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Sustainability indicators and the shadow price of natural capital

Masayuki Sato[†], Runsinarith Phim[†] and Shunsuke Managi[‡]

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Abstract

This paper investigates the effect of shadow price regarding weak sustainability indicators based on the genuine savings indicator. We analyse the forest resources considering positive externalities of natural capital, as the approximation from market rent alone would under-estimate the true shadow price. On the basis of previous valuation results of forest resources, we estimate the non-market value and shadow price of forest, which are further used in deriving sustainability indicators measurement. The results show the importance of shadow pricing of natural capital to reflect weak sustainability indicators. Re-calculations of the sustainability indicator provide evidences suggesting that existing weak sustainability indicators tend to over-estimate sustainability, especially among countries with a higher dependence on forest-resource exploitation.

Key Words: Sustainable Development, Inclusive Wealth Index, Natural Capital, Shadow Price

JEL classification: Q23, Q51, Q56, Q57

[†]Graduate School of Human Development and Environment, Kobe University

3-11 Tsurukabuto, Nada-ku, Kobe 657-8501, Japan

Tel&Fax: +81-78-803-7808, E-mail: msat@port.kobe-u.ac.jp

[‡] Graduate School of Environmental Science, Tohoku University

1. Introduction

Since Pearce and Atkinson (1993) introduced the concept of genuine savings (GS) as an indicator of weak sustainability, a considerable amount of theoretical and empirical work on this issue has been published. More recently, Arrow et al. (2012), UNU-IHDP and UNEP (2012, 2014) and the World Bank's adjusted net savings (ANS) database have provided a theoretical framework and empirical analysis for assessing the sustainability of each country's development. This literature focus on the temporal change of comprehensive wealth or inclusive wealth as a source of human well-being. Inclusive wealth here refers to not only manmade capital but also human capital and natural capital (Arrow et al., 2003). Therefore, because inclusive wealth is a source of well-being, non-declining well-being requires non-declining inclusive wealth. As a result, the temporal change of inclusive wealth act as an indicator of sustainability.

It is widely accepted that the estimation of the values and amounts of human, natural and social capitals is not easy. Though methods to include the environmental and social capital into national economic account beyond traditional GDP have been discussed (e.g., European Commission, 2013), the valuation or pricing procedure of non-market capital is difficult. Often due to the data availability, we need to estimate such non-market capital elements. Our study intends to check the validity of the shadow prices used in constructing a sustainable development indicator.

Shadow price reflects the social value and relative importance among various types of capital. When we integrate these various components into one united indicator to assess sustainability, the estimations can have a crucial impact on the indicator for assessing whether a country is sustainable. Traditionally, the estimation of shadow prices for natural capital has been studied in the context of environmental economic valuation techniques. It should, therefore, be helpful to consider the validity of the shadow price of natural capital applying environmental economic valuation.

This paper investigates the effect of shadow price on weak sustainability based on the GS indicator, mainly using the World Bank's ANS database for this analysis. In Section 2, we identify sustainability indicator and shadow price of natural capital common with GS and the Inclusive Wealth Index and elaborate on how shadow price is approximated. In Section 3, we discuss problems related to the approximation of shadow prices, with special reference to forest stock and considering its externalities and multi-dimensionality. In Section 4, we introduce the data and econometric model for estimating shadow price of forest resources. In Section 5, we update their valuation from a purely market-based valuation. Then, we provide evidences of the importance of shadow price on sustainability. Finally, we suggest implications for constructing more comprehensive sustainability indicators.

2. Economic framework of sustainability indicators and shadow prices

Since Dasgupta and Heal (1974), Solow (1974), Smith (1974), Koopmans (1974) and Stiglitz (1974a, 1974b) provided a theoretical economic framework for analysing the sustainability of development paths, significant amount of research has investigated economic growth with regard to environmental and resource limitations. Today, rich sources of data on sustainability indicators can be obtained from the United Nations University-International Human Dimensions Programme (UNU-IHDP), the United Nations Environment Programme (UNEP) and the World Bank, all of which facilitate wealth accounting.

Arrow et al. (2003) defines sustainable development as non-declining well-being in the future, and these sustainability indicators have almost the same level of identification and interpretation as the economic description:

$$V_t = \int_t^{\infty} U(C_t) e^{-\delta(\tau - t)} d\tau \quad \text{and} \quad \frac{dV}{dt} \geq 0 \quad \textit{for all } t, \tag{1}$$

where V, U, C and δ respectively represent well-being, current well-being, consumption and social discount rate. This is therefore an approach aimed at directly measuring well-being, V. Because of the difficulty of observing well-being, however, we call for another approach, proposing measurement of the productive base of V through observing the determinants of well-being (Dasgupta, 2004).

This method is called capital approach[1], and it focuses on the amounts of all types of capital that contribute to well-being. We can reasonably assume that the amount of capital represents the productive ability for well-being. This aggregated capital is known as inclusive wealth and includes

[1] The concept of genuine savings was introduced in Pearce and Atkinson (1993).

not only man-made capital but also human capital, natural capital, and intangible capital, such as knowledge and institutions. This approach assumes substitutability of each type of capital and considers the total amount of wealth as the target of monitoring; as such, we can represent it as in (2)[2].

$$W_t = p_{KM} \cdot K_{Mt} + p_{KH} \cdot K_{Ht} + p_{KN} \cdot K_{Nt} \qquad (2)$$

Here, K_{Mt}, K_{Ht} and K_{Nt} are the accumulated monetary values of man-made capital, human capital, and natural capital at time t, respectively. In theory, each type of capital is evaluated at their own shadow price p.

Because we are confirming the criterion of weak sustainability in this paper, only the temporal changes in inclusive wealth are of interest:

$$\frac{dW_t}{dt} = p_M \frac{dK_{Mit}}{dt} + p_H \frac{dK_{Hit}}{dt} + p_N \frac{dK_{Nit}}{dt}\ . \qquad (3)$$

Our criterion requires a non-negative left-hand-side in (3) at all times t. This is consistent with the basic concepts of the GS indicator and the Inclusive Wealth Index.

For obvious reasons, if important capitals are not monitored, the reliability of this indicator is low. This implies that the right-hand side of (3) should cover all important capitals as much as possible. In fact, some studies have proposed other important capitals. For example, the Inclusive Wealth Index is proposed for extending the coverage of counted capital by including health capital in human capital. Yang et al. (2015) proposes measuring other natural capital, such as ecological capital, by using a multiple-imputation method to enrich the database of sustainability indicators.

There is another aspect of each shadow price p: because non-market capital does not have a market price, it is necessary to estimate or approximate p. The existing indicators use related market capital and rent as proxies, but when some type of natural capital has an externality or a multi-dimensional value, this approximation leads to under-estimation of natural capital depletion and over-estimation of sustainability (Dasgupta 2004). In fact the ANS data provided by the World Bank

[2] The World Development Indicators (WDI) database includes man-made capital, human capital and natural capital, but has limitations due to data availability. The WDI database includes only man-made capital, education expenditures as a proxy of human capital, and data on a few kinds of natural capital depletion, such as energy depletion, mineral depletion, forest depletion and carbon dioxide damage. The data for knowledge capital are unfortunately not available. Therefore, knowledge capital is omitted in the proposed formulation.

occasionally show positive wealth change even in countries with serious depletion and deterioration of resources and the environment, despite observations and concerns about sustainability. Based on the discussion above, our assumption is that natural capital depletion is under-valued in most existing research by setting too low a shadow price given the rapid economic capital accumulation; this causes the total change of wealth dynamics to result in a positive value (i.e., sustainable). However, because natural capital depletion is critical and irreversible, there are some cases in which the true shadow price of natural capital should be higher. If the indicator is calculated with a higher shadow price of natural capital, some countries may have negative sustainability, or be revised down as a result of depletion of high-value natural capital. In order to construct a more comprehensive indicator of sustainability, therefore, an adequate estimation of shadow price is crucial.

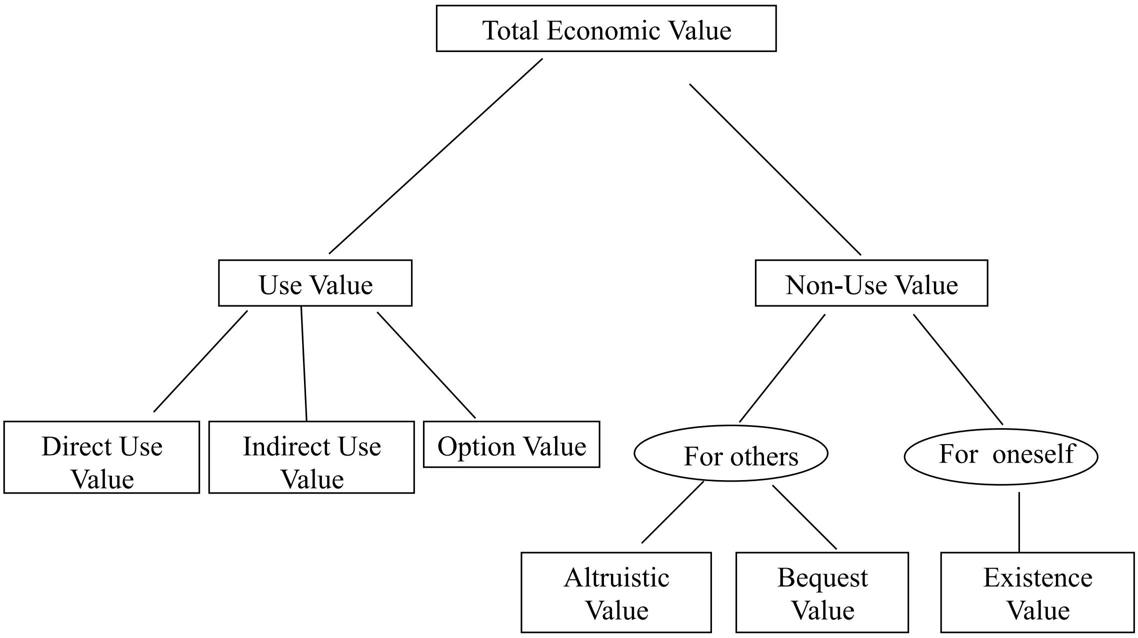
In this regard, estimations of natural capital shadow prices described in the literature on environmental valuation techniques are useful. In the next section, therefore, we consider how best to utilize the research implications of environmental valuations.

3. Shadow price of natural capital

Conceptually, natural capital includes the environment, natural resources and ecosystem stocks. Traditional studies have also included energy resources such as coal, oil and natural gas, and exhaustible mineral stocks such as steel, tin and copper. The use of these capital stocks also leads to external diseconomy through the emission of carbon dioxide and other air pollutants, but capital itself does not have a multi-dimensional value or a complex value structure. The damage caused by carbon dioxide is separately considered in the indicator and as such approximations based on market rent would appear to be justified. Such natural resources have rich data on market transactions and have sufficiently accurate price data.

In contrast, forest stock has a multi-dimensional value due to its complex externalities. As Bateman et al. (2002) summarizes, ecological stock has both use value and non-use value (Figure 1), and the non-use value sometimes has a relatively high value compared with its use value.

Figure 1. Multi-dimensional value of ecological capital



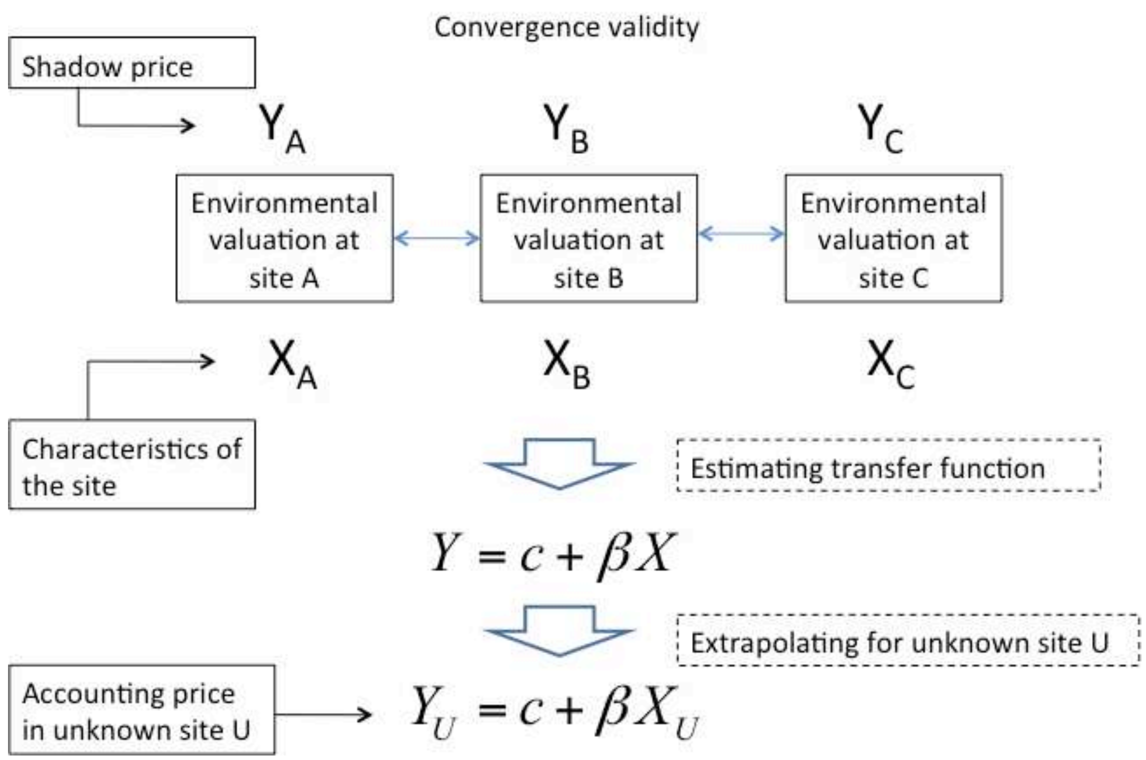
Source: Based on Bateman et al. (2002)

The category of *use value* includes direct use value, indirect use value and option value. These values are strongly related to their associated market transactions. The category of non-use value, which is not considered in market transactions, includes altruistic value, bequest value and existence value. From here, we note that the approximation of the shadow price of forest resources by market rent alone represents a limited part of the whole value of forest stock. Based on forests as a resource, market rent represents only direct use value, but Figure 1 suggests forest stock also has a recreation value as an indirect use value, genetic resource as an option value and an existence value from acting as a habitat of animals and plant life. Therefore, the approximation of the shadow price by market rent alone leads to undervaluation of forest stock. Prior research on forest valuation provides evidence of undervaluation from focus on only direct use value only and estimating willingness to pay (WTP) to determine external value. Barrio and Loureiro (2010) indicates that this type of valuation research has focused mainly on the value of wetland, forest recreation, endangered species and outdoor recreation.

Environmental economists have developed various techniques for valuation, including the contingent valuation method (CVM) and choice modelling, while the travel cost method has also been applied to value the recreation value of forest stocks (Limaei et al. 2014). Within the studies of economic valuation, the pros and cons of each technique have been clarified. For example, CVM can estimate non-use value but is easily affected by biases in the necessary questionnaire data. The travel cost method, based on market data, is objective and reliable but is not able to estimate non-use value. Each method has been well researched and the results have led to a considerable accumulation of empirical valuations.

Using the accumulated evidences of valuation studies as a data source, the benefit transfer approach can be used to estimate the relationship between the WTP for forest stock and other explanatory variables, such as targeted forest characteristics, research methodology, and socio-economic and political situations (Figure 2).

Figure 2 Framework of benefit transfer



Valuation studies are based on case studies and so the estimated values are both local and endemic. Therefore, benefit transfer research tends to estimate the domestic transfer function. However, Barrio and Loureiro (2010) estimates the international transfer function by using studies from all over the world. Even in the international context, the methodology itself is the same across domestic studies, although it is often difficult to choose and capture the characteristics of relevant explanatory variables because different countries have quite different socio-economic situations. Barrio and Loureiro (2010) classifies explanatory variables into three categories: study characteristics, characteristics of targeted goods and site and socio-economic characteristics. Study characteristics include the measurement period of WTP, the unit of respondents, valuation techniques, the format of questionnaires, survey methods and sample size. The characteristics of targeted goods include type (e.g., coniferous), forest use, biodiversity and recreation. Site characteristics include GDP (as an economic variable), forest area with respect to national land and geographical variables. It is difficult, however, to estimate the coefficient of the transfer function with sufficient accuracy, although Barrio and Loureiro (2010) finds a relatively robust effect from using economic variables (in that study, GDP). The WTP for forest value other than direct use value is expected to have a high value in rich countries. However, this finding has implications only for how the shadow price can be revised in the context of constructing sustainability indicators.

In the following section we re-estimate the relationship between the value of forest resources and GDP, and then we estimate the shadow price which should be used in relation to market rent when considering WTP. From this, we calculate the revised indicator of sustainability.

4. Data and Model

4.1 Data

We focus on the effect of the shadow price with respect to the judgement of sustainability on the basis of the indicator. For this purpose, we estimate the shadow price of natural capital, especially forest resources, using the existing research results of economic valuation of forest. Our research hypothesis is that the shadow price which is used in existing indicators is lower than the appropriate value; therefore, the indicator is over-estimating sustainability, especially in forest resource-dependent countries.

Firstly, we apply the international benefit transfer approach, following similar methods to Barrio and Loueiro (2010) in utilizing data extracted from the literature on valuing ecosystem forests from the 1990s. Table 1 summarizes the articles from which the observations of the current study are taken. As can be seen, the data used for this meta-analysis are compiled from 32 studies worldwide, but most significantly from Scandinavian countries, which make up about one third of the sample size. The reported figures on per capita GDP and WTP are homogenized through conversion into US dollars and adjusting by purchasing power parity (PPP) rates for 2011, which cancel out the variations arising from different price levels and standards of living between countries.

After estimating the transfer function, we calculate the forest shadow price which should be used in the re-calculation of the sustainability indicator. We focus on the 13 countries with data available on forest resource change among 43 countries with complete panel data regarding sustainability indicators from 1970 to 2005; this follows Sato et al. (2014). The 13 countries are China, Denmark, Ghana, Guatemala, India, Kenya, Malaysia, Nicaragua, Pakistan, the Philippines, Rwanda, Sri Lanka and Thailand.[3]

4.2 Regression Model

The model employed in this study follows that used by Brander et al. (2006) and Barrio and Loueiro (2010). Specifically, to explain the mean WTP, independent variables are grouped into three different categories that include the study characteristics, X_s, the forest and programme characteristics, X_f, and the site socio-economic characteristics, X_e. The estimation model corresponds to the following equation.

$$y_i = \alpha + X_{si}\,\beta_s + X_{fi}\;\beta_f\; + X_{ei}\;\beta_e\; + \varepsilon_i \qquad (4)$$

Here, α is the usual constant term, the β vectors are coefficients associated with the respective

[3] The panel data in this paper uses World Development Indicators (WDI) data from the World Bank and other open access databases. Note that industrialized countries such as Japan, the USA and the UK have stable forest areas. Because the change of forest stock in this countries is quite small, the effect of shadow price change is negligible.

explanatory variables to be estimated, and ε is a vector of independently and identically distributed residuals.

In the present study, log WTP is used as the dependent variable; the explanatory variables include those denoting study characteristics, the forest and programme characteristics and the site and socio-economic characteristics. The study characteristics are represented by four variables concerned with surveys: multiple payments, survey of individuals, dichotomous question format, and face-to-face survey. The forest and programme characteristics include recreation-only and tropical forest dummies. The socio-economic characteristic variables are a Scandinavian country dummy, GDP per capita, forested area in square kilometres in the country of study and the time of study. Summary statistics for these variables and their descriptions are given in Table 2.

Meta-regression analysis was performed using the stepwise regression method. This technique facilitates selection of a set of suitable explanatory variables to be included in the regression model. In stepwise regression, each candidate variable in the model is checked to determine whether its statistical significance has been reduced below the specified tolerance level. If an insignificant variable is found, it is removed from the model.

Heteroskedasticity is a common econometric problem when dealing with cross-sectional data analysis. To tackle this issue, the coefficients of variables are estimated using the "robust" option of STATA; the regression tool offers this option for estimating the standard errors by Huber–White sandwich estimators. When applying the robust option, point estimates of the coefficients are exactly the same as those produced by ordinary least squares analysis, but the standard errors take into account issues regarding heterogeneity and lack of normality.

Table 1: List of literature and collected data

Author (currency)	country	survey	wtp ppp2011	GDP per capita ppp2011	forest area (km2)	multiple	individual	dichotomous	face to face	recreation	scandi country	period1	tropical
Adams et al. (BRL)	Brazil	2002	4.4	11,144	5,397,634	1	0	0	1	0	0	0	1
Amirnejad et al.(IRR)	Iran	2004	167.8	12,753	110,750	1	0	1	1	0	0	0	1
Bernath and Roschewitz (CHF)	Switzerland	2004	87.2	47,286	12,124	0	1	0	0	1	0	0	0
Broberg (SEK)	Sweden	2005	35.1	39,176	282,030	1	1	0	0	0	1	0	0
Duthy (AUD)	Australia	1995	15.7	30,353	1,547,100	1	1	0	0	0	0	1	1
Gregory (USD)	USA	1994	62.8	38,807	2,978,790	1	1	1	0	0	0	1	1
Hadker et al. (INR)	India	1995	16.5	2,111	646,645	1	1	0	1	0	0	1	1
Horton et al. (GBP)	UK	2000	80.6	31,419	27,930	1	0	0	1	0	0	0	1
Hung et al. (VND)	Vietnam	2003	46.6	3,085	125,362	1	1	0	1	0	0	0	1
Hutchinson and Chilton(GBP)	Ireland	1992	6.1	21,838	4,990	0	0	0	1	1	0	1	0
Kleibera(CHF)	Switzerland	2000	75.5	46,809	11,940	1	1	0	1	1	0	0	0
Kniivila et al.(EUR)	Finland	2000	75.1	32,926	224,590	1	1	0	0	0	1	0	0
Kohlin (INR)	India	1995	33.2	2,111	646,645	1	0	0	1	0	0	1	1
Kramer and Mercer (USD)	USA	1992	49.7	37,241	2,971,070	0	0	0	0	0	0	1	1
Kwak et al. (KRW)	South Korea	2001	2.7	21,536	62,814	1	0	1	1	0	0	0	0
Lehtonen et al. (EUR)	Finland	2002	334.1	34,135	223,382	1	0	0	0	0	1	0	0
Lockwood et al. (AUD)	Australia	1993	337.7	28,150	37,946	1	0	0	1	0	0	1	1
Loomis et al.(USD)	USA	1993	55.9	37,762	2,974,930	1	0	0	0	0	0	1	1
Loomis et al. (AUD)	Australia	1991	122.0	28,150	1,545,420	1	0	1	0	0	0	1	1
Mantymaa et al.(FIM)	Finland	1999	110.8	31,327	224,020	1	0	0	0	0	1	1	0
Mattsson and Li (SEK)	Sweden	1992	589.8	28,549	273,026	1	1	1	0	0	1	1	0
Mill et al. (EUR)	Ireland	2003	56.2	43,393	6,710	1	1	1	1	0	0	0	0
Pouta (EUR)	Finland	1998	63.7	33,137	6,010	0	0	1	0	0	1	1	0
Reaves et al. (USD)	USA	1998	18.3	44,644	2,994,230	1	0	0	0	0	0	1	1
Sattout et al. (USD)	Lebanon	2004	99.1	12,348	1,354	1	0	0	1	0	0	0	1
Scarpa et al. (GBP)	Ireland	1992	6.5	21,838	4,990	0	1	1	1	1	0	1	0
Shechter et al. (ILS)	Israel	1989	34.6	23,762	1,320	0	1	1	0	0	0	1	1
Svedsater (SEK)	Sweden	1997	71.3	30,740	273,566	1	1		1	0	1	1	1
Tyrvainen (FIM)	Finland	1995	81.9	26,391	221,740	1	1	1	0	1	1	1	0
Tyrvainen and Vaananen(FIM)	Finland	1995	157.6	26,391	221,740	1	1	0	0	1	1	1	0
Veisten and Narvud (Norway)	Norway	1995	28.5	50,019	92,155	0	0	0	0	0	1	1	0
Walsh et al. (USD)	USA	1987	67.2	36,982	2,963,350	1	1	0	0	1	0	1	1

Source: Authors' compilation

Table 2: Summary of statistics

Variable	Definition	Obs	Mean	Std. Dev.	Expected sign
Dependent					
wtp	log of willingness to pay (ppp 2011)	32	3.92	1.23	
Explanatory					
Study characteristics					
multiple	= 1 if the wtp is per year with or without specified duration	32	0.78	0.42	+
	= 0 if the wtp is one time payment				
individual	= 1 if the respondents are individuals	32	0.50	0.51	-
	= 0 otherwise				
dichotomous	= 1 if the question format has dichotomous format	32	0.31	0.47	+
	= 0 otherwise				
face	= 1 if the survesy are conducted face to face	32	0.44	0.50	-
	= 0 otherwise				
Program and forest characterstics					
recreation	= 1 if the program has only a recreational component	32	0.22	0.42	+
	= 0 otherwise				
tropical	= 1 if the forests are in the tropical area	32	0.53	0.51	-
	= 0 otherwise				
Site and socio-economic characteristics					
sc	= 1 if the study is conducted in Scandinavian countries	32	0.31	0.47	+
	= 0 otherwise				
gdp	log of per capita GDP (ppp 2011)	32	10.05	0.83	+
forest	forest areas (km2)	32	847385	1351141	
period1	= 1 if the study conducted before 1999	32	0.63	0.49	-
	= 0 if the study was conducted after 200				

5. Results

5.1 Regression analysis

Table 3 contains the results of the meta-regression analysis with the logarithm of the mean WTP as the dependent variable. Stepwise regression removed half of the explanatory variables as insignificant. Only five variables were found to be statistically significant in explaining the mean WTP; these conform well to expectation. These include multiple (multiple payments), gdp (log per-capita GDP), forest (relative forest area), face (face-to-face survey) and tropical (tropical forest).

Table 3: Meta-regression results for wtp

Variable		Coefficient	t-value	
constant		0.0739873	0.04	
multiple		1.161666	2.83	***
gdp		0.3419885	2.11	**
forest		-5.83E-07	-4.81	***
face		-1.133356	-2.58	**
tropical		0.9175443	1.75	*
dochotomous	*removed*			
period1	*removed*			
individual	*removed*			
recreation	*removed*			
sc	*removed*			
Number of observations 32				
R-squared 0.469				

Note: *** statistically significant at 1 % level
** statistically significant at 5 % level
* statistically significant at 10 % level

The results show that the model fits the data well. In relation to study characteristics, the frequency of payment (‘multiple’) was found to be positive and statistically significant. Its coefficient suggests that the conservation programmes which require annual payment (with or without specified duration) tend to have a higher WTP compared with those that require one-time payment. In contrast, the face-to-face variable appears to exert a negative effect on the mean WTP, and its coefficient suggests a 1.13 percent reduction of mean WTP when the survey is conducted face to face.

With regards to the forest characteristics, the meta-regression results suggest that tropical forests have a higher value than other types of forest. Its coefficient is positive and statistically significant and implies that people are willing to pay more (around 91.7 percent higher than usual) in order to preserve tropical forests.

Finally, from the site and socio-economic aspects, the forest area of the studied country appears to be negatively related to the mean WTP. It is likely that the larger the forest area the lower the mean WTP. However, the analysis found that the coefficient of the variable *gdp* is also positive and statistically significant at the 5% level. This suggests that a one percent increase in GDP per capita would be associated with 0.34 percent increase in the mean WTP for forest conservation.

Based on the results of the regression analysis, we calculate the shadow price which we argue should be used when constructing the sustainability indicator. Note that, as discussed in Section 2, the shadow price of forest, P_f, should include both parts of market rent, R_f, and non-market value, W_f:

$$P_f = R_f + W_f$$

Then, the social loss of forest resource depletion, K_f, should be calculated on the basis of the shadow price of forest, giving

$$K_f = P_f \times \Delta forest,$$

where Δ*forest* represents the decrease in the amount of forest resource. From the regression results, when we focus on the effect of the GDP term, the non-market value is affected by GDP per capita as follows.[4]

$$W_{ft} = 1.0034 \times \left(\frac{GDP_{ct} - GDP_{c0}}{GDP_{c0}}\right) \times W_{f0} \quad (5)$$

Here, W_{ft} represents the WTP for the non-market value of forest at time *t*, GDP_{ct} represents GDP per capita at time *t*, and $GDPc_0$ represents the base year's GDP per capita. Then, we obtain the formula of forest resource depletion as (6).

$$\begin{aligned} K_f &= P_f \times \Delta forest \\ &= \left\{R_f + 1.0034 \times \left(\frac{GDP_{ct} - GDP_{c0}}{GDP_{c0}}\right) \times W_{f0}\right\} \times \Delta forest \\ &= R_f \times \Delta forest + W_{f0} \times \Delta forest \times \left\{1.0034 \times \left(\frac{GDP_{ct} - GDP_{c0}}{GDP_{c0}}\right)\right\} \quad (6) \end{aligned}$$

Using this equation, we re-estimate forest depletion considering the lost non-market value.

[4] Because this paper does not focus on the method of forest valuation, we ignore some variables related to valuation technique.

5.1 Re-calculation of forest depletion and sustainability indicator

As the calculation of the GS indicator in the previous section shows, when we consider the non-market value of forest in the construction of the sustainability indicator, the judgement of sustainability is sometimes revised down. In some cases, the judgement is revised from sustainable to unsustainable. In this subsection, we provide the results for individual countries. Figure 3(a)-(f) provides the calculated results for forest depletion (left) and GS (right) on each country. The solid line represents the recalculated results from using the newly estimated shadow price of forest.

Figure 3(a) Forest depletion and sustainability indicator for China and India

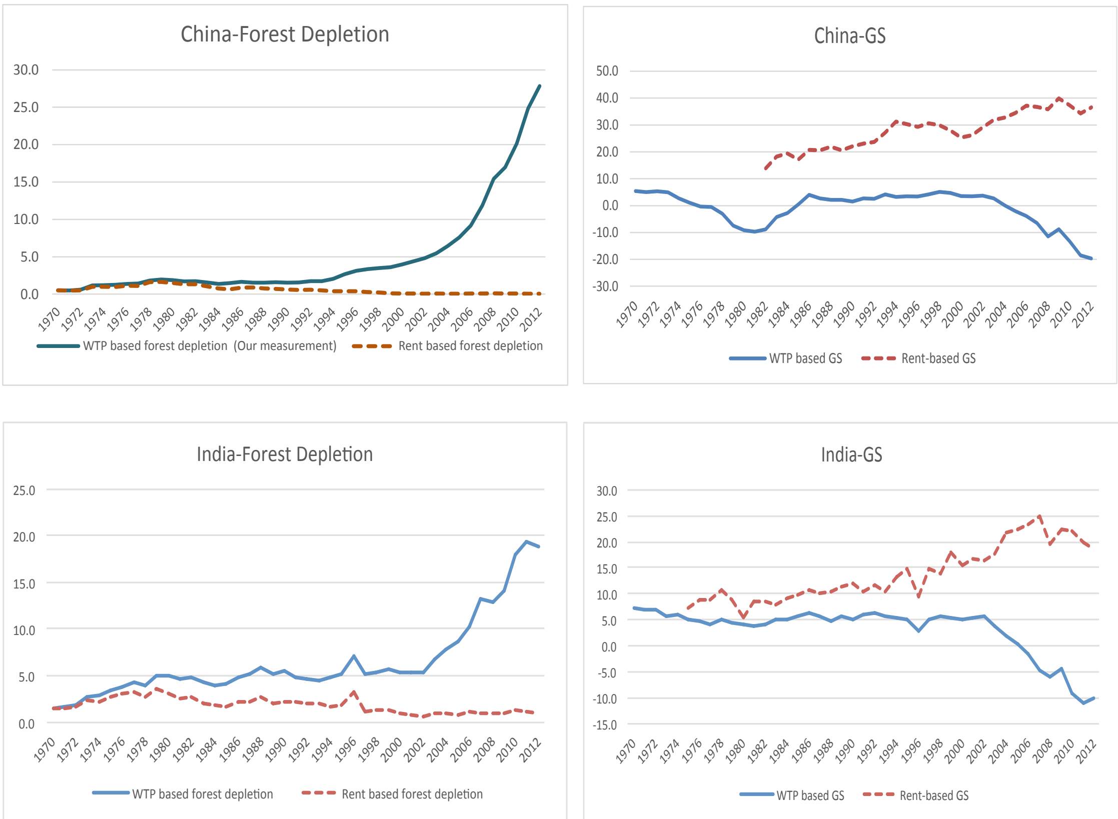


Figure 3(b) Denmark

Figure 3(c) Ghana and Guatemala

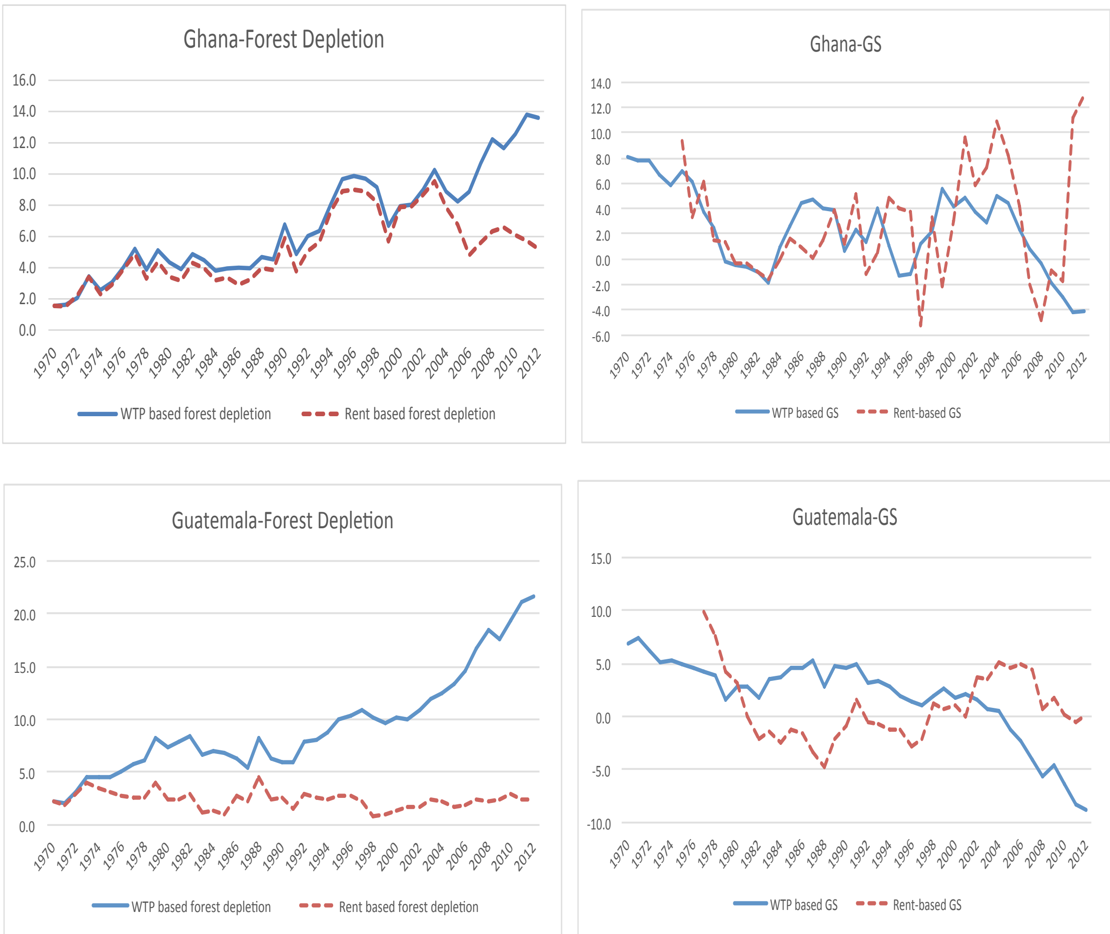
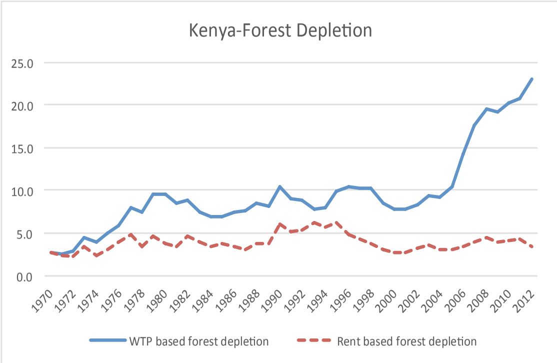
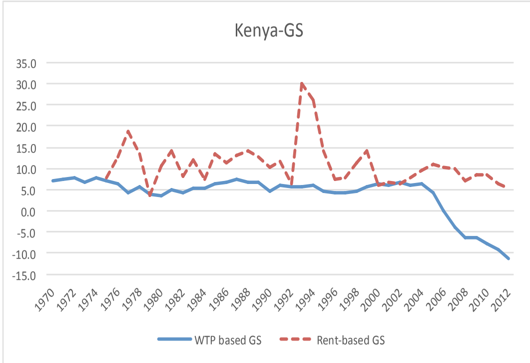
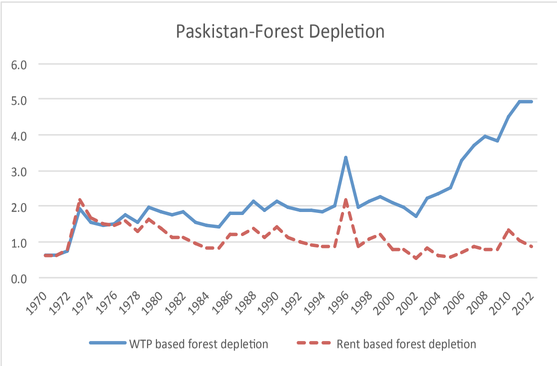
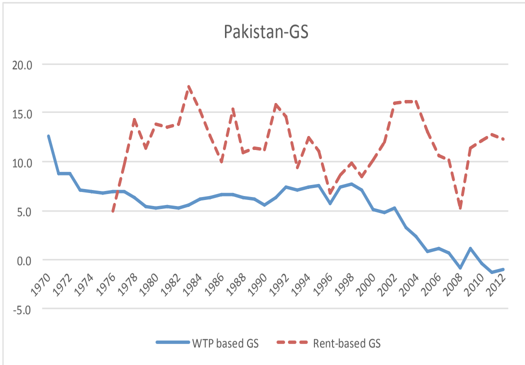


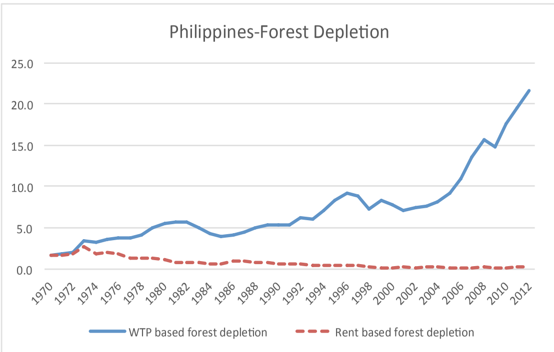
Figure 3(d) Kenya, Pakistan, the Philippines and Malaysia

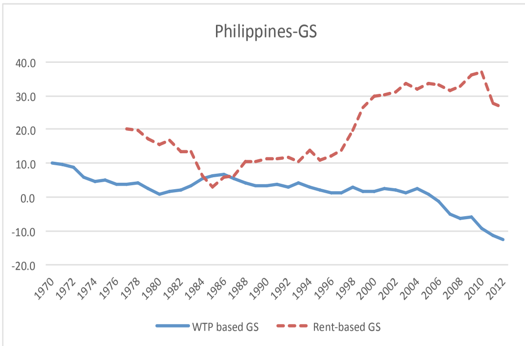


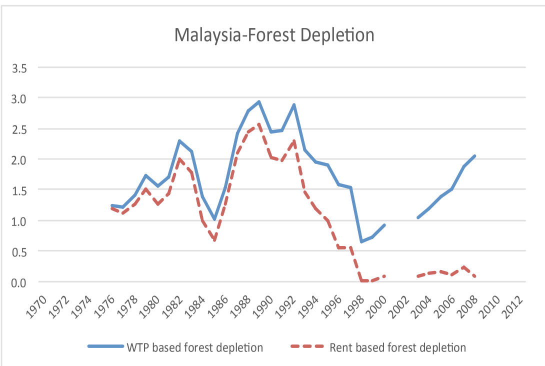












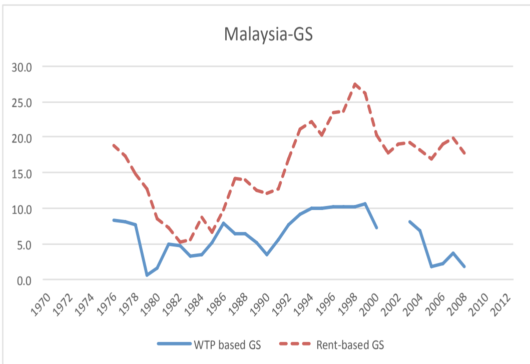


Figure 3(e) Rwanda, Sri Lanka and Thailand

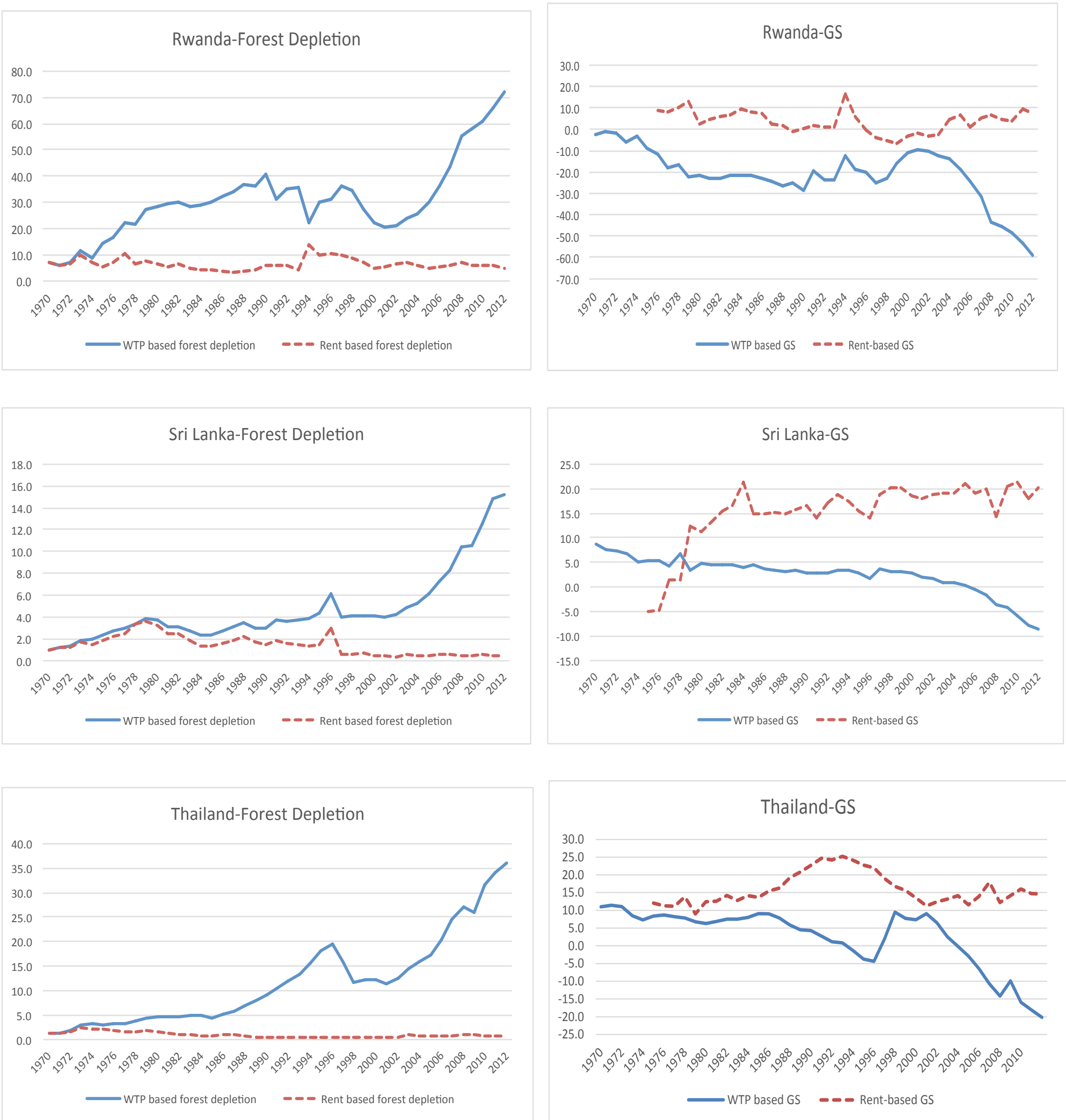
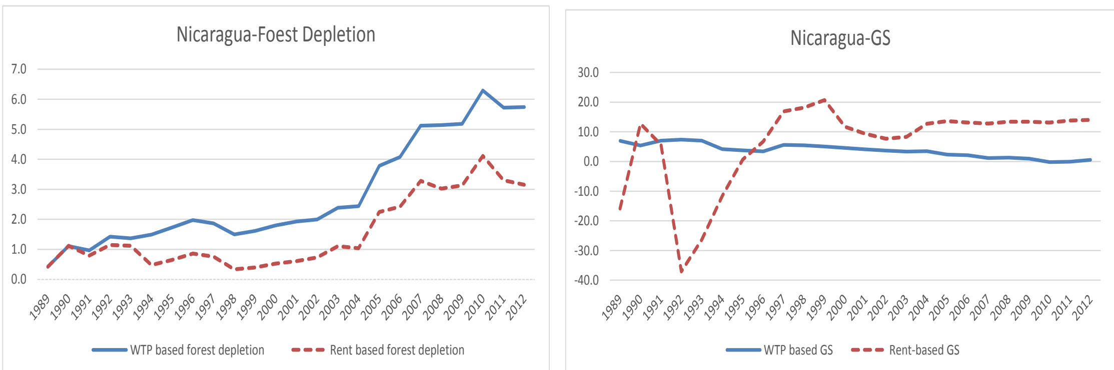


Figure 3(f) Forest Depletion and Sustainability Indicator in Nicaragua



China and India

As can be seen, the social loss of forest depletion is valued higher when we use the estimated shadow price, which includes non-market value. Therefore, the GS data should be revised downward. The non-market value in China and India is not negligible. As a result, the judgement of sustainability using GS changes from sustainable to unsustainable at many points of time.

Denmark

Compared with the case of China, the effect of revising the shadow price of forest is small in Denmark. This is because the amount of decrease of forest is also small and the revision of shadow price has a negligible effect. Therefore, the judgement of sustainability using the revised indicator is the same as that found when using the existing indicator.

Ghana and Guatemala

As can be seen in Figure 5, the cases of Ghana and Guatemala reveal an interesting relationship between WTP-based GS and rent-based GS. In some years, we can observe the reverse of WTP-based and rent-based GS due to a change of GDP level. In both countries, the shadow prices have a critical effect on the judgement of sustainability in some periods.

Kenya, Pakistan, the Philippines and Malaysia

In these countries, the shadow price of natural capital recently became important due to growth in GDP and increases in the non-market value of forest. However, the amount of downward revision of GS is insufficient to change the judgement of sustainability.

Rwanda, Sri-Lanka and Thailand

As in the findings for Kenya, Pakistan, the Philippines and Malaysia, the cases of Rwanda, Sri Lanka and Thailand have a number of similar characteristics. However, these countries have effects from revising shadow prices that change recent judgements of sustainability. In these countries, the shadow price of forest resources is of critical importance in judging sustainability.

Nicaragua

As a country, Nicaragua is difficult to interpret regarding the influence of the shadow price. The social loss of forest depletion is shown to be higher in its WTP-based valuation. However, the actual amount does not have a significant impact on the country's sustainability assessment.

6. Concluding Remarks

This study shows the importance of the shadow price of natural capital in elaborating weak sustainability indicators. We focused on the shadow price of forest resources due to the fact that forests have a multi-dimensional value and approximations by means of market rent alone lead to an under-estimation of the true shadow price.

The results of provides evidences which indicating that existing studies that use weak sustainability indicators tend to over-estimate sustainability, especially among those countries that have a higher dependency on forest resource exploitation. The results are intended to fill the gap between existing indicators through illustrations of our own estimates of each country's sustainability.

This study has also demonstrated that there is a need to introduce the attainment of environmental economic valuations into the construction of sustainability indicators. This will enhance the research into estimations of shadow prices in order to build up a richer database source that can be used for the economic valuation of natural capital and sustainability indicators. In this regard, more detailed information about species, biota, biodiversity, cultural and aesthetic characteristics, among others, will clearly be helpful.

In terms of beneficial future research initiatives it is important to expand the coverage of types of capital. In this paper, we have placed a focus on forest resources within the economic category of natural capital as there is no natural capital with an associated externality in existing indicators. However, when we extend capital by including, for example, biodiversity, fisheries and land use, the methodology outlined and applied within this paper should be useful in estimating other shadow prices based on the concepts and theoretical approaches of environmental economics. Recently, rich data on the value of ecosystems have been provided by important research findings, including those addressing the economics of ecosystems and biodiversity (De Groot et al., 2013), and a more sophisticated method to estimate shadow prices (Fenichel and Abbott, 2014). Recent and on-going research, makes clear that there is a pressing need to develop a database of inclusive wealth suitable for assessing and managing sustainability.

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