

# Empirical Measurement of Sustainable Welfare from the Perspective of Extended Genuine Savings

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## ABSTRACT

The original genuine savings (GS) model started from a concern mainly with unchanged capital: if the stocks of all forms of capital decline through time, welfare will decline, too, eventually leading to unsustainability. In other words, negative GS rates indicate unsustainability. In the context of sustainable development evaluation, however, income distribution and change of *per capita* welfare are two significant dimensions that the GS model has totally ignored and that need to be aptly incorporated into the model. This is because, behind a positive GS ratio, a country still faces other factors such as current income inequality and population growth, which may undermine the enjoyable sustainable welfare. This paper therefore adjusts the GS framework for these reflections and tests its application to the United Kingdom and Taiwan between 1970 and 1998. Our result shows that the United Kingdom has more depressed GS rates and more eminent sustainable welfare loss than Taiwan over the years. This result has been accordant with some prior research claims: many resource-rich countries have achieved slow or no long-term improvements in their standards of living. Copyright © 2007 John Wiley & Sons, Ltd and ERP Environment.

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## Introduction

**A** PART FROM SOME PHYSICAL AS WELL AS SOCIAL MEASURES OF SUSTAINABLE DEVELOPMENT (SD),<sup>1</sup> another simple way to define SD is to ensure that human well-being generated from all forms of capital is sustained over time (Atkinson *et al.*, 1997). This points out that the significant features of SD involve *intergenerational equity* and *present well-being*.

The main concept of genuine savings (GS) is from 'unchanged capital' and 'savings rule'. They are fairly consistent with the mainstream definition of sustainable development. The concept of capital allows the stock-flow analysis that can make indices dynamic. It is *future oriented*, referring to trends due to the notion of capital. In addition, the general notion of the constant capital rule and savings rule is

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<sup>1</sup>I.e. stress–response models and carrying capacity for physical measurement; human development index (HDI) for social measurement.

to ensure non-declining capital stocks through generations (Atkinson *et al.*, 1997); accordingly, the issue of *intergenerational equity* can be reflected by the GS measure. That is, by definition, negative GS rates would reveal that the development is unsustainable due to *intergenerational inequality*.

Excluding the above, the genuine savings indicator (GSI), as a SD measure, can also address other sustainability issues well by meeting the operational SD criteria proposed by Pezzey in 1992b.

- (1) They are long-term criteria. Although 'sustainable economic growth' by using skilful macroeconomic management to avoid short term cycles of unemployment, inflation and trade deficits is clearly of prime policy importance, it is not our concern here, and we assume throughout that all factors of production are 'fully' employed.
- (2) Most criteria derive from a common school of ethical principles regarding intragenerational and/or intergenerational fairness or justice.
- (3) SD criteria are mostly mathematical inequalities and are therefore constraints, rather than maximizing criteria like optimality.

In view of these, the GSI predominantly addresses the operational SD issues, takes account of the SD main aspects and, very importantly, it serves as a straightforward mathematical inequality to indicate an unsustainable path if the GS rates are negative. Nevertheless, from the above, the deficiencies of the GS framework can also be clearly found in not sufficiently addressing the issues of *intragenerational equity* and *welfare measurement*.

This paper takes the broad framework developed for an extended model based on adjusted GS measurement in order to assess sustainable welfare more efficiently and accurately. Previous research results (i.e. Friedmann *et al.*, 1987; Mamingi, 1997; Iversen and Cusack, 2000) have mostly shown that many resource-rich or developed countries have achieved slow or no long-term improvements in their standard of living compared with newly industrialized countries. In order to make such comparisons, this research tests an application from the perspective of how the nations reach their sustainable welfare, with respect to the United Kingdom and Taiwan between 1970 and 1998.

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## Conceptual Background

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### Capital and Welfare

The concept of the GSI is based on the 'constant capital rule' or 'Hartwick rule'<sup>2</sup> (Hartwick, 1977); the rationale of the GSI's measuring sustainability is also through its measurement of 'changes in wealth' (wealth is the sum of all forms of capital, including man-made, natural and human capitals). The purpose of the indicator is therefore to offer an indication of whether a nation's economy is sustainable or not, through assessing the changes in a nation's wealth: if the savings of the wealth (all capital) are not enough (i.e. GSI is consistently negative) for the future, then the economy of a nation is not sustainable; however, if the savings of the wealth are positive, the development might be sustainable.<sup>3</sup>

For future generations to be better off than we are today, they must have the *capacity* to generate more well-being than we have. Indeed, as there are going to be many more people in the future, that increase in capacity must be quite marked if *per capita* well-being is to improve. But on what does well-being

<sup>2</sup> In 1977 Hartwick published an influential paper, giving conditions under which an economy dependent on a non-renewable resource could maintain a constant consumption stream into the infinite future. This was possible by observing a savings and investment rule, which ensured that the aggregate capital stock remained constant over time.

<sup>3</sup> It is argued that the GSI is a one-sided test of sustainability. A positive GS rate does not exactly indicate sustainability, since there are still other factors that might affect the path of sustainable development, i.e. population growth, technology changes and current income distribution. In this dissertation, the notion that the GSI is a one-sided sustainability indicator is acknowledged.

depend? It depends on the capability for self-realization and fulfilment, and we know that this depends heavily on education, skills and knowledge. This is *human capital* (Common, 1995).

We know that the capacity to generate high *per capita* output of goods and services, upon which well-being undeniably depends, is determined by the availability of human capital and also stocks of machinery and infrastructure, or *man-made capital*.

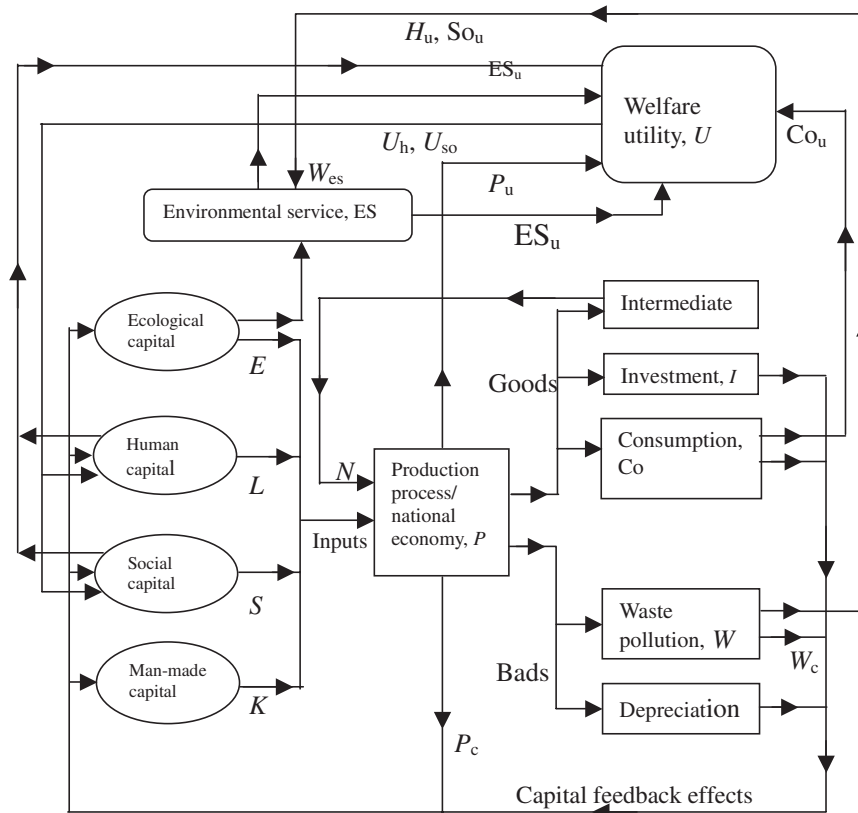
Then, it is more and more recognized that the stock of environmental assets, or *natural capital* (*ecological capital*), is important for well-being, not just because they create amenity and beauty, but because they affect our physical and mental health as well.

Finally we have *social capital*. Social capital refers to a social and cultural degree that makes a society more than the sum of a collection of individuals. Putnam (1993) views social capital as a set of 'horizontal associations' between people – it consists of social networks and associated norms that have an effect on the productivity of the community.

Capital provides the capability to generate well-being through the creation of the goods and services upon which human well-being depends (Pearce *et al.*, 1989, 1990).

Figure 1 explains how the different forms of capital work together to create the economic output (wealth) associated with the negative economic effects in the process of production. Hence, different welfare outcomes (including positive and negative) are generated throughout the whole array.

As noted above, the four forms of capital are ecological capital, human capital, social capital and man-made capital. Each of these capital stocks produces a flow of 'services' from the environment (*E*), from human capital (*L*), from social capital (*S*) and from man-made capital (*K*), services that serve as inputs



**Figure 1.** Capital flow and welfare in the process of production

Source: Ekins and Newby, 1998. Reproduced with permission from Taylor & Francis Ltd, <http://www.tandf.co.uk/journals>

into the productive process, along with 'intermediate' inputs ( $M$ ), which are previous outputs from the economy used as inputs in a subsequent process.

The purpose of production and consumption is to increase human welfare, or utility. As in conventional economic analysis, consumption contributes to welfare ( $Co_u$ ), but, as shown in Figure 1, there are many other effects on welfare from different elements of the economic process. For example, waste and pollution from the production process and consumption affect utility, both directly ( $W_u$ , e.g. litter, noise) and through their mainly negative feedback into the stocks of environmental, human and manufactured capital. These feedbacks,  $W_c$ , can reduce the productivity of environmental resources (e.g. through pollution) and affect the ecological capital that produces environmental services (e.g. by engendering climate change or damaging the ozone layer); they can damage human capital by engendering ill health and they can corrode buildings (man-made capital). They can also affect environmental services directly ( $W_{es}$ , e.g. by reducing the appreciation of natural beauty).

There is also a direct relationship between human capital and welfare; a happy worker will be more productive ( $U_h$ ), and a healthy worker will be happier as well as more productive ( $H_u$ ). Similarly, social capital has a direct relationship with welfare. Social structure (e.g. the family) is a major determinant of welfare ( $So_u$ ), while the welfare of individuals will affect the performance of social structures ( $U_{so}$ ). Finally, welfare is affected by the quality of the environment ( $E_{su}$ ) and by the work process ( $P_u$ ).

So, from the above, it is evident that welfare is generated from all forms of capital working together, and that during the process of economic production the welfare effects of capital use can be positive as well as negative.

### Economic Sustainability and Economic Welfare

The concept of weak sustainability presumes that we can construct a cardinal and comparable measure of welfare for successive generations, and that future technology and welfare functions may be predicted with reasonable accuracy (Brekke, 1997). Pezzey (1992a) also points out that 'Given a definition of sustainability as non-declining welfare or utility, we are also concerned with the way that economic growth creates needs and wants'.

Hicks (1940) defines economic welfare as welfare 'under the hypothesis of constant wants'. With this definition, economic welfare is just social welfare with given preferences, but not a more narrowly defined welfare concept. However, can we define 'economic welfare' as some narrower concept of welfare, perhaps one that is easier to measure?

At the individual level, it is not obvious that economic well-being can be separated from non-economic well-being. A person's economic resources will influence his or her potential achievements in many other areas of life, and the preferences for consumer goods will be influenced by the person's general plan of life. In view of this, we can alternatively interpret economic welfare as the economic determinant of welfare, but not as the economic part of welfare.

Daly and Cobb (1989), who defend strong sustainability, have presented an 'index of sustainable economic welfare'. Like many other such measures, it is based on an adjustment of a national accounting aggregate, in this case GDP. GDP is often interpreted as a measure of national welfare, but much of the main criticism of GDP is that GDP does not reflect the welfare consequences of environmental degradation. Daly and Cobb (1989) claim that the key pollution adjustment is for welfare effects; the underlying reason for all these corrections is that a degradation in one of the capital stocks reduces the capacity to provide future utility and hence sustainable welfare must decrease to account for those pollution and depletion costs.

In addition, economists have long recognized the need for a measure of economic welfare other than GNP or GDP. Many criticized that the focus on market transactions in the existing national income

accounts gave a misleading picture of the true health of the economy. 'It was cogently argued that additional information was required on non-market activity, on the service of consumer and government durables and intangible investment, and on environmental costs and benefits' (Ruggles, 1983, p. 32). There was some discussion of the evaluation of leisure. But including that would have required estimating large values with little available data.

In any case, the concerns of those interested in measuring long-term economic sustainability and economic welfare have not been fully dealt with in the traditional national accounts, although national income is often viewed as a base of national economic welfare. Based on an extended GS model, this paper tries to incorporate the issues in question for consideration. The other central issue in here is the possibility of measuring welfare in a manner that is comparable over time, as the sustainable path is assessed. The main purpose for measuring welfare is therefore to know whether the current policy is improving welfare over time by comparing national welfare at different points in time. This is especially important to the question of environmental degradation and sustainability.

### Inequality and Welfare

In order to take into account the level of well-being as well as the inequality in well-being when designing or evaluating social policies, one needs to use a social welfare function. The main purpose of the welfare function is to address the related factors to welfare itself, or to offer a picture of how other components (i.e. economic growth) could correspond to the welfare change, if any.

A common welfare function used in the literature is  $W = \hat{y}(1 - G)$ , an expression of a Gini-corrected mean national income  $W$ , which is based on rank-order weighted individual income levels.<sup>4</sup> Therefore,  $W$  could also be viewed as *per capita* welfare among the population. So, we denote by  $W$  the mean welfare, by  $\hat{y}$  the mean income in the population and by  $G$  the Gini index of income inequality. The higher the mean income, the higher the level of welfare, but the higher the inequality, the lower the aggregate level of welfare. This welfare function takes into account not only absolute, but also relative deprivation (people assess their own levels of welfare in part by comparing themselves with others).

The rationale of this welfare function is as follows. First, there are several intuitive interpretations of the Gini that make it easy to understand the meaning of what is measured. Two such interpretations are given below. The value of the Gini represents the expected difference in incomes of two individuals or households randomly selected from the population as a whole. For example, a Gini index of 0.60 implies that if the mean *per capita* income in the population is \$1000, the *expected difference in per capita income* of two randomly selected households will be \$600 (60% of mean income of \$1000).

As a result, in terms of welfare, if individuals or households assess their level of well-being not only in absolute terms (i.e. how much income or consumption they have), but also in relative terms (i.e. how much do they have in comparison to how much others have), then the level of welfare ( $W$ ) in a society can be represented as the product of the mean income ( $\hat{y}$ ) times one minus the Gini ( $G$ ), i.e.  $W = \hat{y}(1 - G)$ . By the Gini's definition, (1)  $G = 0$  indicates perfect income distributional equality in society (everyone has the same income), so the total enjoyable welfare among population will be the same as the total income earned by people, (2)  $G = 1$  means perfect income distributional inequality in society (only one individual or household receives the income), so the total enjoyable welfare among the population will be zero, (3) therefore, ' $1 - G$ ' stands for *an actual degree of the social income distribution*, so the total enjoyable welfare among the population will be  $Y(1 - G)$ , and  $Y$  means the total social income.

<sup>4</sup>For details please refer to the work of Sen (1976), Hammond (1978), Roberts (1980) and Yitzhaki (2000).

Based on these, with a Gini index of 0.60, a society with *per capita* (mean) income of \$1000 would have a level of *per capita* (mean) social welfare of \$400. This would be lower than the level of social welfare of a society with *per capita* (mean) income of \$800 and a Gini index of 0.40, yielding a *per capita* (mean) social welfare of \$480.

The other important way of measuring income inequality is referred to as Atkinson's (1970) index. By definition,

$$\text{Atkinson} = 1 - \left[ \sum (y_i / \gamma)^{1-e} p_i \right]^{1/(1-e)} \quad \text{for } e \neq 1$$

where

$y_i$  = mean income of people in  $i$ th income range,  
 $\gamma$  = mean income of the total income population,  
 $p_i$  = proportion of people in the  $i$ th income range,  
 $e$  = inequality aversion parameter.

The Atkinson index attempts to measure the equivalent equalized income associated with each unequal distribution of income (Atkinson, 1970). The Atkinson index falls into a group of inequality indexes based on the social welfare model. Dalton (1920) was the first person to propose measuring social welfare  $W$  as the aggregate of the utilities  $U(y_i)$  associated with each income  $y_i$ . Thus,  $W = \sum U(y_i)$ .

Dalton is also often referenced as the first to argue that a measure of income inequality could be based on this social welfare model. In practice, of course, what is required to carry out this measurement is a way of relating different incomes to the utility associated with them. Atkinson suggests that it would be possible to derive the total welfare corresponding to a particular distribution of income according to the following formula:

$$W = Y \left[ \sum (y_i / \gamma)^{1-e} p_i \right]^{1/(1-e)}$$

where  $Y$  is the total income,  $y_i$  is the mean income of the  $i$ th group,  $\gamma$  is the mean income of the total income population,  $p_i$  is the proportion of the total income population in the  $i$ th group and  $e$  is a factor that represents the weight attached by society to inequality in the distribution of income. The Atkinson index is then defined by

$$A = 1 - W/Y.$$

This therefore leads to  $W = Y(1 - A)$ , which is actually the same expression of welfare as the one just noted above.

Since welfare falls as the inequality of income distribution rises, the Atkinson index provides an increasing function of inequality in the economy, defined by the difference (normalized with respect to total income) between the total income and the welfare which it delivers. In a perfectly distributed economy,  $y_i = \gamma$  for each income group, and so the welfare level is given by

$$W = Y \left[ \sum p_i \right]^{1/(1-e)} = Y$$

and the inequality measure reduces to zero, as would be expected. The factor  $e$  is an important parameter in the measure. It represents society's preference for equality of distribution of incomes. Since it is possible to think of societies that have a positive preference for an unequal distribution of income, it is clear that  $e$  can take both negative and positive values. When  $e$  is zero, society is indifferent to the distribution of income, and welfare again reduces to the total income in the economy:



$$W = Y[\sum (\gamma_i/\gamma)p_i] = Y.^5$$

This parameter therefore allows explicitly for the possibility of attributing different welfare levels according to different attitudes towards inequality in society. In principle, the value of  $e$  can be determined in a given society by using attitudinal survey data on the level of well-being associated with different income levels. Schwartz and Winship (1980) suggest that 'after reflecting on the different interpretations of  $e$ , most sociologists would agree that when using Atkinson's measure to address normative questions,  $e$  should be between  $-0.5$  and  $2.5$ '.

So obviously here comes a problem: the acceptance of (or aversion to) income inequality is an issue that legitimately should refer to a social evaluation (for instance by surveys of public attitudes) as well as to market behaviour, and such an evaluation is not readily available for most of the countries. In this research, we therefore use the Gini index in the inequality measure.

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## Methodology

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### Genuine Savings

The concept of GS is based on a measure of wealth that is expanded to include human and natural, as well as economic, wealth. It measures the net annual increase or decrease in a nation's wealth. According to previous definitions, development is considered to be sustainable if and only if the stock of capital (wealth) remains constant or rises over time. Thus, the rate of GS can be used to measure sustainability, in that if the GS is negative it means that the capital stocks are declining and that it leads to unsustainability. In fact, the first notion of 'genuine savings' was presented briefly and informally by Hamilton (1994) and Pearce *et al.* (1996).

The savings indicator ( $S_g$ ) is

$$S_g = S - \delta_M - n(R - g) - p(e - d) + m$$

where

- $S$  = gross saving ( $S = \text{GNP} - \text{consumption}$ )
- $\delta_M$  = value of produced (man-made) asset depreciation
- $n$  = net resource rental rate
- $R$  = harvest or extraction of the natural resource (resource use)
- $g$  = regeneration rate for the natural resource ( $g = 0$  for non-renewables)<sup>6</sup>
- $p$  = marginal social cost of pollution
- $e$  = emissions of pollutants
- $d$  = rate of natural degradation of pollutants (rate of assimilation)
- $m$  = investment in human capital (current education expenditures).

The calculation of GS involves the itemization of a nation's stock of wealth, and an accounting of changes to that stock. The accounting of GS is as follows:

$$\begin{aligned} \text{genuine savings} &= \text{production} - \text{consumption} - \text{depreciation of produced assets} \\ &\quad - \text{depletion of natural assets} - \text{pollution costs} \end{aligned}$$

<sup>5</sup>To see this, note that  $\gamma = Y/P$ , where  $P$  is the total income population, and  $Y_i = \gamma_i p_i$  is the total income in the  $i$ th group.  $W$  then reduces to  $\sum Y_i = Y$ .

<sup>6</sup>The natural resource stocks grow by an amount  $g$  and are depleted by extraction  $R$ .

Item	Adjustment	Rationale
Gross domestic savings		Basis for the index
Consumption of fixed capital	–	Accounting for replacement value of produced capital in the production process
Education expenditure	+	Adding value of investments in human capital
Air pollution costs	–	Subtracting the environmental degradation costs
Water pollution costs	–	Subtracting the environmental degradation costs
CO <sub>2</sub> damage costs	–	Subtracting the environmental long-term damage costs
Natural resource depletion costs	–	Subtracting the declining costs of natural capital due to extraction or harvest
<b>Genuine savings</b>		Standing for how much a country truly saves for the future

**Table 1.** Summary of the GS calculation methodology

$$\begin{aligned}
 &= \text{gross domestic savings} - \text{consumption of fixed capital (depreciation)} \\
 &+ \text{education expenditure} - \text{air pollution costs} - \text{water pollution costs} \\
 &- \text{depletion of non-renewable natural resources} - \text{CO}_2 \text{ damage costs}^7
 \end{aligned}$$

Table 1 presents a summary of the composition of the GSI with the main rationale for each of the adjustments made.

Preliminary calculations from the World Bank (1997) suggest that the measure of GS tends to depress the savings rates of resource-rich developing countries, meaning that current patterns of economic activity are diminishing national wealth. That is, depressed rates of GS for resource-rich countries represent the fact that resources are being depleted, rather than transformed into assets.

### Extended Genuine Savings

Without attempting to devise a comprehensive measure of social welfare, it may still be possible to develop an improved measure of the contribution of economic activity to well-being. The main purpose of this research is to measure sustainable economic welfare based on an extended GS model.

Economists William Nordhaus and James Tobin (1973) sought to develop just such a measure in their pioneering essay ‘Is growth obsolete?’. Beginning with the national income accounts,<sup>8</sup> they make three different types of adjustment. (1) They reclassify GNP into consumption, investment and intermediate goods.<sup>9</sup> (2) They estimate the value of leisure, housework and the annual services of consumer durables. (3) They use wage differential between cities to evaluate ‘urban disamenities’.

Nordhaus and Tobin draw two primary conclusions from their analysis. First, they note that there are substantial differences between their MEW and GNP. In particular, estimates of the consumption of leisure and the products of housework increase the magnitude of consumption in MEW far above the

<sup>7</sup>According to standard national accounting, this also equals ‘gross domestic investment + education expenditure + current account balance after official transfers – consumption of fixed capital (depreciation) – air pollution costs – water pollution costs – depletion of non-renewable natural resources – CO<sub>2</sub> damage costs’. This is because ‘gross domestic savings = gross domestic investment + current account balance after official transfers’.

<sup>8</sup>They use personal consumption as the base from which to make adjustments because this is the closest approximation to a welfare measure in the national accounts, according to their declaration.

<sup>9</sup>GNP is intended to measure only final production, not the production of intermediate goods. Thus the cost of a car is included in GNP, but the cost of the steel and other components paid by the automobile maker do not go into GNP because they are intermediate goods.



level in GNP. Second, they argue that the growth of MEW paralleled the growth of net national product (NNP).<sup>10</sup> Although MEW grew more slowly than NNP from 1929 to 1965 (1.0% for MEW, 1.7% for NNP), Nordhaus and Tobin emphasize the fact that the two measures grew simultaneously, which suggests to them that *NNP could serve as a reasonable approximation of a measure of economic welfare*.

Their calculation thus seems to prove their contention that growth as measured by NNP is indeed associated with growth of welfare. The NNP presumably gives us an advanced approximation of economic welfare. There is then perhaps a simpler interpretation of NNP in this context: NNP is what a social planner would choose to maximize, subject to certain efficiency conditions, at each point in time in order to maximize the present value of consumption (Hartwick, 1990).

However, till recent years, the idea of 'green NNP' prevailed. In the MEW model by Nordhaus and Tobin, environmental damage and natural resource depletion are not counted in. This is the most obvious criticism with their MEW. It is now admitted that green NNP is more able to stand for national economic welfare in a broad sense; Weitzman and Lofgren (1997) contend that green NNP is a national accounting concept that subtracts off from NNP not just depreciation of capital, but also depletion of environmental assets. For a time-autonomous technology, green NNP has a rigorous welfare interpretation as an exact measure of the economy's future power to consume.

Green NNP has been discussed in some literature. In the following we conclude the definition and framework of green NNP mainly from Atkinson *et al.* (1997) to be in line with all the preconditions for measuring genuine savings.

$$\text{Green NNP} = C + I - k - n(R - g) - p(e - d)$$

where  $C$  is consumption,  $I$  net investment,  $k$  man-made capital depreciation,  $n$  the unit resource rents,  $R$  resource extraction,  $g$  resource growth,  $p$  the marginal social costs of pollution,  $e$  pollution emissions and  $d$  the natural dissipation of pollution.

By maximizing the present value of utility subject to these accounting constraints, we get the resulting green NNP as expressed above. This new expression for the economic welfare estimate can basically then combine with and follow from the preceding ideas about genuine savings.

The measure of net national product simply drops the last welfare term from this expression. The intuition behind this is clear:  $I - k - n(R - g) - p(e - d)$  is the value of *net* investment when changes in man-made stocks, natural resource stocks and stocks of pollutants, appropriately shadow priced, are included in addition to increments to the stock of produced assets; and this actually equals genuine savings minus 'investment in education', according to definitions as noted before. We know that in any accounting period, savings equals investment (as they each constitute that which is not consumed, whether by the personal sector or by government). Combining all, we therefore can deduce that

$$\text{green NNP} + m = \text{GS} + \text{consumption}$$

where  $m$  means investment in education. By standard national accounting discipline, income equals consumption plus savings. Green NNP plus  $m$  therefore denotes sustainable welfare based on a corrected national income by incorporating the consideration of human capital investment, other capital's depreciation and depletion, and negative pollution effects. Hence, the extended GS model is meant to measure sustainable economic welfare by adding the 'household consumption' to the GS in the first place. Moreover, with the extended GS model, the (sustainable) economic welfare estimate (EWE) is therefore the initiative of welfare measure:

<sup>10</sup>  $\text{NNP} = C + I - k$ , where  $C$  is consumption,  $I$  net investment and  $k$  man-made capital depreciation.

$$\text{EWE} = \text{GS} + \text{consumption}.$$

The second step of welfare measurement with the extended GS model is to adjust the welfare by using a welfare function that is originally from an inequality measure. By this, we can address the related factors to welfare itself, or to offer a picture of how other components could correspond to the welfare change. The welfare function we adopt is the one commonly used in the literature, which is

$$W = Y(1 - \text{Gini})$$

where  $W$  equals total enjoyable welfare and  $Y$  stands for total income among the population. According to this welfare function the higher the income, the higher the level of welfare, but on the other hand the higher the inequality, the lower the aggregate level of welfare. The 'inequality-adjusted EWE' is then the goal of welfare measurement in the extended GS model. From the above, we get

$$\text{inequality-adjusted EWE} = \text{EWE}(1 - \text{Gini}).$$

With this measure, we can also obtain a more comprehensive picture of (1) how much the total or *per capita* sustainable economic welfare is for a country in a given year: is it positive or negative?; (2) what the gap between the national welfare and economic output (GNP or GDP) is; (3) how the national welfare changes through the years – has the welfare declined or grown? These are all critical welfare related issues for the policy makers to look at.

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## Empirical Measurement of Sustainable Welfare Based on Extended GS: Conclusions and Discussions

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According to the welfare function presented above, welfare is certainly affected by income distribution: the higher the income inequality, the lower the aggregate level of welfare. Therefore, the inequality-adjusted  $\text{EWE} = \text{EWE}(1 - \text{Gini})$ .

Next, further to previous unadjusted GS compilation by Lin and Hope (2004), the following is concerned with the 'inequality-adjusted' economic welfare, for both Taiwan and the UK, from 1970 to 1998. Figure 2 and Figure 6 below present the Gini index and its growth trends during the years for both nations.

### Taiwan

From Figure 2, we see that for Taiwan, after year 1980, the income inequality mostly grew higher each year. We can then predict a larger decreasing amount of economic welfare due to higher income inequality during the same period. (See Figure 5 below for the estimated result regarding this.)

Figure 3 shows a comprehensive welfare figure for Taiwan in a time series, presenting how the Taiwan welfare accounts vary from genuine savings, then sustainable economic welfare, then inequality-adjusted economic welfare, and finally economic output. Accordingly, we see the growth trends of the GS, EWE, inequality-adjusted EWE and GDP over the years. Taking into account the dynamic of population growth, we then get the result of the Taiwan EWE *per capita* (both inequality-adjusted and non-inequality-adjusted) from 1970 to 1998, as shown in Figure 4. The *per capita* welfare for Taiwan has increased year by year generally.

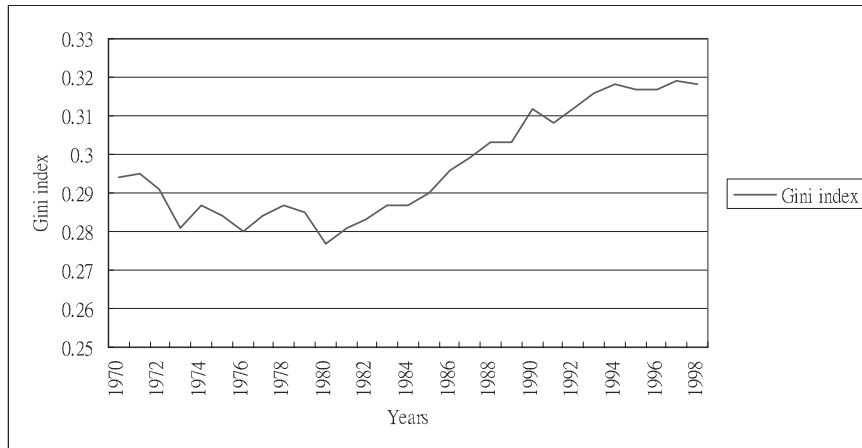


Figure 2. Gini index, Taiwan, 1970–1998

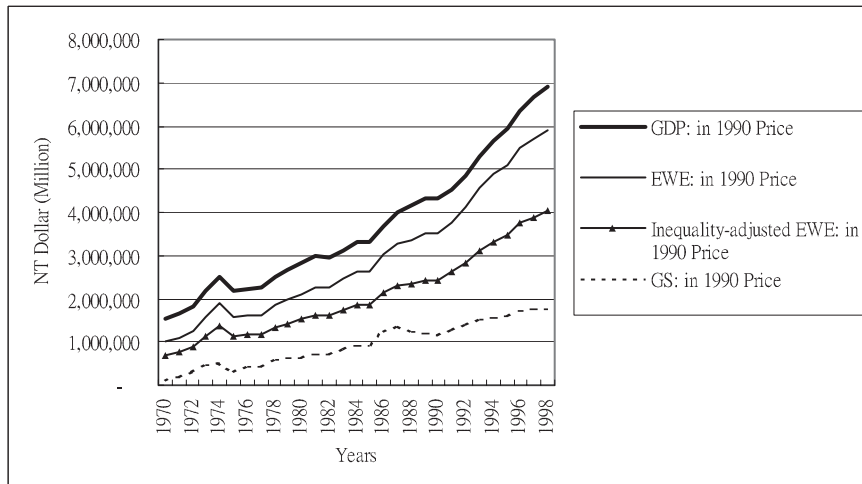


Figure 3. Sustainable economic welfare estimates, Taiwan, 1970–1998

Over the years in question, the Taiwan GDP and Taiwan EWE remain highly and steadily growing and both have a similar growth pace. But the inequality-adjusted EWE has a slower growth rate, especially after 1981, due to a larger income inequality since then. See Figure 5 for ‘welfare loss caused by income inequality for Taiwan, 1970–1998’.

The positive Taiwan GS implies that the country is not going toward unsustainability in terms of all forms of capital utilization in the first place. However, the welfare that people can share is actually lower than what is shown by the GDP value. In addition, income inequality has also lowered the welfare so the inequality-adjusted welfare can more justly account for actual welfare enjoyed by people, which is much lower than GDP but still in a growing trend in the aggregate amount.

What is more interesting here is thus the *welfare loss* items. These welfare loss accounts should attract policy makers’ attention if the country goal is to reach sustainable development – one of the critical steps leading to policy options in the economic–environmental model is ‘consequences for welfare’. In this sense, to diminish or offset the ‘welfare loss’ accounts is to increase sustainable economic welfare and

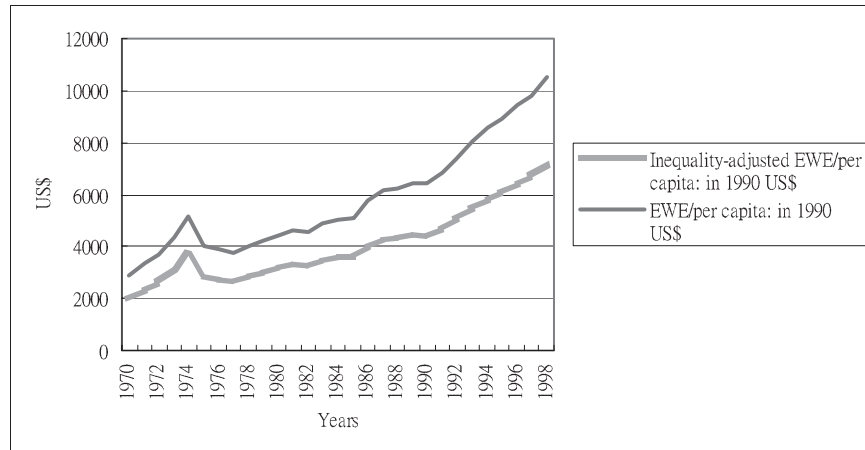


Figure 4. Sustainable economic welfare *per capita*, Taiwan, 1970–1998

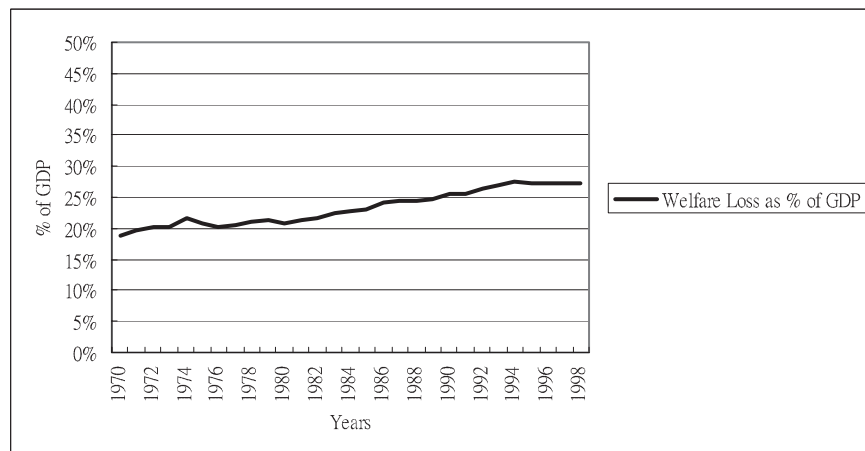


Figure 5. The welfare loss caused by income inequality, Taiwan, 1970–1998

therefore help to attain better sustainable development, and as a result is the main policy implication. After all, the main principle of sustainable development is to make sure of non-declining welfare from generation to generation (Pezzey, 1992b; Pearce *et al.*, 1996). Based on the previous discussion, the welfare loss accounts mostly contain air pollution cost, water pollution cost, natural resource depletion cost, CO<sub>2</sub> damage cost and income inequality.

The welfare loss caused by income inequality accounts for about 20–30% as a percentage of the GDP for Taiwan over the years. It is the largest welfare loss compared with the welfare loss caused by all the other accounts – the welfare loss caused among other accounts represents 0–16% of the GDP individually (see Lin and Hope, 2004). The policy makers should make efforts to increase national income equality by setting relevant tax levy and welfare policies, although this is a separate topic and will not be included in this paper.

## The United Kingdom

Figure 6 portrays the growth changes of the UK Gini index over the years. From 1972 to 1978, the Gini rates decreased, which means income inequality became lower. So, we can expect that the welfare loss should be lessened during this period. However, since 1985, the income equality condition worsened gradually, as the Gini rates increased each year since then. Therefore, an increasing welfare loss can be expected under such a circumstance. (See Figure 9 below for the estimated result in connection with this.)

Figure 7 is a complete welfare figure for the UK in a time series, indicating how the UK's welfare accounts change from genuine savings, then sustainable economic welfare, then inequality-adjusted economic welfare and in the end economic output. As a result, we see the growth trends of the GS, EWE, inequality-adjusted EWE and GDP over the years. If we consider the factor of population growth, we get the result of the UK's EWE *per capita* (both inequality adjusted and non-inequality-adjusted) from 1970 to 1998, as shown in Figure 8. The *per capita* inequality-adjusted economic welfare for the UK did not virtually grow until after 1988.

Over the years, the UK GDP and UK EWE remain growing and both are at a similar growth speed, but the inequality-adjusted EWE has a slower growth rate particularly after the 1990s, because of a larger income inequality since then. See Figure 9 for 'welfare loss caused by income inequality for the UK, 1970–1998'.

Likewise, the positive UK GS indicates that the country is not going toward unsustainability concerning all forms of capital use in the first place. However, if we look at the 'welfare' that people can share, the information is that it is lower than what is shown by the GDP value. Furthermore, inequality-adjusted welfare, which is even lower than original welfare but still in a growing trend, can more truly stand for actual welfare enjoyed by people, due to the fact that it additionally takes account of income inequality.

The main policy implication here is as follows. The welfare loss caused by income inequality accounts for about 20–40% as percentage of the GDP for the UK over the years. From the evidence it follows that this is the largest welfare loss compared with the welfare loss caused by all the other accounts – the welfare loss caused among other accounts represents 0–10% of the GDP individually (see Lin and Hope, 2004). How to minimize income inequality and then to increase sustainable welfare would be a critical policy setting.

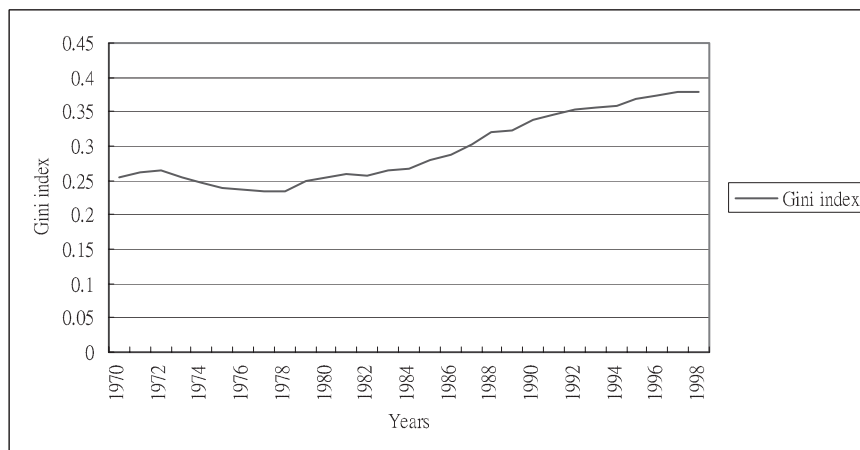


Figure 6. Gini index, UK, 1970–1998

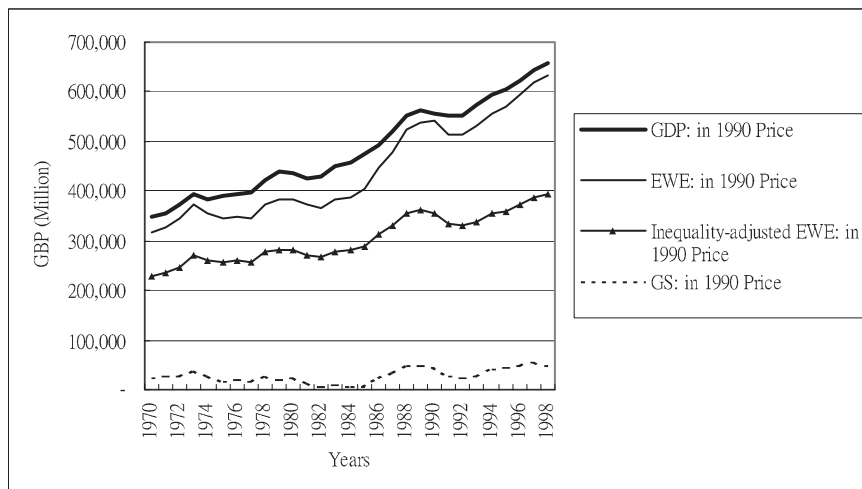


Figure 7. Sustainable economic welfare estimates, UK, 1970–1998

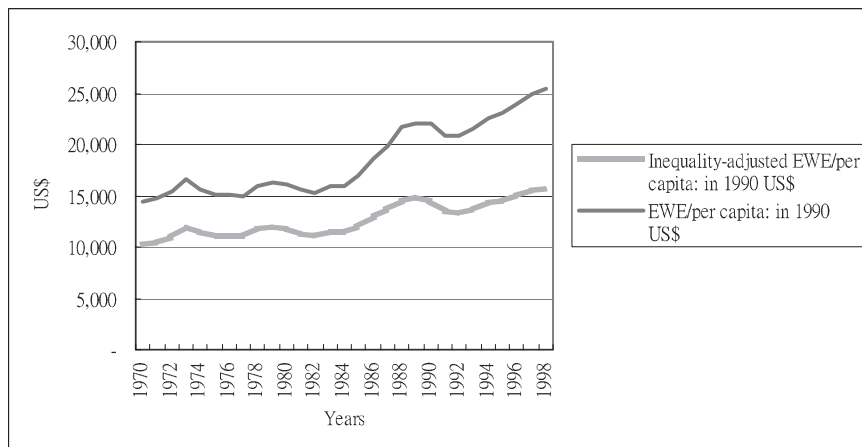


Figure 8. Sustainable economic welfare per capita, UK, 1970–1998

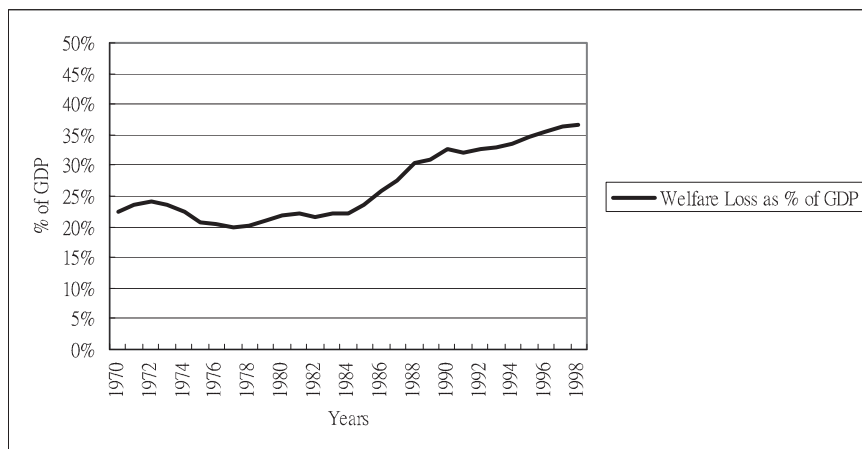


Figure 9. The welfare loss caused by income inequality, UK, 1970–1998



## Concluding Remarks

In terms of sustainable development, negative genuine savings rates indicate unsustainability. The higher the GS rates, the higher the degree of SD is. On the other hand, positive GS rates cannot ensure sustainable development. Hence, it is also necessary to look at other important factors of SD to assess the SD situation more soundly. The original GS model started from a concern mainly with unchanged capital: if the stock of all forms of capital declines through time, welfare will decline too, eventually leading to unsustainability. At this point the GS framework has already covered most primary aspects of sustainable development – economic, environmental and human dimensions. In the context of SD evaluation, however, income distribution and change of *per capita* welfare are two significant dimensions that the GS model has totally ignored and that need to be appropriately incorporated into the model. The main reason for this, as mentioned before, is that behind a positive GS a country still faces other factors such as population growth and current income inequality, which may undermine sustainable development. In this paper the GS model is extended for this concern and the main issues of income inequality and welfare are treated.

The extended GS model also suggests a set of corresponding accounts for arriving at a more correct welfare estimate, green NNP. Conventional NNP is just one subset of economic welfare. This also supports the claim that green measures of income are distinct from the measurement of economic activity in the production account (for example, NNP or GNP). Here, the EWE is basically a green NNP aggregate, and, by its definition, a highly integrative measure of resource deletion and environmental degradation. Two general conclusions following the extended model are the following: (1) NNP should be adjusted to value resource depletion and the effects of pollution emissions; (2) when including the above, this green aggregate is necessarily a (better) welfare measure rather than just a national income measure, although NNP is a starting point.

Taking inequality into account while measuring welfare is important because individuals and households do not assess their well-being only with respect to their own absolute levels of consumption or income. They also compare themselves to others. This implies that for any given level of mean income in a country, a high level of inequality reduces the overall level of welfare. In other words, inequality has a negative impact on sustainable welfare as well as on sustainable development, as mentioned before. In this sense, the *per capita* inequality-adjusted welfare in a time series will point towards how 'actual welfare' changes as population grows through time.

Although it is difficult to gain an intuitive feel for what constitutes a welfare estimate that is 'too high' or 'too low' for a given country, one certainty is that declining welfare leads to unsustainability, just as negative GS rates also result in unsustainability. The problem of welfare loss is certainly what the policy makers should pay attention to and find policy solutions to.

Through the compilation for arriving at the relevant sustainable accounts, we see clearly that natural resource and environmental accounts each have policy uses, although on their own these accounts do not provide measures of progress towards sustainable development. More specifically, while EWE also equals GS plus consumption, national sustainable economic welfare is primarily determined by the country's gross savings, consumption and various capital depletions and degradations. The analysis of welfare loss caused by various accounts including air pollution, water pollution, natural resource depletion, CO<sub>2</sub> damage and even income inequality fit well into the whole sustainable development measurement, leading to policy examinations and therefore appropriate policy choices.

The study provides evidence that recent economic outputs – GDP levels – for both the United Kingdom and Taiwan seem to be sustainable. However, as a resource-rich country, the United Kingdom has more depressed GS rates and more eminent sustainable welfare loss over the years. This result has been accordant with the prior research claims: many resource-rich countries have achieved slow or no long-term improvements in their standard of living. One possible explanation is that they failed to offset

the depletion of their natural resource stocks with sufficient investment in physical (equipment, plant and infrastructure) and human capital (knowledge and skills). However, for both countries, action could be taken to increase investment in reproducible capital and to decrease income inequality so as to offset the sustainable welfare loss for all concerned.

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