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THE ECONOMIC VALUATION OF URBAN ECOSYSTEM SERVICES

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ABSTRACT: The economic valuation of ecosystem services in cities often relies on the concept of willingness to pay. Such reliance invariably leads to the adoption of methods that have several inherent limitations. The object of this paper is to present both a conceptual and methodological framework within which valuation could proceed. The conceptual premise rests on the principle that several ecosystem services cannot be compromised if the urban economy is to be sustainable. Hence methodologically, the valuation of such services could be approached by recourse to the opportunity cost concept, namely the levels of income that need to be sacrificed in order to retain the sustainability of the urban economy. In the long-run the enhanced productivity and sustainability of the urban systems would offset the short-run losses which are incorrectly magnified.

1. INTRODUCTION

The valuation of ecosystems that support urban areas is primarily for policy formulation and decision making. For example, consider a decision to clear a wooded area within an urban precinct for some form of development that yields monetary returns. A question that policy makers often ask in such an instance is: "Would the benefits of development exceed the benefits of preserving the wooded area"? The indiscriminate adoption of the cost-benefit criterion in such instances is inevitably flawed. This is because decision making of this vein overlooks important linkages between the ecosystem and the (urban) economy. The most vital linkage to be acknowledged is the premise that any economy – urban or otherwise – could not exist without a minimal threshold level of ecosystem support. Very often the value of urban

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ecosystem services is elicited by recourse to the valuation of visible uses such as recreation and nature appreciation. The dominant valuation approaches in such contexts are methods based on contingent valuation, travel costs and hedonic prices; for example see Pearce (2006), Thampapillai (2006) and Sinden and Worrell (1979). Apart from the myriad of issues associated with such methods (Knetsch 1994), the monetary estimates elicited can never depict the true value of ecosystem services. For example, consider the case of the aforementioned wooded area. The value of the ecosystem service provided by this area can extend far beyond visible uses. It could for instance include watershed services, bio-diversity benefits and micro-climate regulation. Further, an acknowledgement of the premise that some threshold level of ecosystem services needs to be retained for sustaining the (urban) economy implies that the value of ecosystem services would exponentially increase with their utilization.

The aim of this paper is to present a valuation framework based on the opportunity cost method. The main argument herein is that at any time, one could only assess the minimum value of ecosystem services. Such minimum value has to be equated to the monetary benefits that need to be foregone in order to preserve ecosystems. The same way as subjectivity is central to methods such as contingent valuation – subjectivity is central to opportunity cost methods as well. The subjective assessment is guided by the notion of an "acceptable sacrifice" and added scientific inquiry. Returning to the case of the wooded area, it is possible in the first instance, to ascertain the value of income that needs to be foregone in order to preserve this area. If the size of income sacrifice is (subjectively) deemed small, then the preservation option may be preferable in the light of the broad spectrum of ecosystem services that are not readily visible. Alternatively, even when the income sacrifice is substantially large, scientific inquiry may dictate that preservation is in order.

The paper is structured as follows. The next section deals with a conceptual framework that provides the basis for eliciting the opportunity cost value within the urban context. This is followed by the consideration of a quasi-hypothetical case study.

2. THE CONCEPTUAL FRAMEWORK

The framework for valuation rests on the concepts of entropy, assimilative capacity and assimilative ability from environmental science; for example see Daly (1992) and Leandri (2009). Urban ecosystems are generally highly entropic with limited assimilative capacity and ability. Hence urban development will inevitably entail an erosion of assimilative capacity (and ability) alongside the raising of entropy. This is illustrated in Figure-1.

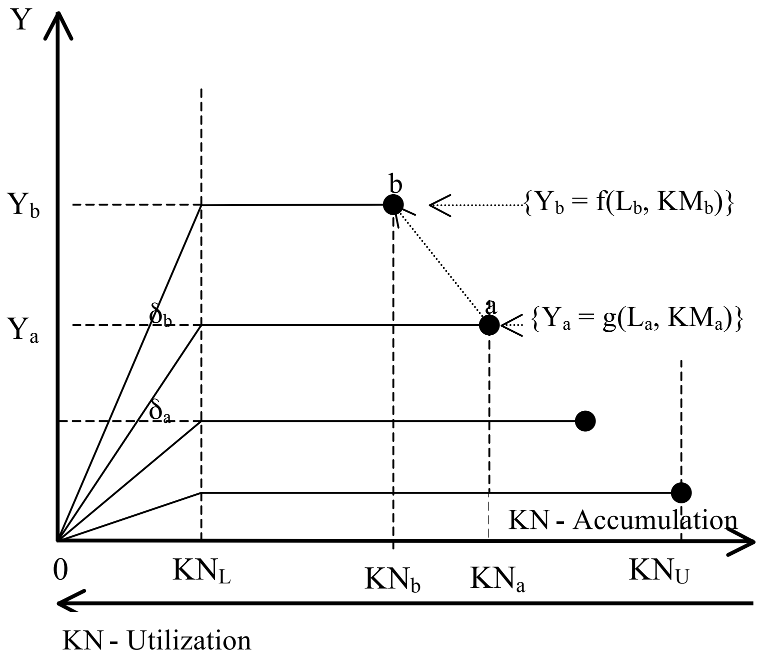

Figure-1: Conceptual Framework for relating Ecosystem and Income

Consider Figure-1.Suppose that some metric is available for the quantification of the ecosystem which supports the urban environment. That is, all components and attributes of the ecosystem can be aggregated into a single numerical scale such as an index and is represented by KN along the horizontal axis. The accumulation of KN runs from left to right, whilst its utilization is represented from right to left. It is also assumed that in the primitive state – where no urban development has occurred - the maximum capacity of the ecosystem is KN_U and the domain of assimilative ability is represented by $\{0 \leftrightarrow KN_U\}$. This state is consistent with the lowest level of entropy for this system and the absence of any income (Y) which is represented on the vertical scale. Urban development would entail the generation of Y. Higher levels of Y are enabled by utilizing more labour (L) and capital (KM). For example, in Figure-1, the level of income Y_b is due to the utilization intensity (L_b, KM_b), which exceeds (L_a, KM_a) that is associated with income level Y_a. But as illustrated, the higher level of Y would also entail a contraction in the domain of assimilative ability including a reduction in the maximum capacity. Further, higher levels of Y also prompt an increase in the gradient of degradation (δ), namely the rate at which Y falls per unit loss of KN. In Figure-1, it is supposed that the degradation commences when the level of utilization exceeds some minimum threshold level of KN, namely KN_L. That is, once the size if the ecosystem falls below KN_L, assimilative ability is lost and degradation sets in. The essence of the conceptualization presented in Figure-1 is that the ecosystem becomes more fragile with higher entropy as resource utilization and income increase.

For example suppose that the present position of an urban economy is point **a** in Figure-1 and that a commercial development project will take this economy to point **b**. In such an instance the increase in income (Y_b - Y_a) is associated with:

- Contraction in the domain of assimilative ability by $\{KN_a - KN_b\}$ and
- Increase in the gradient of degradation by $\{\delta_b - \delta_a\}$.

Note that $\{KN_a - KN_b\}$ is the amount of KN that gets utilized or lost when income increases from Y_a to Y_b. However, some uncertainty exists as to whether the increase in income $(Y_b - Y_a)$ can be maintained. This is because higher levels of income are associated with higher levels of ecosystem fragility and entropy. In such a context, the increase in the degradation gradient $\{\delta_b - \delta_a\}$ can be regarded as an indicator of the higher level of risk of ecosystem failure. Hence the opportunity cost of preventing the loss and enduring a higher level of risk is the increase in income less the potential to lose income because of higher entropy and fragility. This can expressed as:

$$OC = \{Y_b - Y_a\} - \lambda\{[\delta_b - \delta_a] * [KN_a - KN_b]\} \tag{1}$$

In (1), the increase in potential income loss per unit of KN lost, namely $\{\delta_b - \delta_a\}$ is taken as a proxy for the cost of risk induced by the enhanced fragility of the ecosystem; and λ is a risk aversion coefficient that ranges between zero and 1. That is, if the urban planner is a pure risk taker, then $\lambda = 0$ and the OC amounts to $\{Y_b - Y_a\}$. If the policy maker is fully risk averse, then $\lambda = 1$, the OC is reduced in full by the cost of risk. Also note that in terms of the premises presented in Figure-1:

$$\{\delta_b - \delta_a\} = \left(\frac{(Y_b - Y_a)}{KN_L}\right) \tag{2}$$

Hence, the expression given in (1) is also equivalent to:

$$OC = \{Y_b - Y_a\} - \left(\lambda * \left[\frac{[KN_a - KN_b]}{KN_L}\right] * [Y_b - Y_a]\right) \tag{3}$$

Note that besides λ, the ratio $\left[\frac{[KN_a - KN_b]}{KN_L}\right]$ also scales the cost of risk. That is, for example:

$$\left(\left[\frac{[KN_a - KN_b]}{KN_L}\right] > 1\right) \text{ for } \left([KN_a - KN_b] > KN_L\right) \qquad (4)$$

The opportunity cost is maximum only when ($\lambda = 0$); that is, when risk aversion is totally absent.

At least two implications emerge from the conceptual analysis presented thus far. The first is that when many of the invisible contributions of KN are known and yet cannot be readily quantified, decision makers would prefer to err on the side of caution and forego potential income gains. The legitimate question in such a context is whether the OC of preserving KN an acceptable sacrifice. When the risk of system failure is also included (as in (1) and (2) above), the size of the OC becomes smaller. As a result, the task of subjectively assessing whether the sacrifice is acceptable or not becomes easier. That is, the smaller the sacrifice, the easier it is to err on the side of caution. The second implication is the need to consider the prospect of stabilizing income levels at a certain magnitude rather than expanding them. This would be particularly pertinent to highly urbanized centres where both entropy and ecosystem fragility are high. In such a context the portfolio of urban activities would have to include the rehabilitation of KN and various measures and innovations to maintain the prevailing levels of KN.

3. A QUASI-HYPOTHETICAL CASE STUDY

This case-study is partially hypothetical because some of the data is assumed. Hence the case is more illustrative than real. The Singapore economy has at in its central region some 3000 hectares of parkland that also contain a set of 5 reservoirs which form part of the urban area's water supply. 1000 hectares of this space represents a catchment area for the reservoirs. Some hydro-geologists claim that whilst the catchment terrain assists with surface run off to feed the reservoirs, the parkland is also a source for recharging the ground water system. The recharge attribute contributes to the maintenance of water levels not only in reservoirs in the vicinity of the parkland but also elsewhere. Further suppose that some hydro-geologists have estimated that the parkland contributes to the supply of some 60 million gallons of water per day. Owing to the pressure of population growth and increasing demand for housing – there are some proposals for converting the parkland into a housing estate. There are some suggestions that around 450,000 dwellings in the context of high-rise complexes with some open space could be erected. Further, it is suggested that the loss of water supply through the catchment characteristics could be offset by the construction of a desalination plant. Some data for the analysis is as follows:

1. The construction cost of a single dwelling is assumed to be \$140,000 and construction is spread over three years
2. Average returns from housing is approximated to \$2000 per dwelling per month over a 25 year time period
3. The desalination plant of 60 million gallons per day capacity could cost \$890 million to construct and thereon \$3 million per year to maintain.
4. The metric for KN in the conceptual framework proposed above is reduced to water supply capacity. KN_a and KN_b are assumed to be respectively 60 and 40 million gallons of water per day. This is because despite the housing construction, residual land area would retain some catchment characteristics and the housing infrastructure itself would have drainage designs to feed the reservoirs. KN_L is assumed to be 30 million gallons per day.

With reference to this illustration the basic opportunity cost of preserving the 1000 hectares of parkland, that is $(Y_b – Y_a)$, would amount to:

(Rental returns from Housing) – (Housing construction costs) – (Costs of desalination)

As illustrated in Table-1 below, this opportunity cost is approximately $154.6 billion in present value terms.

Table-1: Summary of Housing Benefits and Costs

Present Value of Housing Benefits	$217,307,186,190.91
Present Value of Costs (Housing + Desalination)	$62,703,461,912.67
Net Present Value of Housing Development	$154,603,724,278.24

The risk adjusted value of opportunity cost as per (2) and (3) above will depend on the magnitude of the risk aversion coefficient as illustrated in Table-2 and Figure-2.

Table-2: Opportunity Cost of Preservation including Risk

λ	Risk Cost (R)	OC-R
1.0	$103,069,149,519	$51,534,574,759
0.9	$92,762,234,567	$61,841,489,711
0.8	$82,455,319,615	$72,148,404,663
0.7	$72,148,404,663	$82,455,319,615
0.6	$61,841,489,711	$92,762,234,567
0.5	$51,534,574,759	$103,069,149,519
0.4	$41,227,659,808	$113,376,064,471
0.3	$30,920,744,856	$123,682,979,423
0.2	$20,613,829,904	$133,989,894,374
0.1	$10,306,914,952	$144,296,809,326
0.0	$0	$154,603,724,278

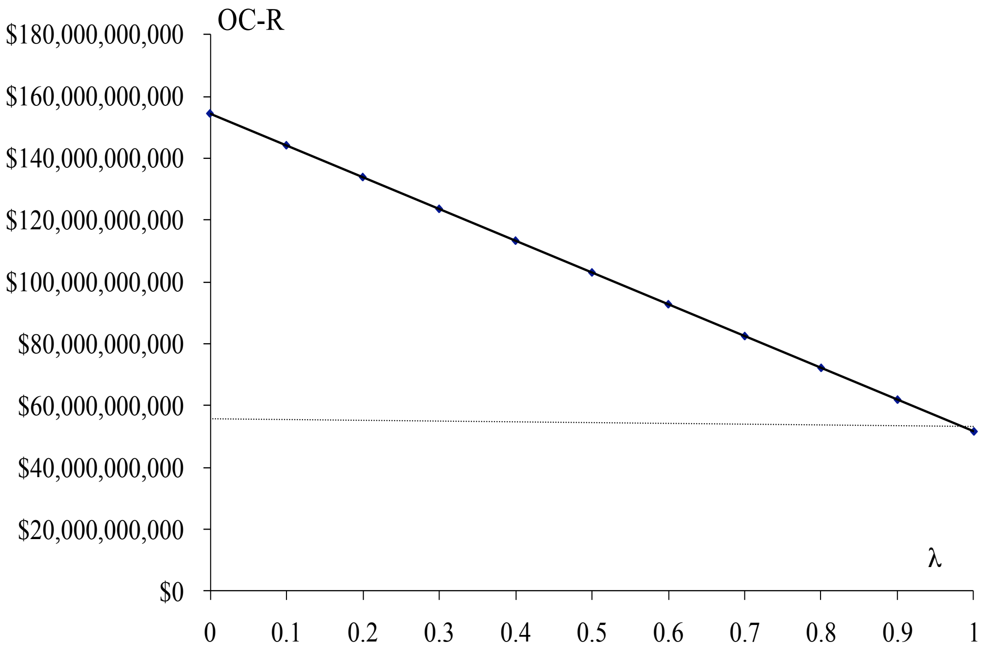

Figure-2: The Income-Risk Trade-Off

As illustrated the opportunity cost of preservation reduces from \$154.6 billion in the context of pure risk-taking to about \$51.53 billion in the context of pure risk aversion. In the event the decision maker is risk-neutral (λ = 0.5), the he/she will opt for the choice of \$103.07 billion as preferred income and this could be tantamount to preserving 50% of the land area.

The question of acceptable sacrifice for preserving the parkland is a difficult issue. This is because even with complete risk aversion (λ = 1), the value of income benefits to be given up is \$51.53 billion. In this context the assessment of acceptability could be aided by applying the concept of a threshold value (TV) (Krutilla and Fisher 1975). A definition of TV to the context of the case study considered here is as follows: *The minimum value of the benefits of preserving the parklands in the initial year and that would grow at a specific rate such that the present value of preservation is at least equal to the net present value housing development.* That is, the threshold value (TV) is the initial year's minimum value for preservation benefits that would render preservation just as desirable as housing development. Following Krutilla and Fisher (1975), TV can be estimated as:

$$\mathrm{TV} = \left[\frac{(\text{Present value of housing benefits})}{(\text{Present value of \$1 growing at the rate of growth of the preservation benefits})} \right]$$

The nomination of an appropriate rate of growth for preservation benefits is a difficult task, and has to be guided by scientific inquiry. For illustrative purposes, a growth rate of 0.5% per year is assumed below and the TV for different levels risk aversion is illustrated in Table-3 below.

Consider the extreme scenario of pure risk-taking ($\lambda = 0$). If those who seek preservation could clearly demonstrate that the value of preservation benefits as of now is in excess of $6.51 billion, then there is a case for preservation taking precedence over housing development.

Table-3: Threshold Values and Risk Aversion

λ	TV
1.0	$2,169,876,832
0.9	$2,603,852,198
0.8	$3,037,827,565
0.7	$3,471,802,931
0.6	$3,905,778,298
0.5	$4,339,753,664
0.4	$4,773,729,030
0.3	$5,207,704,397
0.2	$5,641,679,763
0.1	$6,075,655,130
0.0	$6,509,630,496

An alternative line of reasoning could proceed as follows. The preservation benefit per unit of housing in the context of ($\lambda = 0$), namely ($6.51 billion/450,000), is $14,500. Property analysts have claimed that the land value that is built into residential house prices is in excess of $100,000 per dwelling. The TV analysis reveals that an initial outlay at the rate of $14,500 per dwelling growing at 0.5% per annum would yield the same net present value as an outlay of $100,000 per dwelling. Hence there exists a case for arguing in favour of preservation. Such a line of reasoning is no doubt tenuous in the context of scarce housing, high house prices and rentals.

4. CONCLUDING THOUGHTS

As indicated, the opportunity cost criterion dictates that the value of the ecosystem must at least equal the value of development if preservation is to be given precedence. The example considered above dealt with the issue of water conservation versus housing development. It is true that in most urban contexts, housing is scarce and the provision of shelter is a noble objective. Nevertheless, water is also a basic need. Uncertain regimes of climate change could render vulnerabilities of water shortages that could be difficult to contend with. Also note that the adoption of desalination as a substitute for traditional water supply is not without difficulties – especially with reference to brine disposal; for example see Lattemann and Höpner (2007).

It is also pertinent for urban planners seeking to enhance incomes to consider portfolio activities that would fall within the realm of closed-loop production systems. For example, the closed-loop type of sewerage treatment practiced in Singapore protects the marine ecosystem and enhances the capacity to capture atmospheric carbon. Similarly closing the loop on industrial wastes and reusing them in various innovative ventures help protect fragile urban ecosystems. The added expenditures incurred with reference to diversifying the urban economy portfolio is more than likely to deliver long-term ecosystem stability.

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