direct the effort of doing so. However, so far, the evidence that comprehensive accounting indicators can predict changes in welfare, and so indicate sustainability, is scarce. Moreover, one would expect that there exists by now firm evidence that greener national accounts' measures are indeed better indicators of long-run economic indicators than conventional macroeconomic aggregates. This is not the case, although efforts have been made by Hamilton, Vincent and Ferreira to

[2] Hence, in a context where utility and monetary units are essentially indistinguishable.

check the consistency with the theory and the predictive accuracy of GS. It is worth mentioning that there are articles that check empirically the consistency of the GS message with other indicators of sustainability or well-being, namely the Human Development Index and Infant Mortality in Gnègnè (2009) and Ecological Footprint in Pillarisetti (2005), which have no clear formal relation with the theory of comprehensive accounting.

We should note that in all the works mentioned above, the econometric techniques employed (panel data and cross-section) are adequate for global welfare comparisons whereas the expressions that are being tested are derived for local over-time comparisons. Asheim (2009) shows that to use GNNI or GS for local welfare comparisons, it is sufficient to establish that GNNI growth or positive GS indicate welfare improvement, whereas for global welfare comparisons one must establish that per capita GNNI is positively related to per capita welfare. For this result to hold the economies compared must have the same technology and when estimating per capita welfare, the economy must exhibit constant returns-to-scale. Also, welfare comparison between different economies must be made in local real prices calculated according to "purchasing-power-paritiy" rather than international prices calculated according to exchange rates, as performed in the all the studies we found.

Since the theory of comprehensive accounting has primarily been concerned with developing and applying the theory of national accounting to the question of making local, over-time welfare comparisons within economies we use a model for a small open economy to derive the welfare comparison expressions and use time series techniques. The downside of this approach is that, since the obvious argument for using cross-section and panel data techniques is to counteract the lack of degrees of freedom of the regressions, while being more theoretically consistent we may obtain less robust regressions.

In this article we contribute to the existing tests of comprehensive accounting results by using time series techniques for a single country as the expressions to be tested are derived for within country over-time welfare comparisons. Moreover, besides the common adjustments for minerals and roundwood resource depletion we include a set of flow pollutants, the value of technological progress as estimated by the total factor productivity (TFP) and check the impact of the effects of business cycles by using the potential GNNI as estimated in Mota et al. (2010). Moreover, according to the theory (Asheim and Weitzman, 2001), the green accounting measures are deflated using the Consumer Price Index (CPI).

We thus conduct an investigation of the GNNI and GS estimates made for Portugal in Mota et al. (2010). The next section presents a critical review of the results of previous tests of comprehensive accounting indicators. Section 3 summarizes the theory and results behind the GNNI and GS's sustainability and welfare interpretations in a general setting and in the case of a small open economy following Mota et al., (2010). Moreover, in section 3 we present the expressions that are used to test the theory. Section 4 presents the results of the econometric tests. Section 5 concludes and suggests future work.

2. Review of previous tests of comprehensive accounting

The literature on testing comprehensive accounting indicators is very scarce. Vincent (2001) and Ferreira and Vincent (2005) try to assess whether current GS predicts the difference between a weighted average of future consumption and current consumption. If GS is negative, then current consumption is higher than the present value of future consumption, which means that sometime in the future there is a decrease in consumption. In other words, they investigate whether GS today indicate a cange in future consumption. In Vincent (2001) the relationship between GNNI and the present value of future consumption (not consumption changes) is also tested. An alternative approach to testing GS is used in Hamilton (2005) based on the result demonstrated in Hamilton and Hartwick (2005) that GS must equal the present value of future consumption changes. This result also holds for a competitive economy with appropriate pigouvian taxes. Moreover, a significant mismatch between genuine saving and discounted changes in green NNI is investigated in Pezzey et al. (2006) using data for Scotland. Excluding Pezzey's (2006) articles, all other works referred here use either cross-section (Hamilton, 2005) or panel data (Vincent, 2001 and Ferreira and Vincent, 2005) techniques.

To estimate the forward-looking measure of the present value of future consumption a time period of 10 years is used. For the various expressions tested, an increasing degree of comprehensiveness of the indicators is used. Starting from gross savings, the terms are added in each test to form the final GS or GNNI measures. Moreover in Vincent (2001) a disaggregated expression is also used to check the explanatory power of individual components of the indicators. In Vincent (2001) a panel data model for 1973-97 using the GNNI and GS for 13 Latin American countries is used to test two hypotheses: GNNI should predict the present value of future consumption, and GS should predict the difference between the present value of future consumption and current consumption. Included in the GNNI and GS measures is the depletion of minerals and forests (roundwood). A discount rate of 2% is used for all countries and all years, also using 5% for sensitivity analysis purposes. Vincent also controlled for population by dividing each variable by each country's population. Asheim (2009) shows, however, that to include the effect of population differences between countries, GNNI and GS indicators must be changed in more complex ways than dividing by total population.

Generically, Vincent's estimates of GS are systematically related to consumption in subsequent years. All the coefficients of the individual components of GS have the correct signs and are highly statistically significant. In contrast, the evidence is mixed for GNNI in the sense that fewer of the coefficients have the correct signs. Until and unless more convincing evidence emerges for GNNI, GS 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 is far from perfect.

In Ferreira and Vincent (2005) a per capita analysis is also made but not using the accurate expressions of Asheim (2009) as they comment (p.744). Here they test the same expressions as in Vincent (2001) but using only GS. Four decreasingly stringent hypotheses are used. These are tested for 139 countries for the period 1970-2001. Adjustments for non-renewable and roundwood resources are also included. A discount rate of 3.5% is used, but their results suggest a lack of sensitivity to discount rate changes. Changing the time period used in the present value of future consumption has a significant impact on the results.

Their results reject the hypothesis that GS measures coincide with the difference between current and average future consumption, although they found partial support for the less stringent hypothesis regarding the correct sign in the expressions. It is also suggested that components of GS that are excluded from the World Bank's measures are more important in explaining the evolution of consumption over time than the components those measures include. The general conclusion is that although the World Bank's GS estimates tend to move in the same direction as the difference between current and average future consumption in non-OECD countries, they have little value for predicting the magnitude of this difference. It is interesting to stress that current educational expenditure provides such a poor proxy for the change in human capital that it substantially increases measurement error in the GS variable. This is related to their separate testing for OECD and non-OECD countries. For OECD countries their results are worse, suggesting that capital accumulation, even when expressed in net terms and extended beyond produced capital, offers a less powerful explanation for the increased consumption that occurred in OECD countries during the sample period than it does for the non-OECD countries. This is consistent with the argument that developing countries whose economies grew rapidly into the early 1990s did so via factor accumulation instead of improvements in total factor productivity. It is also consistent with an observation by Weitzman and Löfgren (1997), that the omission of technological progress from empirical GS measures causes NNP to understate average future consumption. The Bank's net investment estimates for OECD countries are evidently so incomplete, or put another way, technological progress is so much more important than factor accumulation in those countries that the estimates do not even signal whether average future consumption will be higher or lower than current consumption (Ferreira and Vincent, 2001). This conclusion also appears in Hamilton (2005) and supports the inclusion of technological progress in future estimates of GNNI and GS especially for developed countries, as made in Pezzey et al. (2006) for Scotland and in Mota et al. (2010) for Portugal. Although it must be included in the estimates of GNNI and GS, the data currently available to estimate technological progress, i.e., Total Factor Productivity (TFP) is not adequate for the models used in comprehensive accounting to derive GNNI and GS (Mota et al., 2010). TFP as a proxy for technological progress may over- or underestimate the relevant TFP since some forms of natural capital used as production factors are not included in the conventional models used to estimate TFP. In Mota et al. (2010) we acknowledge the need for a green growth accounting estimates of TFP.

Hamilton (2005) equates GS with the present value of future consumption changes and tests this using a cross-section model. The GS measures include non-renewable resources and roundwood. They exclude the emissions of CO_2 and education expenditures (based on Ferreira and Vincent's results). Four measures of saving are used, gross, net, GS and Malthusian savings (including population growth). The last one present the worst fit to the theory, whereas gross and GS present the more robust fit. Again, the various savings measures are poor at signaling future changes in welfare in developed countries probably due to technical innovations.

3. Results of the theory of comprehensive accounting

Here we present a summary of comprehensive accounting results. Consider a representative agent, competitive, open economy with constant population. Although we present the results using a discounted utilitarianism setting this need not be the case as shown in Asheim (2007). The consumption bundle $\mathbf{C}(t)$

contains everything that influences utility $U(\mathbf{C}(t))$,[3] including all non-market commodities (environmental or produced at home) and amenities. The economy's stocks include physical, financial, natural and human capital (education and knowledge accumulated in R&D), forming a vector $\mathbf{K}(t)$.

Welfare is defined as $\int_0^\infty U(\mathbf{C}(t))e^{-\rho t}dt$, with a constant and positive utility discount rate, ρ. In real prices of the consumption $\mathbf{P}(t)$and the investment good $\mathbf{Q}(t)$, where $Q^t(t)$ is the price associated to technological progress, deflated using an extended Divisia consumer price index (CPI) $\lambda(t)\pi(t)$, GNNI is $Y = \mathbf{P}\cdot\mathbf{C} + \mathbf{Q}\cdot\mathbf{I} + Q^t$, and the following expression holds on the optimal path

$$\dot{Y} = R\mathbf{Q}\cdot\mathbf{I} = \frac{R}{\lambda\pi}\dot{W}, \qquad (1)$$

where $R(t)$ is the real interest rate.

The property that defines a Divisia CPI is $\mathbf{P}\dot{\mathbf{C}} = 0$ (Asheim, 2007). The first equality in expression (1) was estimated in Pezzey et al. (2006) for Scotland and they conclude that it is not verified by a significant amount. Regarding other predictions of the green accounting theory it is known that the present value of future changes in consumption must equal the value of net investments,

$$PV\Delta C_t \equiv \int_t^\infty \left(\mathbf{P}_s\dot{\mathbf{C}}_s\right)e^{-R(s-t)}ds = \mathbf{Q}_t\cdot\mathbf{I}_t \equiv GS_t, \text{ (Asheim, 2007).} \qquad (2)$$

This is the expression Hamilton (2005) uses to test the fit of the GS estimates to the theory. Using equation (1), we obtain an expression to test the fit of GNNI estimates to the theory,

$$PV\Delta C_t = \frac{\dot{Y}_t}{R} \qquad (3)$$

that has not been tested yet, has far as our literature review concluded. Moreover, it can be shown that the present value of consumption at time *t* obeys

$$PVC_t \equiv \int_t^\infty \mathbf{P}_s\mathbf{C}_s e^{-R(s-t)}ds = \frac{Y}{R}, \text{ (Asheim and Weiztman, 2001).} \qquad (4)$$

[3] The convention throughout the text is that vectors are represented in bold.

This equation is used to test the fit of the GNNI estimates to the theory, in Vincent (2001). Using the definition of GNNI we obtain another way to test the fit of GS to the theory,

$$R\int_t^{\infty} \mathbf{P}_s \mathbf{C}_s e^{-R(s-t)} ds - \mathbf{P}_t \mathbf{C}_t = \mathbf{Q}_t \mathbf{I}_t . \tag{5}$$

This expression was tested in Vincent (2001) and Ferreira and Vincent (2005). Here we use the expressions (2), (3), (4), (5) and the first equality of expression (1) to check the how our estimates of GNNI and GS for Portugal fit with the theory.

In Mota et al. (2010) we used a model for a small open economy adapted from Pezzey et al. (2006). We included the stocks of commercial forest and human capital, the welfare costs of air emissions and the value of technological progress. Moreover, the effect of the business cycles was excluded from the variables. The household's utility function is $U(\mathbf{C}) := U(C, \mathbf{E})$, where $C(t)$ is material consumption and $\mathbf{E}(t)$ is the vector of net emission flows dependent on production and abatement expenditure, $\mathbf{E}(F(\bullet), \mathbf{a})$. The marginal cost of abating pollutant *j* is $e^j(t) := -(\partial E^j(\bullet) / \partial a^j(t))^{-1}$. With this formulation, note that $\mathbf{P}_t \mathbf{C}_t = P^C C + P^E E = C_t - e_t E_t$, where the second equality comes from the fact that the relative price of emissions is equal to minus the marginal cost of emissions, using the maximum principle. Thus, for the purposes of testing the theory, for instance, the present value of consumption is given by,

$$\int_t^{\infty} (C_s - e_s E_s) e^{-R(s-t)} ds .$$

According to Mota et al. (2010), GNNI and GS are respectively given by

$$Y_t = NNI + (\mathbf{Q}^R - \mathbf{f_R}) \cdot \dot{\mathbf{S}} - \mathbf{e} \cdot \mathbf{E} + Q^t , \tag{6}$$

$$GS_t = NS + (\mathbf{Q}^R - \mathbf{f_R}) \cdot \dot{\mathbf{S}} + \left(F_h^H\right)^{-1} F^H + Q^t , \tag{7}$$

with $Q^t(t) = \int_t^{\infty} F_s e^{-R(s-t)} ds$. (8)

The adjustments to reach GNNI from the usual NNI are shown in (6) and (7), i.e., deduct the welfare cost of emission $\mathbf{e} \cdot \mathbf{E}$, deduct the value of rents from resource stock depletion $(\mathbf{Q}^R - \mathbf{f_R}) \cdot \dot{\mathbf{S}}$ and add the value of time.

So, in this paper we wish to test the validity of expressions (1), (2), (3), (4), and (5) using the time series of GNNI and GS in expressions (6) and (7) estimated in Mota et al. (2010).

4. Comprehensive accounting tests

4.1 Econometric expressions

First we write the discrete time counterparts of the expressions that present our hypothesis. The present value of consumption and the present value of future consumption changes are respectively approximated by,

$$PVC_t \approx \sum_{s=t+1}^{t+T} \mathbf{C}_s \left(1+R\right)^{-(s-t)} \text{, and} \tag{9}$$

$$PV\Delta C_t \approx \sum_{s=t+1}^{t+T} \left(\mathbf{C}_s - \mathbf{C}_{s-1}\right)\left(1+R\right)^{-(s-t)}. \tag{10}$$

We use $T=\{5,10\}$ to check the sensitivity to different truncations of the sum. To test GS we follow expression (3) and (6),

$$PV\Delta C_t = \beta_0 + \beta_1 GS_t + \varepsilon_t \text{ and} \tag{11}$$

$$PVC_t R - \mathbf{C}_t = \beta_0 + \beta_1 GS_t + \varepsilon_t \tag{12}$$

If our estimates of GS fit the theory perfectly we expect to obtain $\beta_0 = 0 \wedge \beta_1 = 1$. Disaggregating GS in (11) and (12) we get $\boldsymbol{\beta}\cdot\mathbf{GS}_t$, where $\mathbf{GS}_t = \left(GrossS_t,\ CFC_t,\ Depl_t,\ Q^t{}_t,\ Educ_t\right)$ and $\boldsymbol{\beta}$ is the vector of respective coefficients, $GrossS$ is gross saving, CFC is consumption of fixed capital, $Depl$ is depletion of natural resources that includes forests (eucalyptus and pine forests) and minerals (obtained from the World Bank estimates of GS for Portugal) and $Educ$ is education expenditures.

When estimating expression (11) and (12) we proceed step by step with increasing comprehensiveness of the savings measure. First gross, then net savings, and so on until we get to our formula of GS. This is also done for the tests using GNNI. Regarding GNNI, we follow expressions (4) and (5) which correspond to,

$$PV\Delta C_t R = \beta_0 + \beta_1 \left(Y_t - Y_{t-1}\right) + \varepsilon_t \text{ and} \tag{13}$$

$$PVC_t R = \beta_0 + \beta_1 Y_t + \varepsilon_t \tag{14}$$

Again, to test the disaggregated model of GNNI we use in the above expressions (13) and (14), $\boldsymbol{\beta} \cdot \mathbf{Y}_t$, where $\mathbf{Y}_t = \left(GNI_t,\ CFC_t,\ eE_t,\ Depl_t,\ Q^t{}_t \right)$ with the respective vector of coefficients. We perform these tests with and without excluding business cycles to assess their effect on the fit to the theory and with increasing comprehensiveness in the definition of GNNI.

Following the idea of Pezzey et al. (2006) when referring to the mismatch in the first equality of expression (1) we also perform the test in aggregate form only,

$$GS_t = \beta_0 + \beta_1 \frac{Y_t - Y_{t-1}}{R} + \varepsilon_t \tag{15}$$

with increasing completeness in the measures of GS and GNNI. This can be seen in the appendix were we present the definition of the variables used in the table. For each estimated expression, we also checked for spurious regressions by applying the augmented Dickey-Fuller test.

4.2 Results

As mentioned before, here we use the time series of GNNI and GS estimated for Portugal (1990 - 2005) in Mota et al. (2010). Additionally we include mineral depletion by using the data estimated for Portugal by the World Bank.

Table 1 presents the results from estimating the relationship (15) between GS and changes in GNNI. A mismatch was found in Pezzey et al. (2006) that led us to check here the validity of the green accounting measures. Figure 1 illustrates that there is a significant difference between changes in GNNI and interest on GS. It is also illustrated the effect of technological progress. Changing the truncation of the integral that approximates the value of technological progress has a significant effect, particularly to GS. This is so because the value of technological progress is somewhat constant (has little effect in the change of GNNI) but is a high absolute value (big impacts in GS). This can also be observed in the coefficients of table 1. They get closer to unity when the truncation of the integral in expression (8) increases.

The results on table 1 confirm the idea of a mismatch of figure 1 since we can reject the hypothesis that the data fits expression (15), i.e, the coefficients are significantly different from unity. This is true also when we perform the test excluding business cycles from the variables (potential GNNI), and also when using different truncations for the value of technological progress (this has a large impact on the regression). With a less stringent hypothesis, we expect that as we increase the comprehensiveness of the measures of savings and income, the coefficients approach unity. So a progressive reduction in omitted variables is expected to increase the accuracy of the regression. This is globally verified except when the depletion of minerals and education expenditures are included, suggesting that the measurement error in this term counteracts the effect of omitting fewer variables. This result concerning education expenditures was also found in Ferreira and Vincent (2005). The best result is provided when using the pair GNNI and GS. Overall in table 1, the effect of excluding business cycles from GNNI is also observed. Using potential GNNI increases the fit with the theory. In the first column of table 1 all the coefficients are significantly different from zero, but several regressions are spurious. Excluding the business cycles the hypothesis of having spurious regressions is rejected and with more certainty. This supports the idea that GNNI has cycles that are not related to the long term relation we want to test. Moreover, using potential GNNI decreases significantly the standard errors of the coefficients.

Regarding the tests on GS, tables 2, 3, 4 and 5 presents the results of the regressions in (11) and (12) either using aggregate terms with increasing comprehensiveness (tables 2 and 4), and in a disaggregated form (tables 3 and 5). Here we also check the impact of using a different time period to estimate the present value of consumption and future consumption changes in expressions (9) and (10). It can be seen that the regressions of expression (11) regarding the equality between GS and present value of future changes in consumption, in table 2, present the best agreement with the theory in the sense that the coefficients are close to unity. In fact, according to the values of the coefficients we cannot reject the hypothesis that they are significantly different from unity, i.e., we cannot reject the hypothesis that the data does fit the theory.

Overall, increasing the comprehensiveness of GS increases the fit with the theory, and again the formula used in section 3 to estimate GS presents the best results. We also see, as in table 1 that including education expenditures and using the World Bank's model decreases the fit to the theory. Changing the time period used in expressions (9) and (10) alters the results of the regressions. In our case we used T = 5 years instead of the original T = 10 years. This increased the number of observations but also increased the measurement error of expressions (9) and (10). The consequence is that the coefficients are further away from unity and we have stronger support in rejecting the hypothesis that the data fits the theory. Nonetheless, note that almost all the regressions found are not cointegrated and consequently it is possible that these regressions are spurious. This is a recurrent conclusion throughout the regressions using GS.

In table 3 we present the results of the disaggregated form of expression (11). Most of the coefficients are not significantly different from zero, but nonetheless, the significant coefficients all depict the correct sign. The coefficients for CFC are negative, for depletion of forests are positive and for the depletion of minerals are negative. Probably due to lack of degrees of freedom the interpretation of the results in this table is unclear. Moreover we cannot reject the hypothesis that the regressions are not cointegrated. This also happens in table 5 where we perform tests using disaggregated GS. Most variables are not significantly different from zero. Since the discount term in the present value of consumption and future consumption changes is very low the future values of consumption that are left out are a considerable part. So even using T = 10 in expressions (14) and (15) might not be sufficient to estimate accurately their continuous counter parts.

Regarding table 4, we present the results of the regressions on expression (12). As before the indicator that presents the best results is GS and rejecting the hypothesis of a spurious regression. Moreover, the results suggest that including forest depletion and education expenditures decreased the fit to the theory. The regressions presented in table 2 and 4 were also tested in Hamilton (2005) and Ferreira and Vincent (2005) respectively as discussed in section 2. It is also observable from table 4 that the effect of changing the truncation of the present value of consumption on the results is not clear since some coefficients became closer to unity while others did not and most importantly it is not possible to assure that the regressions are not spurious. The conclusions taken from table 5 are very similar to those described for table 3. Most coefficients are not significantly different from zero and most regressions may be spurious. This is probably related to the lack of degrees of freedom in the regressions.

Regarding the GNNI, generically the coefficients are worse when compared with GS but the tests for spurious regressions present better results. In table 6 we see that the best fit with the theory is obtained when using GNNI although we reject the hypothesis that the data fits the theory, i.e., the coefficients are significantly different from unity. It is evident that the more inclusive the measure of income the more it is related with the value of future consumption. Moreover, and has seen in table 1, excluding business cycles from the measures of income, increased the accuracy of the predictions. Also, we conclude that decreasing the time period in expressions (9) and (10) gives worse results. For most the regressions the hypothesis of spurious relationships is rejected. Again due to the lack of degrees of freedom, the disaggregated form of

GNNI does not present clear results, although the significant coefficients all have the correct sign excluding the last column. The coefficients for CFC, depletion of minerals and emissions are negative whereas for the value of technological progress and GNI are positive.

The results presented in table (8) suggest that changes in present income are not related with the value of future changes in consumption. All empty cells mean that the regressions did not pass the F-test, implying that we reject the hypothesis that the model in question is linear. That is to say, there is no support for a linear equation. Only when using T = 5 in expression (10) we could obtain some results for the coefficient. In figure 2 we represent the time series used for the regressions in table 7. It appears that the dependent variable is not integrated of the same order as the other series. This illustrates why the hypothesis of a linear equation is rejected. The cycles in the income measures cannot explain the evolution of the present value of future consumption. We believe this is the main reason why, not just here in this paper but also in Vincent (2001), the GS data generally presents the best fit with the when compared with estimates of GNNI.

For GS the best results were obtained using the expression for the present value of future changes in consumption, whereas for GNNI the best results were obtained using the expression for the present value of future consumption. Nonetheless, it is surprising to note that overall our results suggest that using GS yields better fit with the theoretical predictions but these regressions may be spurious whereas using GNNI the regressions are not spurious but the fit with the theory worsens.

5. Concluding comments

The literature devoted to testing the existing estimates of genuine savings and green net national income to the predictions of its underlying theory is scarce. Most of the efforts made use panel data or cross-section techniques to test results that are derived for within-country over-time comparisons while the data requirements to compare welfare between countries (Asheim, 2009 and 2010) are not yet met in any of the available estimates of genuine savings and green net national income. To overcome this we used time series analysis, although we regard as interesting to make the modifications suggested in Asheim (2009) to the World Bank data, thereby overcoming the problem of lack of degrees of freedom we encountered when using time series.

For the first time, the value of technological progress and the effect of business cycles are included in the tests of the theory of green accounting. Moreover, the CPI is used to deflate measures into constant prices as the theory indicates (Asheim and Weitzman, 2001). We use an estimated time series of genuine savings and green net national product for Portugal to check whether the data follows the predictions of the green accounting theory.

Our results suggest that we reject the hypothesis that the estimated green accounting measures coincides with the theoretical predictions. The results also suggest that the more comprehensive the measure of savings or income used the best it fits the theory. Generally, genuine savings present the best results. Excluding the business cycles increases the accuracy of the regressions, whereas the terms that present most measurement errors are the education expenditure and, particularly to our case, the mineral depletion. Both genuine savings and green net national income move in the same direction of changes in welfare. The value of technological progress has a more important role in the mismatch between changes in GNNI and interest on GS than on the expressions related to predictions of future consumption evolution. We observed in Mota et al. (2010) that the TFP as estimated by usual growth accounting expressions is not adequate for green accounting purposes due to the fact that this estimates use a production function that is not consistent with those used in green accounting. Moreover, the CPI used is also not adequate for measuring changes in welfare since the consumption vector should include all that influences welfare and that is not the case for the usual consumption bundles use to obtain the CPI. There is still a need for an effort to obtain estimates of TFP and CPI that are consistent with the models used in green accounting. The existing estimates of GNNI and GS are far from comprehensive, but even for the usually included terms there are some problems with measurement errors, of which even the depreciation of physical capital is not exempt from. All the existing estimates of GNNI and GS are initial ones and we are still a long way to go until the theoretical results of green accounting are verified empirically.

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Appendix - Definition of the variables used in the tables:

GNNI1 = NNI – eE;

GNNI2 = GNNI1 + Depl. Forest;

GNNI3 = GNNI2 + Depl. Minerals;

GNNNI = GNNI3 + Q^t.

NS = Gross Saving – CFC;

GS1 = NS + Depl. Forest;

GS2 = GS1 + Depl. Minerals;

GS = GS2 + Q^t;

GS3 = GS + Educ.

Table 1: Testing $GS_t = \beta_0 + \beta_1 \frac{Y_t - Y_{t-1}}{R} + \varepsilon_t$.

	β_1	β_1 potential	β_1 with T=100 in Q^t
Gross Savings , GNI	12.0**+ (4.4)	9.61**+ (1.9)	=
NS , NNI	7.70*+ (3.1)	6.85**++ (1.16)	=
NS , GNNI1	6.7* (2.6)	6.24**++ (1.05)	=
GS1 , GNNI2	6.36* (2.5)	6.25**++ (1.0)	=
GS2 , GNNI3	9.44** (1.8)	9.2**+ (0.57)	=
GS , GNNI	6.32**+ (2.0)	5.9**++ (0.62)	4.56**++ (0.57)
GS3 , GNNI	6.75**+ (2.14)	6.35**++ (0.61)	4.85**++ (0.58)

Note: Standard errors in parenthesis. Number of observations: 15. * Estimate is significantly different from zero at 5% level. ** Estimate is significantly different from zero at 1% level. + (++) Reject the hypothesis that the time series are not cointegrated at 5% (1%) level.

Table 2: Testing $PV\Delta C_t = \beta_0 + \beta_1 GS_t + \varepsilon_t$ for GS in aggregate form.

	β_1	β_1 with T=100 in Q^t	β_1 T=5 in $PV\Delta C$	β_1 T=5 in $PV\Delta C$ Q^t T=100
Gross Savings	-0.87 (0.72)	=	-0.11 (0.48)	=
NS	1.24**++ (0.41)	=	0.62** (0.18)	=
GS1	1.31**++ (0.39)	=	0.63** (0.17)	=
GS2	1.28* (0.33)	=	0.40** (0.1)	=
GS	1.13** (0.14)	1.33**+ (0.2)	0.56** (0.1)	0.67** (0.13)
GS3	1.44** (0.25)	1.55**+ (0.39)	0.70** (0.13)	0.81** (0.19)

Note: Standard errors in parenthesis. Number of observations: 12, except for the last column which is 16. * Estimate is significantly different from zero at 5% level. ** Estimate is significantly different from zero at 1% level. + (++) Reject the hypothesis that the time series are not cointegrated at 5% (1%) level.

Table 3: Testing $PV\Delta C_t = \beta_0 + \beta_1 GS_t + \varepsilon_t$ for GS in disaggregated form.

	β_1	β_1, no Educ	β_1, Q^t with T=100	β_1 T=5 in $PV\Delta C$	β_1 T=5 in $PV\Delta C$ Q^t T=100
Gross Savings	1.05 (0.58)	0.89* (0.32)	0.92** (0.32)	-0.29 (0.59)	-0.03 (0.38)
CFC	-1.66 (1.31)	-1.21** (0.21)	-1.41** (0.19)	-1.37 (1.23)	-0.56* (0.22)
Depl. Forests	8.83 (4.61)	8.77* (4.26)	8.64* (4.34)	6.5* (4.37)	4.81* (3.56)
Depl. Minerals	-0.63 (1.0)	-0.9 (0.61)	-0.83 (0.64)	-0.43 (0.41)	-0.64* (0.3)
Qt	0.82 (0.7)	0.67 (0.52)	0.68 (0.53)	0.42 (0.38)	0.34 (0.35)
Educ	1.08 (3.08)	-	-	2.12 (2.8)	-

Note: Standard errors in parenthesis. Number of observations: 12, except for the two last columns which is 16. * Estimate is significantly different from zero at 5% level. ** Estimate is significantly different from zero at 1% level.

Table 4: Testing $PVC_t R - \mathbf{C}_t = \beta_0 + \beta_1 GS_t + \varepsilon_t$ for GS in aggregate form.

	β_1	β_1 with T=100 in Q^t	β_1 T=5 in $PV\Delta C$	β_1 T=5 in PVC_t Q^t T=100
Gross Savings	-1.9 (1.36)	=	-0.11 (1.76)	=
NS	2.76**+ (0.68)	=	3.03** (0.38)	=
GS1	2.85**+ (0.64)	=	3.03** (0.37)	=
GS2	2.66** (0.58)	=	1.66** (0.31)	=
GS	2.15**++ (0.31)	2.42**++ (0.48)	2.19** (0.3)	2.51** (0.45)
GS3	2.56**+ (0.6)	2.48*++ (0.94)	2.51** (0.51)	2.63** (0.79)

Note: Standard errors in parenthesis. Number of observations: 12, except for the last column which is 16. * Estimate is significantly different from zero at 5% level. ** Estimate is significantly different from zero at 1% level. + (++) Reject the hypothesis that the time series are not cointegrated at 5% (1%) level.

Table 5: Testing $PVC_t R - \mathbf{C}_t = \beta_0 + \beta_1 GS_t + \varepsilon_t$ for GS in disaggregated form.

	β_1	β_1, no Educ	β_1, no Educ, Q^t T=100	β_1 T=5 in PVC_t	β_1 T=5 in PVC_t Q^t T=100
Gross Savings	0.74 (0.59)	0.93* (0.33)	0.95* (0.34)	0.18 (0.31)	0.84** (0.27)
CFC	-2.4 (1.33)	-3.0** (0.21)	-3.14** (0.2)	-1.88** (0.66)	-3.7** (0.16)
Depl. Forests	8.36 (4.69)	8.42* (4.34)	8.58* (4.78)	1.42 (2.35)	5.18* (2.55)
Depl. Minerals	-0.49 (1.02)	-0.19 (0.62)	-0.17 (0.66)	-0.09 (0.22)	0.35 (0.21)
Q^t	0.33 (0.71)	0.49 (0.53)	0.461 (0.54)	-0.22 (0.21)	-0.13 (0.25)
Educ	-1.23 (3.14)	-	-	-4.31** (1.5)	-

Note: Standard errors in parenthesis. Number of observations: 12, except for the last column which is 16. * Estimate is significantly different from zero at 5% level. ** Estimate is significantly different from zero at 1% level.

Table 6: Testing $PVC_t R = \beta_0 + \beta_1 Y_t + \varepsilon_t$ with GNNI in aggregate form.

	β_1	β_1 potential	β_1 potential T=5 in $PV\Delta C$
GNI	0.23**++ (0.2)	0.24**++ (0.01)	0.15**++ (0.00)
NNI	0.29**++ (0.03)	0.31**++ (0.01)	0.19**++ (0.00)
GNNI1	0.30**++ (0.02)	0.32**++ (0.02)	0.20**++ (0.00)
GNNI2	0.31**++ (0.02)	0.32**++ (0.01)	0.2**++ (0.00)
GNNI3	0.30**+ (0.03)	0.32**++ (0.02)	0.16**++ (0.01)
GNNI	0.33** (0.02)	0.36** (0.02)	0.15**++ (0.01)
GNNI, Q^t T=100	0.31** (0.02)	0.33** (0.02)	0.14**++ (0.01)

Note: Standard errors in parenthesis. Number of observations: 12, except for the last column which is 16. * Estimate is significantly different from zero at 5% level. ** Estimate is significantly different from zero at 1% level. + (++) Reject the hypothesis that the time series are not cointegrated at 5% (1%) level.

Table 7: Testing $PVC_tR = \beta_0 + \beta_1 Y_t + \varepsilon_t$ with GNNI disaggregated.

	β_1	β_1, Q^t T=100	β_1 potential, Q^t T=100	β_1 T=5 in $PV\Delta C$
GNI	0.34** (0.1)	0.33** (0.1)	0.25** (0.01)	0.18** (0.06)
CFC	-0.19 (0.41)	-0.19 (0.4)	0.02 (0.08)	-0.29** (0.27)
Depl. Forests	2.08* (1.23)	1.96* (1.2)	-4.8** (0.81)	3.36* (1.84)
Depl. Minerals	-0.49* (0.18)	-0.47* (0.19)	-1.0** (0.03)	-0.04 (0.06)
Emissions	-1.36* (0.69)	-1.32* (0.7)	-1.57** (0.28)	2.85** (0.67)
Q^t	0.16 (0.15)	0.16 (0.14)	0.56** (0.08)	0.46* (0.18)

Note: Standard errors in parenthesis. Number of observations: 12, except for the last column which is 16. * Estimate is significantly different from zero at 5% level. ** Estimate is significantly different from zero at 1% level.

Table 8 ("7"): Testing $PV\Delta C_tR = \beta_0 + \beta_1 (Y_t - Y_{t-1}) + \varepsilon_t$ with GNNI in aggregate form.

	β_1	β_1 potential	β_1 T=5 in $PV\Delta C$
GNI	-	-	0.06**++ (0.02)
NNI	-	-	0.07**++ (0.02)
GNNI1	-	-	0.08*++ (0.03)
GNNI2	-	-	0.08**++ (0.03)
GNNI3	-	-	0.04**++ (0.01)
GNNI	-	-	0.05**++ (0.01)
GNNI, Q^t T=100	-	-	0.05**++ (0.01)

Note: Standard errors in parenthesis. Number of observations: 11, except for the last column which is 15. * Estimate is significantly different from zero at 5% level. ** Estimate is significantly different from zero at 1% level. All empty cells mean that the regressions did not pass the F-test with 5% probability, implying that we reject the hypothesis that the model in question is linear. + (++) Reject the hypothesis that the time series are not cointegrated at 5% (1%) level.

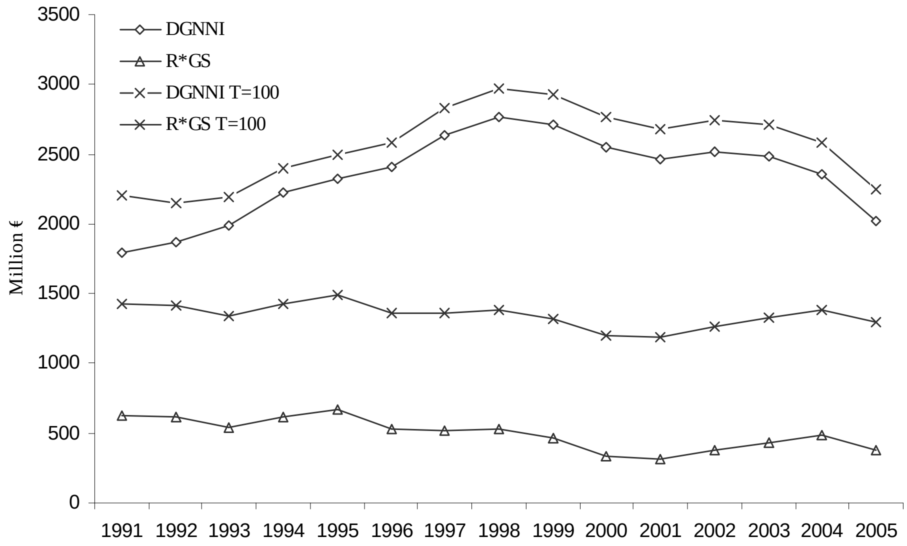

Figure 1. Representation of the mismatch between changes in GNNI and interest in GS.

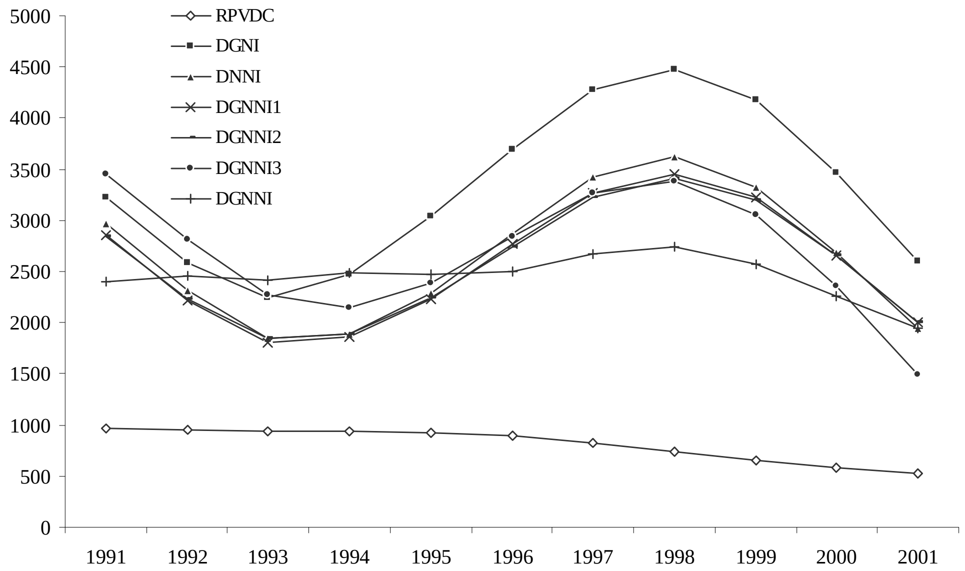

Figure 2. Times series used to perform the tests in table 8, first column.