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# A SIMPLE NUMERICAL STUDY ON SUSTAINABLE DEVELOPMENT WITH GENUINE SAVING

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# A simple numerical study on sustainable development with Genuine Saving

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**Abstract**

This paper provides numerical examinations on sustainability of genuine saving (GS) using the World Bank database. Unlikely to previous criteria of sustainability, we consider future sustainability by focusing on evolution of GS. In this case even if the historical average GS of a country is positive, there is a possibility that the GS become negative in the future, depending on time series path of the GS. We will show that some countries that were argued to be sustainable in previous studies are shown to be otherwise.

**Keywords:** Sustainability; Genuine Saving

**JEL classifications:** Q01; O13

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# 1 Introduction

The concept of genuine saving (GS), first introduced by Pearce and Atkinson (1993), is now considered one of the most important indicators in the study of sustainable development.[1] Using GS database, several influential studies provide evidence on the sustainability of development by focusing on the historical averages or the current levels of GS.

Hamilton and Clemens (1999) calculate the GS averages for 1970s and 1980s, and provide some single-year values for 1990s across countries. They then assess the sustainability of each country by seeing if those GS indicators are positive or not. Neumayer (2000) revises the GS calculation method of Word Bank and shows that based on its new approach, some countries' GS judged as unsustainable based on WB database, are indeed improved. This paper uses the averages of countries' empirical GS data as its yardstick to assess the sustainability. Arrow et al. (2004) calculate GS values for some countries and regions and take their averages over the period 1970-2001. They argue that if a country's average GS is negative, the country does not meet the criteria of sustainability while they also point out that when taking into account the population growth and technological change, the results are significantly changed. Finally, Hamilton and Atkinson (2006) observe spot GS values and find that the positivity in GS values is strongly depending on the population growth rate of each country.

One issue among those previous GS studies will be that their criteria for assessing sustainability do not guarantee that currently sustainable countries remain sustainable in future as well. This point is actually crucial since one of the most influential definition of "sustainability" by Arrow et al (2003) requires "non-declining welfare in the future" for being sustainable. They also argue that their sustainability condition is equivalent to having positive GS for any point of time onward. Analytical studies of Asheim (1994) and Velligna and Withagen (1996) also show that positive current genuine savings are not sufficient for sustainability.[2]

[1]Genuine savings is also referred to as "Genuine Investment" (Arrow et al., 2003), "Adjusted Net Saving" (World Bank), and "Inclusive Investment" (Dasgupta, 2007). All of these terms imply a change of wealth as a source of welfare. See Arrow et al. (2003) and Dasgupta (2004) for recent theoretical developments and sophistication in the literature.

[2]Recently, Valente (2008) analytically investigates a one-to-one relationship between the sign of long-run GS and the limiting condition for sustained utility in a framework

In this paper, following the spirit of Arrow et al. (2003), we examine the stochastic process of GS measures thereby assessing the "future sustainability" of world developments. As a first step of such an attempt, we employ AR(1) process and simulate the GS path of each country to calculate the percentage of experiencing negative GS in 50 years and the average years before the first negative GS in the stochastic process. We can expect that countries with higher volatility may break the sustainability condition in future, even though they have positive current GS and are judged to be sustainable from the previous criteria of assessing sustainability. Our numerical study below shows that it is the case.

The rest of this paper is organized as follow. In section 2, we recap concepts of GS and sustainable development. In section 3, we describe our method of analysis, and in section 4 we provide estimations of stochastic process of GS and provide simulation results to assess the sustainability. Section 5 concludes the paper.

## 2 Sustainable development and dataset

This section briefly recaps the definition of sustainability by Arrow et al. (2003) and the measure of GS for readers' reference. Arrow et al. (2003) define the sustainability of GS as "non-declining welfare in the future" and, as such, inclusive wealth, which is the source of welfare, must be maintained at all points of time onward. The inclusive wealth can be defined as

$$W_t = KM_t + KH_t + KN_t, \tag{1}$$

where $W_t$ is the inclusive wealth at $t$, and $KM_t$, $KH_t$ and $KN_t$ are the accumulated monetary values of inclusive man-made capital, human capital, and natural capital at the point of time $t$, respectively. GS is defined as the time-differentiation of (1) as

$$GS_t \equiv \frac{dW_t}{dt} = \frac{dKM_t}{dt} + \frac{dKH_t}{dt} + \frac{dKN_t}{dt}. \tag{2}$$

Then the "sustainability condition" is written as

$$GS_t \geq 0 \quad \text{for all } t. \tag{3}$$

of capital resource growth model. Also, Hamilton and Hartwick (2005) investigate the timing of zero net investment in an unsustainable economy where future genuine savings are negative by construction.

GS is conceptually equivalent to investment in a standard economics sense if natural resources are inputs of production. Also, note that if an economy is on a balanced growth path and if the production function of an economy is homothetic, GS will be constantly increasing while the ratio of GS to output (henceforth GS rate) remains constant when the economy grows. In such a case, as previous studies argue, positive GS (or positive GS rate) will be sufficient for confirming the sustainability.

However, if the economy is not on a balanced growth path, possibly due to structural or environment changes, the growth patterns in GS will be non monotonic and GS rate will be volatile. In this case if we just consider the historical average of GS as previous studies, we may overlook the possibility of breaking the sustainability condition in future. We explore this point in this paper.

With respect to the measurement of GS, we follow the World Bank and we address the published dataset of GS in World Development Indicators (WDI), which is available from the World Bank. In WDI database, natural capital includes the depletion of energy, mineral and forest resources, and $CO_2$ emissions.

The database contains information on 208 countries and regions. Among them, we select 23 countries for our study group. This is because we do not have enough time series observations for AR(1) estimations for some countries and also because there is inconsistency in measurement of historical GS data for some countries. The list of the selected countries is given in Table 1.

# 3 Methods

Following Hamilton and Clements (1999) and Arrow et al. (2004) we consider evolution of GS rate. Information about GS is obtained from WDI and our output measure of GNP is also drawn from WDI.

We estimate AR(1) processes of GS rate for each country as

$$GS_{t,i} = \text{constant}_i + \beta GS_{t-1,i} + \epsilon_i, \tag{4}$$

where $\epsilon \sim (0, \sigma)$ is the normally distributed random term and $i$ is the country index. With estimated AR(1) processes and the initial conditions, which are the latest GS rates available from WDI, we simulate the predicted GS rate paths over 50 times (meaning 50 years). Then we see if the

GS rate becomes negative in 50 years to calculate the percentage of violating "future sustainability condition". We also present the average years before the first negative GS, if those countries actually has probability of experiencing negative GS.[3]

Some remarks on our strategy are in order. First, the major reason that we employ AR(1) process for GS rate is quite simple: we do not have enough time series observations to conduct more complex stochastic processes. Secondly, when we examine the AR(1) process, we assume away unit root. This is because if we assume that a GS rate process has unit root, then the GS rate of that country will diverge as time goes while the GS rate lies between zero and one by definition. Hence, we presume that GS process does not have unit root. Also note that we can obtain the steady state values of GS rate from estimated AR(1) process, which are depicted in Table 1.[4]

# 4 Results

In this section we provide the main results. The results are shown in Table 1.

## 4.1 Latin America and the Caribbean

About Latin America and the Caribbean countries, according to Hamilton and Clemens (1999), Brazil, El Salvador and Mexico are judged to be sustainable. From our simulation analysis, however, the results indicate that only Brazil will be judged to be sustainable: the probability of facing negative GS in 50 years is more than 90 percent for the other two countries and

[3]The python code for simulations is available upon requests from the authors. In our study, those figures are obtained after 10 thousands times of simulations.

[4]We find that for some countries estimated constant term in (4) is not statistically significant even at 10 percent level. If, however, we omit the constant term in simulations, it implies that the GS rate will trivially approach to zero when the estimated $\beta$ is less than one. Hence, though it might not be a standard procedure but in this study we address estimated constant terms even though they are not statistically significant in order to exclude these trivial results. Note, however, that in this case the direction of bias is that we are under-evaluating the possibility of having negative GS. As the results below show, even if we under-evaluate, there are some countries that violate future sustainability condition while they satisfy the positive current GS criteria.

the average years toward the first negative GS are approximately 15 years for both countries. This finding suggests that the urgent policies for future sustainability are needed for these countries.

## 4.2 East Asia and the Pacific

For the case of East Asian and the Pacific countries, our results indicate that these study group countries are sustainable. This finding is consistent with Hamilton and Clemens (1999). It is worth noting that even the estimated result of China shows that it has moderately high probability of negative GS rate, its average years toward the first negatiev GS rate exceed 200 years. From this result, we can argue that in the future, China's GS may still satisfy the sustainable criteria. However, China may need policies that make GS less volatile.

## 4.3 Middle East and North Africa

In Arrow et al. (2004) countries in Middle East and North Africa are judged to be un-sustainable. They argue that un-sustainable countries in the regions are depending on the oil resource too much. Hamilton and Clements (1999) propose a different view: among un-sustainable countries in the area, there are some exceptions such as Algeria, Israel and Jordan. Our analysis on future sustainability shows that Algeria and Israel have high probability of experiencing negative GS rate, indicating un-sustainability of these countries. These high rates are due to high volatilities of GS rates relative to its steady state values. Also, Jordan's probability of negative GS rate is exceeding 50 percent. It is noteworthy that while our findings on the case of East Asian and Pacific countries are consistent with Hamilton and Clements (1999) our results about Middle East and North Africa countries cast a contrast against them.

## 4.4 South Asia

In Hamilton and Clemens (1999), Bangladesh and Nepal are judged to be not sustainable. For the case of Bangladesh, like the previous study, our analysis also indicates that it has high probability of facing negative GS rate; however, Hamilton and Clemens (1999), Arrow et al. (2004) and our analysis show inconsistent results for Nepali case. For India, our result is consistent with those of previous studies. Finally, while the previous studies judge Pakistani GS performance as being sustainable, our analysis indicates that it may not be.

### 4.5 Sub-Saharan Africa

For Rwanda and Uganda, our results are consistent with those of Hamilton and Clemens (1999) which argued that these two countries are not sustainable. For Kenya, while Hamilton and Clemens (1999) judged to be on the edge of unsustainability, our results differently indicate that it can be judged as being sustainable. Our estimated results show that Kenya has high steady state GS rate and GS's volatility relatively becomes small.

### 4.6 High Income Countries

For the cases of France, Japan, Spain and UK, like the previous study, our analysis also judges that they can be thought to be sustainable. However, for the cases of Australia and USA, The simulation results indicate that both countries have the probability of negative GS rate exceeding 20 percent. However, their average years toward the first negative GS rate are as long as approximately 180 years. Given these findings, the assessment of sustainability of these two countries should be done with caution.

## 5 Conclusion

In this paper, we provide a simple numerical examination on GS-based sustainability using the World Bank database (WDI). With this simple method, our sustainability' s assessment results show that in 50 years countries including El Salvador, Mexico, Algeria, Israel, Jordan and Pakistan will break the sustainability condition a la Arrow et al. (2003). It is also worth noting that for countries such as China, Australia and the U.S., the assessment on their sustainability should be done with cautions. These countries have high average in the GS rates and their average years toward the first negative GS rate are quite long. However, due to the high volatility of GS rate paths, our simulation indicates that the risk of becoming unsustainable in the future is arguably high. This finding suggests that these countries should adopt policies that make GS paths less volatile.


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Table 1. Comparison of Genuine Saving as Percent of Output and Simulation Results

| | (1) Hamilton and Clements (1999) GS as Percent of GNP | (2) Arrow et al. (2004) GS as Percent of GDP | (3) This study Estimated Results of AR(1) process constant | beta | sigma | Steady State GS as Percent of GNP | Simulation Results % of experiencing Negative GS in 50 years | Average Years before the first negative GS |
|---|---|---|---|---|---|---|---|---|
| *Latin America and the Caribbean* | | | | | | | | |
| Brazil | 11.8 | | 2.80** | 0.72*** | 2.04 | 9.97 | 1.3% | 3667.5 |
| El Salvador | 5.9 | | 1.26 | 0.79*** | 3.24 | 6.26 | 92.2% | 16.0 |
| Mexico | 3.6 | | 0.38 | 0.88*** | 2.64 | 1.43 | 95.5% | 15.0 |
| *East Asia and the Pacific* | | | | | | | | |
| China | 21.5 | 22.72 | 0.86 | 0.97*** | 4.18 | 26.38 | 16.3% | 218.8 |
| Philippines | 8.0 | | 2.89* | 0.83*** | 3.33 | 16.80 | 5.3% | 747.3 |
| South Korea | 29.6 | | 3.27* | 0.86*** | 2.49 | 23.72 | 0.0% | N.A. |
| *Middle/East North Africa* | | -7.09 | | | | | | |
| Algeria | 6.7 | | 1.88 | 0.73*** | 3.94 | 7.06 | 96.3% | N.A. |
| Israel | 16.7 | | 3.64** | 0.45** | 3.81 | 6.65 | 90.4% | 22.7 |
| Jordan | 13.5 | | 9.53** | 0.36 | 6.46 | 14.89 | 55.2% | 65.3 |
| *South Asia* | | | | | | | | |
| Bangladish | -2.3 | 7.14 | 1.25 | 0.91*** | 3.66 | 13.56 | 43.5% | 83.7 |
| India | 8.4 | 9.47 | 0.82 | 0.95*** | 1.90 | 17.23 | 1.7% | 1530.8 |
| Nepal | -12.3 | 13.31 | 1.43 | 0.94*** | 2.79 | 24.14 | 1.8% | 2087.6 |
| Pakistan | 4.7 | 8.75 | 2.12* | 0.76*** | 2.90 | 8.88 | 55.8% | 71.4 |
| *Sub-Saharan Africa* | | -2.09 | | | | | | |
| Kenya | 1.4 | | 9.74* | 0.21 | 3.11 | 12.35 | 0.4% | N.A. |
| Rwanda | -1.4 | | 2.63*** | 0.57* | 4.41 | 6.09 | 98.2% | 13.7 |
| Uganada | -8.6 | | -1.33* | 0.68*** | 3.73 | -4.15 | 100.0% | N.A. |
| *High Income Countries* | | | | | | | | |
| Australia | 5.5 | | 1.43* | 0.77*** | 1.69 | 6.35 | 23.8% | 193.8 |
| Canada | 7.4 | | 1.50 | 0.82*** | 1.63 | 8.46 | 5.6% | 1045.8 |
| France | 13.5 | | 1.44* | 0.88*** | 1.08 | 11.61 | 0.0% | N.A. |
| Japan | 26.2 | | 1.10 | 0.92*** | 1.50 | 14.46 | 0.2% | N.A. |
| Spain | 12.3 | | 1.39 | 0.88*** | 1.16 | 11.69 | 0.0% | N.A. |
| United Kingdom | 6.6 | 7.38 | 1.62** | 0.78*** | 1.29 | 7.38 | 0.6% | 7253.2 |
| United States | 9.6 | 8.94 | 1.03 | 0.85*** | 1.64 | 7.06 | 28.8% | 180.4 |

* significant at 10%, ** significant at 5%, *** significant at 10%

The first column shows results in Hamilton and Clement (1999). The figures are the latest ones available for each country, i.e., 1993 for Brazil. With respect to Israel and Uganada, the initial values in our simulations are negative so that we do not consider the average years before having the first negative GS rate. The other countries with N.A. in the last columun do not have the probability of facing the event in our simulations.