THE ENVIRONMENT IN MACROECONOMIC ANALYSES - COMPARISONS BETWEEN SWEDEN AND THE UNITED STATES[1]

Dodo J. Thampapillai[2]
Macquarie University, Sydney NSW 2109, Australia.

Stig Wandén
The Swedish Environment Protection Agency, Stockholm Sweden S - 171 85.

Markus Larsson
Swedish University of Agricultural Sciences, Uppsala Sweden S-750 07.

Hans-Erik Uhlin
Swedish University of Agricultural Sciences, Uppsala Sweden S-750 07.

ABSTRACT Following the tradition of defining sustainable income as the difference between net national product and the allowance for the depreciation of environmental capital, a proxy is sought for the latter. By recourse to a Cobb-Douglas production function and some simplifying assumptions, the proxy is equated to energy consumption expenditure. The resulting income measure is tested for Sweden and the United States. The comparative analysis illustrates the scope for formulating policies that reconcile objectives that pertain to environmental sustainability income and employment. The policies considered are: improvements in environmental capital efficiency, real wages, and environmental capital investments.

1. INTRODUCTION

The recognition of the natural environment as a capital asset in aggregate production (Hartwick 1993, Mäler 1991, and Solow 1992) warrants a certain proportion of net national product (NNP) to be set aside to offset the asset's depreciation. If this depreciation allowance is denoted as C_{EM}, then

$$Y = NNP - C_{EM} \tag{1}$$

becomes a measure of sustainable income. However, a pre-requisite for sustainability is that the allocation of C_{EM} should prevent any diminution in the stock of environmental capital. Because the efforts to value macro-level environmental damages have been rather recent, only a few point estimates of C_{EM}

[1] With the usual disclaimers we remain grateful for the support given by the Swedish Environment Protection Authority and for valuable suggestions from our colleagues at SLU

[2] Visiting Professor, Department of Economics, The Swedish University of Agricultural Sciences at Uppsala

seem available, and these too in a few countries. The object of this paper is two fold. The first is to illustrate a proxy method of valuation for C_{EM} in the context of a Cobb-Douglas production technology and sparse environmental data. The second is to illustrate how these aggregate environmental values can be used in adapting a standard macroeconomic policy model. We follow earlier analyses of the United States (US) economy (Thampapillai and Uhlin 1995, 1996) and consider a simple Keynesian model of income determination where the price level is given and output is determined by aggregate demand. The illustrations here are made in the context of the US and Swedish economies.

The paper is structured as follows. The conceptual framework for valuation is developed in the next section, and the values of C_{EM} are then illustrated for Sweden and the US. This is then followed by an evaluation of macroeconomic policies that are related to the concept of environmental capital efficiency. We compare the effects of achieving efficiency gains in the utilisation of environmental capital against those of increasing investments and lowering real wages. Though sufficient evidence is not at hand, we also present a case for a special class of investments for raising incomes and employment - environment capital investments.

2. THE VALUATION FRAMEWORK

As Peskin and Lutz (1993) reveal in their review, most practitioners of environmental accounting appear to concede that C_{EM} is primarily made up of pollution abatement expenditures. Hence, we suggest a valuation procedure based on the premise that the depreciation of environmental capital is due to the accumulation of residuals which originate from the utilisation of environmental resources.

Since we have assumed that C_{EM} deals primarily with residuals (R_Q) which originate from the utilisation of environmental resources (R) in aggregate production (Y_n = NNP), it can be valued in terms of the marginal change in aggregate output. That is,

$$C_{EM} = (\_Y_n / \_R_Q)^* R_Q \qquad (2)$$

A simple form for this expression can be derived by combining a Cobb-Douglas production function as proposed by Solow (1974, 1986) with a linear relationship between R and R_Q as follows.

$$Y_n = \alpha R^{\lambda} K^{\theta} L^{(1-\lambda-\theta)} \qquad (3)$$

$$R = \rho R_Q \qquad (4)$$

Following the properties of the Cobb-Douglas function, θ, $(1-\lambda-\theta)$ and λ are the income shares respectively of capital (K), labour (L) and environmental resources (R). In (4), the parameter ρ can be interpreted as one that describes the technology of resource utilisation for the production of Y_n, and is simply the ratio of resource inputs to their residuals. If we assume that all R_Q of a given period emerge from the R employed in the same period, then R_Q ² R and ρ ³ 1, due to the first law of thermodynamics and the fact that a certain proportion of R is retained within output.

Letting $[\gamma = (C_{EM} / NNP)]$, and using $[C_{EM} = (\_Y_n / \_R_Q)*R_Q]$, an expression for γ can be derived as follows.

$$C_{EM} = \lambda\alpha\rho^{\lambda}R_Q{}^{\lambda}K^{\theta}L^{(1-\lambda-\theta)}, \tag{5}$$

and

$$\gamma = [\lambda\alpha\rho^{\lambda}R_Q{}^{\lambda}K^{\theta}L^{(1-\lambda-\theta)}] / [\alpha\rho^{\lambda}R_Q K^{\theta}L^{(1-\lambda-\theta)}] = \lambda \tag{6}$$

That is, if the relationship between R and R_Q is linear, and the unit cost in C_{EM} is the marginal change in output, then "the share of C_{EM} in NNP" equals "the share of resource expenditures in NNP" regardless the size of ρ. In such an economy, sustainable income is NNP less the aggregate resource input expenditures.

To estimate γ, it is assumed that R is made up of all forms of energy that are consumed by the economy. This assumption, though arduous, can be defended on the grounds that energy is a basic input in all production, and that its utilisation is the dominant source of residuals. To generate the values of C_{EM}, the total consumption of energy in coal equivalents was multiplied by the 1982 price of coal. These C_{EM} values are then subtracted from the observed values of NNP to provide estimates of sustainable income as shown in Table 1. However we caution that energy consumption expenditure is a weak proxy which could understate the true magnitude of C_{EM}.

Tests for convergence between linear trends of "observed NNP" and "NNP-C_{EM}" are illustrated in Figures 1a and 1b. As indicated in these figures, there is an explicit potential for convergence in the US economy, whilst it is not the case for Sweden. When tested with nonlinear trends, the potential for convergence was diminished in the case of the US. But, for Sweden, the nonlinear tests revealed divergence instead of convergence. This lack of convergence for Sweden is perhaps more the outcome of using a weak proxy rather than actual inefficiencies in the Swedish system. This is because Sweden as a nation, is perceived to be more environmentally friendly than the US. Anecdotal evidence suggests that environmentally friendly activities such as recycling, public transport and modest consumption are more dominant in Sweden than in the US. Nevertheless, two economies can be still compared in terms of the relationship between the depreciation allowance and sustainable income.This is considered next.

3. DEPRECIATION ALLOWANCE AND SUSTAINABLE INCOME

In attempting to formulate a relationship for $C_{EM} = f(Y)$, the simplest is to assume a relationship by supposing that C_{EM} is a fixed proportion of NNP; say, $C_{EM} = \gamma\ (NNP)$ as in the case of Cobb-Douglas method presented above. By splitting NNP into two aggregate components, namely C - consumption , and Φ -

Table 1. Values of C_{EM} and Estimates of Sustainable Income

The United States				Sweden		
C_{EM}	NNP	NNP-C_{EM}	Year	C_{EM}	NNP	NNP-C_{EM}
158.39	2542.37	2383.98	1976	19.41	538.38	518.97
157.27	2659.07	2501.80	1977	19.49	524.21	504.72
172.07	2797.03	2624.96	1978	19.34	531.40	512.06
163.85	2854.22	2690.37	1979	27.62	552.36	524.74
164.96	2832.57	2667.61	1980	25.89	556.25	530.36
154.24	2878.59	2724.35	1981	28.48	549.59	521.10
144.87	2782.81	2637.94	1982	27.75	549.64	521.89
149.50	2897.40	2747.90	1983	27.01	557.05	530.04
154.05	3115.91	2961.86	1984	26.58	580.19	553.61
155.03	3278.01	3122.98	1985	30.44	592.11	561.67
154.70	3313.71	3159.01	1986	29.94	609.24	579.31
157.66	3390.81	3233.15	1987	30.31	630.49	600.18
167.84	3527.85	3360.01	1988	31.08	641.92	610.84
175.82	3625.21	3449.39	1989	29.60	655.25	625.65
174.07	3644.93	3470.86	1990	30.52	646.04	615.52
168.18	3578.45	3410.27	1991	28.37	638.96	610.59
174.20	3659.81	3485.61	1992	26.24	622.26	596.02

$$C_{EM} = \gamma\Phi + \gamma\beta Y \qquad (7)$$

However, it is perhaps not reasonable to assume that C_{EM} would increase at a constant rate in response to income creation as implied by a linear function. The entropic nature of environmental changes (Daly, 1991 and Daly and Cobb, 1989) suggests that $C_{EM} = f(Y)$ should satisfy $f'(Y) > 0$ as well as $f''(Y) > 0$. Tests on a range of functional forms in an earlier analysis (Thampapillai and Uhlin, 1995, 1997) indicate that an exponential function best fits the data, when C_{EM} is measured in terms of energy resource expenditure. That is,

$$C_{EM} = e^{\eta(NNP)} = e^{\eta(\gamma\Phi + \gamma\beta Y)} \qquad (8)$$

An examination of the coefficients which influence the shifts in C_{EM}, namely γ (which is C_{EM}/NNP) and η (which is lnC_{EM}/NNP), reveal a distinct downward trend for the US and a mixed trend for Sweden, (Figure 2).

In other words, the environmental depreciation schedule displays rightward shifts in both economies, but, the shift is much less pronounced in the case of Sweden relative to the US. This implies that the US has achieved far greater efficiency gains in using the natural environment towards output formation compared to Sweden.

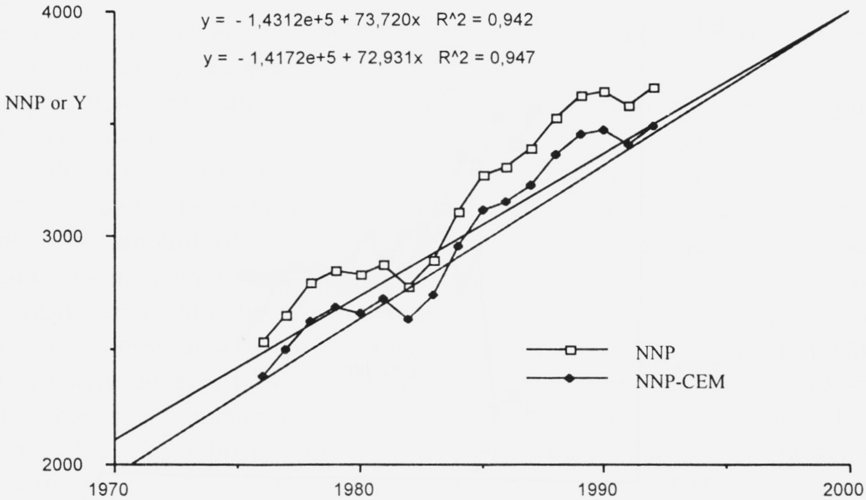

Figure 1a. Test for Convergence between NNP and (NNP-C_{EM}) - US

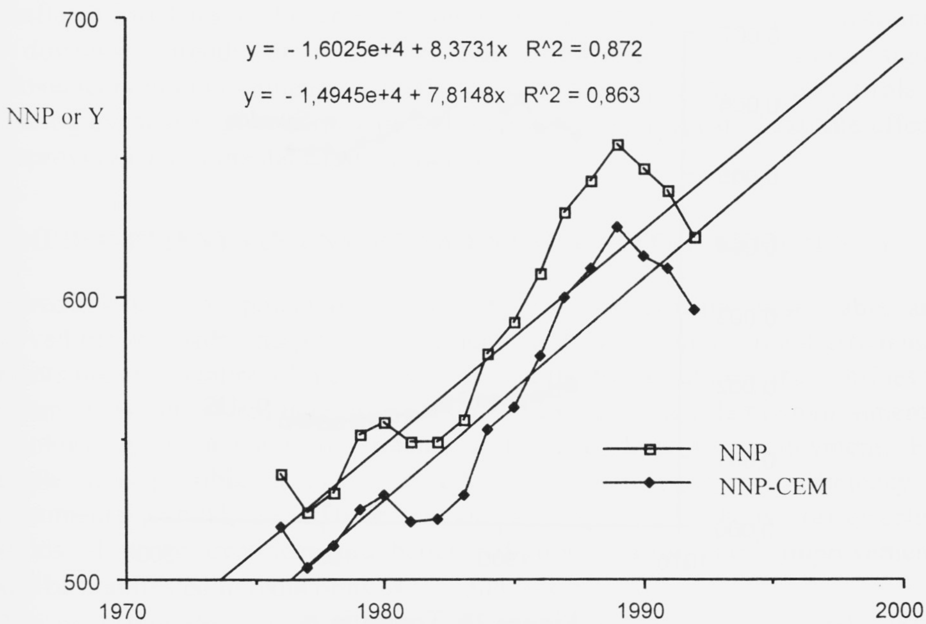

Figure 1b. Test for Convergence between NNP and (NNP-C_{EM}) - Sweden

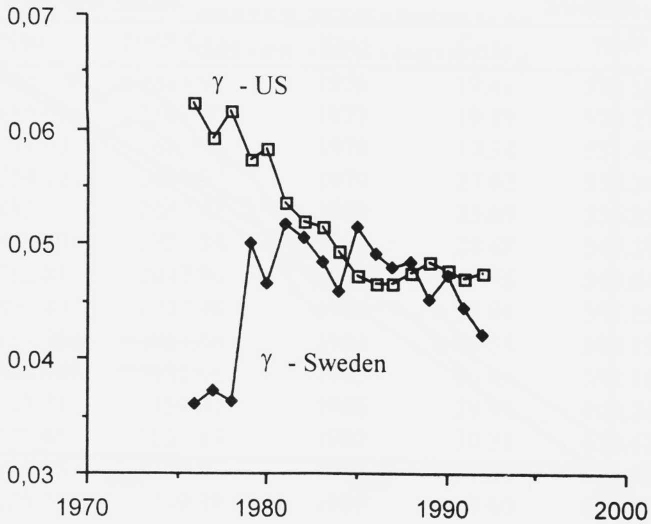

Figure 2a. Trends in γ

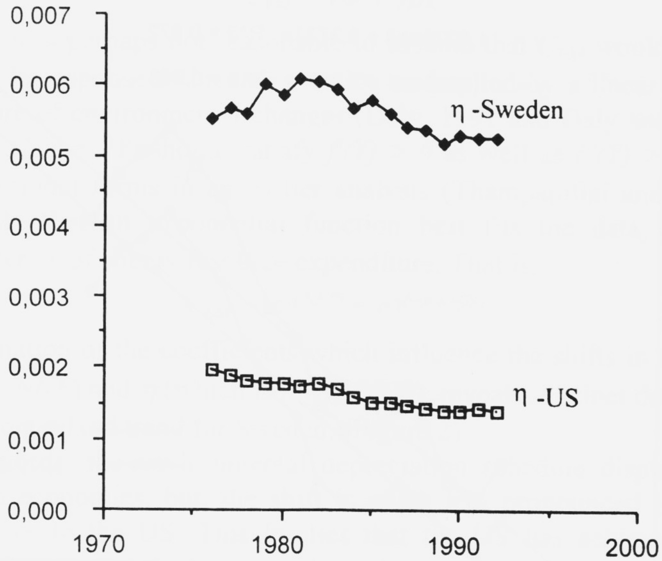

Figure 2b. Trends in η

Efficiency gains in using environmental capital can come from a mixture of two sources:

(i) the adoption of production techniques which are less dependent on environmental capital, and

(ii) changes in society's attitudinal and behavioural characteristics with regard to the environment.

Some items which explain energy efficiency are compared in Table 2. In most production techniques, Sweden is seemingly more efficient than the US. For example, the amount of energy required to create a unit of GDP in either agriculture or industry is less in Sweden than in the US, and the amount of per capita waste generated is far less in Sweden compared to the US. Sweden's relative superiority in these areas (that is, waste generation and energy requirements of GDP) is partly governed by attitudinal and behavioural features. For example, parking spaces of suburban railway stations in Sweden are stacked with commuters' bicycles, whilst in the US one observes these spaces to be stacked with automobiles.

The significant difference between the two economies appears to lie in Sweden's dominant dependence on relatively environmentally unfriendly sources of energy production. In 1991, nearly 80% of all commercial energy in Sweden was produced from nuclear sources, whereas in the US, the share of nuclear energy was under 10%. It is likely that the overwhelming dependence on nuclear energy has inflated Sweden's total energy consumption expenditure and hence constrained the downward trends of γ and η. Such downward trends which signal improvements in environmental capital efficiency could play an important role in achieving expansion of employment and output. So, we evaluate next, the effects of improving environmental capital efficiency.

4. IMPROVEMENTS IN ENVIRONMENTAL CAPITAL EFFICIENCY

Sweden's lack of potential for convergence between the sustainable and observed income paths, despite improvements in environmental capital efficiency, warrants the examination of measures to reverse the trends. Within the confines of the framework considered here, it is possible to examine the role of environmental technology, environmental investments and relate them to employment. For example, it is possible to raise income by improvements in the "efficiency of environmental capital use". These include developments such as cost-effective methods of waste treatment and better pollution control. Such improvements would be manifested in reductions of C_{EM} and γ or η.

We estimated the output effects of improvements in environmental capital efficiency (ECE) for each year between 1987 to 1989. Improvement in ECE was measured as the percentage reduction in η. The estimation was performed by determining equilibrium income for each year in the context of the nonlinear expression for C_{EM}. That is,

Table 2. Sweden and the US: Comparisons in Selected Energy Related Aspects

		Sweden	The US
1.	Energy Intensity in Agriculture (Mega Joules/Agricultural GDP - 1989)	4.0	6.0
2.	Energy Intensity in Industry (Mega Joules/Industrial GDP - 1989)	10.0	12.0
3.	Per Capita Municipal Wastes ('000t - 1985/96)	317.0	864.0
4.	Per Capita CO_2 Emissions ('000t - 1991)	6.23	19.53
5.	% Share of Sources in Commercial Energy Production that are Relatively Environmentally Friendly (1991)		
	• Natural Gas	0.0	28.7
	• Wind and Geothermal	0.0	0.84
6.	% Share of Sources in Commercial Energy Production that are Relatively Environmentally Unfriendly (1991)		
	• Nuclear	78.5	9.80
	• Hydro	21.4	1.50
	• Solid (Coal)	0.0	32.5
	• Liquid (Petroleum)	0.0	26.5

Source: World Resources Institute (1993, 1994)

$$Y = F + bU - e^{h[F+bY]} \qquad (9)$$

For a given value of η, a positive equilibrium is feasible as far as values of NNP exist such that $[\eta e^{\eta[NNP]} < 1]$. The determination of equilibrium income (Y^*) is which is illustrated in the appendix (Figure A-1), involved a computational approach. The value of Y was iteratively changed until the LHS of (9) equalled its RHS.

The estimation of Y^* in response to changes in ECE was done by parametrically reducing η, whilst keeping Φ and β fixed at the levels observed for the relevant years. For example, in the schedule describing the relationship for the US in 1987 (Figure 3a), Φ and β are fixed at the respective observed values of \$889 billion and 0.773.

The estimations enable the identification of the level of ECE that needs to be attained for satisfying specific social objectives such as employment. For example, in 1989, Sweden experienced approximately 3% unemployment. The magnitude of NNP to achieve full employment (at the then average annual wage of SEK 170, 922) would have been SEK 675.14 billion (as opposed to then observed NNP of SEK 655.24 billion). As can be seen from Figure 3b, attaining this employment goal by ECE alone would require a substantial improvement - nearly 40%. In the case of the US, for the same year (1989), a smaller but yet substantial improvement in ECE (20%), would have been required for attaining the full employment income of \$3,827 billion.

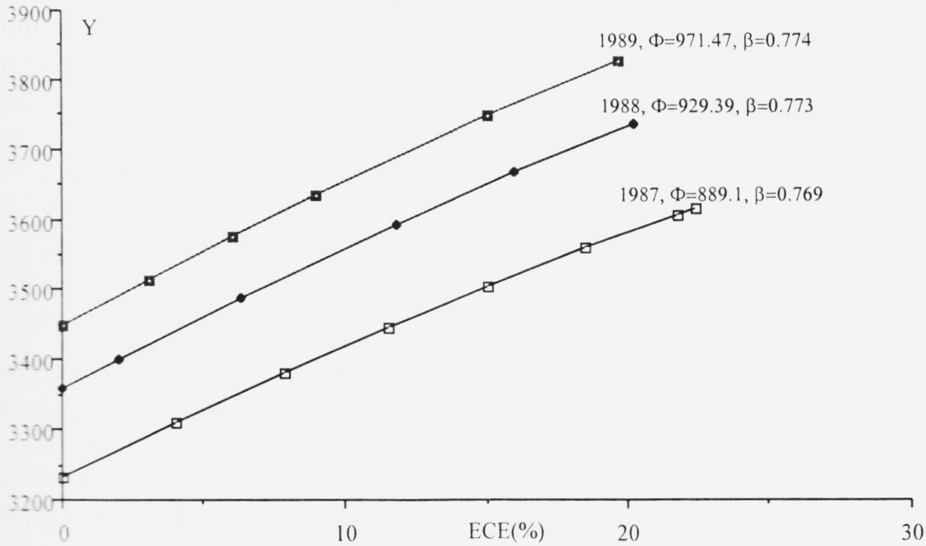

Figure 3a. Improvements in Environmental Capital Efficiency and Output - US

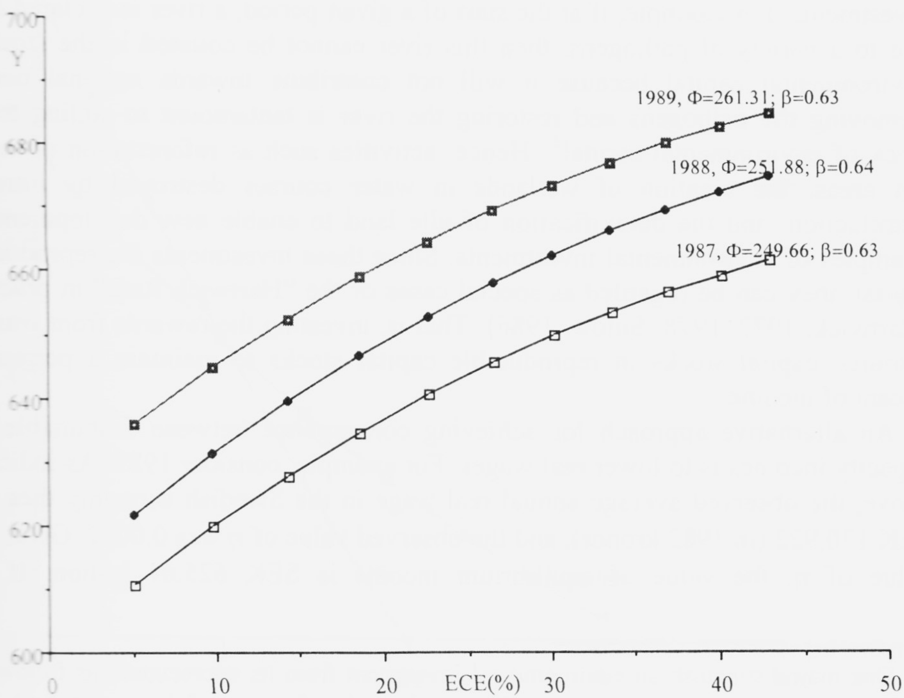

Figure 3b. Improvements in Environmental Capital Efficiency and Output - Sweden

The increases in ECE for full employment, being rather large, may not be technologically feasible, at least in the short term. Hence we also considered the responsiveness of *Y* to changes in Φ (which includes government expenditure, net exports and investment). The following comparison can be made for 1989 in terms of responsiveness of *Y* to changes in ECE as against changes in Φ:

	Sweden	US
Increase in *Y* for a 1% increase in ECE -	0.33% (SEK 2.1 bn)	0.65% ($21.24 bn)
Increase in *Y* for a 1% increase in Φ	0.62% (SEK 4.04 bn)	0.86% ($29.86 bn)

It is evident that output is more responsive to changes in Φ than to changes in ECE. For both Sweden and the US, the upward shift of the income schedule (Figure 3) between successive years is solely due to the increase in $\Phi(t)$. An examination of the Swedish and US national income accounts reveals that between 1987 and 1989, increase in investment was, by far, the most significant contributor to the increase in $\Phi(t)$.

Although the national accounts do not reveal sufficient disaggregation, it is possible to envisage a special class of investments termed "environmental capital investments". These can be important shifters of the income schedule could be defined as the restoration of lost endowments - analogous to replacement investments. For example, if at the start of a given period, a river is declared dead due to a variety of pathogens, then this river cannot be counted in the stock of environmental capital because it will not contribute towards national output. Removing the pathogens and restoring the river is tantamount to adding to the stock of environmental capital[3]. Hence, activities such as reforestation of mined out areas, the creation of wetlands in water courses destroyed by nitrogen putrefaction, and the detoxification of idle land to enable new development are examples of environmental investments. Since these investments are reproducible capital, they can be regarded as special cases of the "Hartwick Rule" in practice; (Hartwick, 1977, 1978; Solow, 1986). That is, investing the rewards from wasting resource capital stocks in reproducible capital stocks to maintain a permanent stream of income.

An alternative approach for achieving convergence between sustainable and capacity incomes is to lower real wages. For example, consider 1989. As indicated above, the observed average annual real wage in the Swedish economy then was SEK 170,922 (in 1982 kronor), and the observed value of η was 0.0052. Given this value of η, the value of equilibrium income is SEK 625.61 billion. If this

---

[3] One may distinguish an environmental investment from its depreciation as follows. In the case of the river, if it currently provides services, then it is part of the capital stock. Any pollution abatement that is conducted on this river is intended towards maintaining its role in providing services, and this abatement is similar to capital consumption or replacement investment; (Thampapillai and Uhlin, 1994).

equilibrium income was to have provided full employment to the then labour force of 3.95 million, real wages needed to have fallen from SEK 170, 922 to SEK 158, 294. That is, those employed would have had to sacrifice SEK 12, 628 to draw the unemployed into the workforce. This is approximately 7.4% of the average annual wage. For the same year and for the same reasons, those in the US would have needed to sacrifice about \$3000 (which was roughly 9.8% of the average wage in 1982 dollars). Should the value of η have fallen (depicting an improvement in environmental capital efficiency), then the sacrifice to be made of real wages for increasing employment would also have fallen.

Figure 4 illustrates the trade-off between "wage sacrifices for sustainability" (WS) and improvements in environmental capital efficiency (ECE). Note that along a given trade-off schedule $\Phi(t)$ and the price level are fixed. Increases in $\Phi(t)$ (due to say environmental investments) and/or reductions in the price level will shift the trade off-curve inwards implying the need for lower sacrifices of real wages. That is, in Figure 4, the origin is optimal since it represents zero wage sacrifices and no further need for improvements in ECE. The comparison of Sweden and the US suggests that a one percent increase in ECE is more expensive in the US in terms of the percentage of wages that need to be foregone.

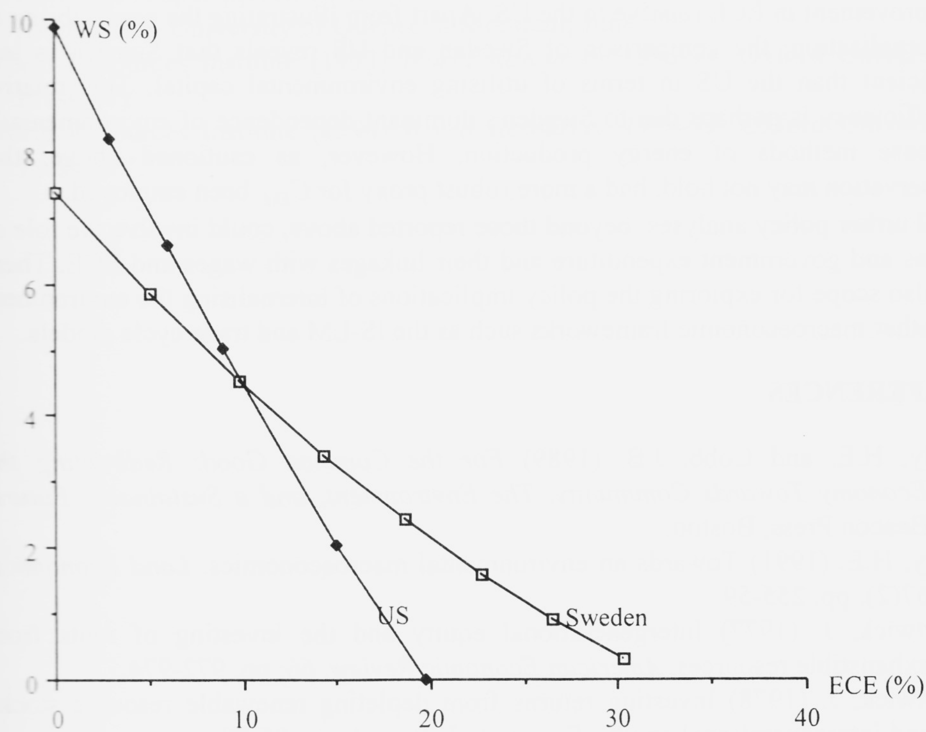

Figure 4. WS - ECE Trade-Off (Sweden and US)

5. CONCLUSIONS

The environment is a grossly neglected area in macroeconomics. Given that nature is capital, or rather ultimate capital as Marshall (1890) defined it, the internalisation of the environment into macroeconomic frameworks needs to be recognised as an essential component of macroeconomics. We illustrated the internalisation of the environment within the context of a simple framework of income determination. By recourse to a constrained Cobb-Douglass production function and some simplifying assumptions, we justified energy consumption expenditure as a proxy for the internalisation. It was possible to evaluate three policies in the context of sustainability with employment. These were: improvements in ECE, investments and wages.

Reliance on ECE alone may be too demanding, at least in the short term, as substantial gains need to be achieved. The analysis suggests that attaining social objectives could involve a mixture of policies rather than a singe policy. The observation pertaining to the responsiveness of income to investments warrants a closer examination of environmental capital investments. In terms of wage sacrifices, some may argue that these are already in place in a high tax economy such as Sweden. Figure 4 above offers some support towards this conclusion; that is, in Sweden lower percentage of wage sacrifice offsets a the need for larger improvement in ECE relative to the US. Apart from illustrating the applicability of internalisation, the comparison of Sweden and US reveals that Sweden is less efficient than the US in terms of utilising environmental capital. This relative inefficiency is perhaps due to Sweden's dominant dependence of environmentally intense methods of energy production. However, as cautioned above, this observation may not hold, had a more robust proxy for C_{EM} been employed.

Further policy analyses, beyond those reported above, could involve the role of taxes and government expenditure and their linkages with wages and ECE. There is also scope for exploring the policy implications of internalising the environment in other macroeconomic frameworks such as the IS-LM and trade cycle models.

REFERENCES

Daly, H.E. and Cobb, J.B. (1989) *For the Common Good: Redirecting the Economy Towards Community, The Environment, and a Sustainable Future.* Beacon Press, Boston.

Daly, H.E. (1991) Towards an environmental macroeconomics. *Land Economics*, 67(2): pp. 255-59.

Hartwick, J. (1977) Intergenerational equity and the investing of rents from exhaustible resources. *American Economic Review*, 66: pp. 972-974.

Hartwick, J. (1978) Investing returns from depleting renewable resource stocks and intergenerational equity. *Economic Letters*, 1: pp. 85-88.

Lutz, E. and Peskin, H. (1993) A survey of resource and environmental accounting approaches in industrialised countries. In E. Lutz (ed), *Toward Improved Accounting for the Environment.* UNSTAT-World Bank Symposium. The

World Bank. Washington. D.C.

Mäler, K-G. (1991). National accounting and environmental resources. *Environmental and Resource Economics*, 1(1): 1-15.

Marshall, A. (1891) *Principles of Economics*. Macmillan: London..

Solow, R.M., (1974) Intergenerational Equity and Exhaustible Resources. Symposium on the Economics of Exhaustible Resources. *Review of Economic Studies*, 0: pp. 29-45.

Solow, R.M. (1974) *An Almost Practical Step Toward Sustainabilty*. Invited Lecture on the Occasion of the Fortieth Anniversary of Resources for the Future, Washington D.C., Resources for the Future, October 1992.

Solow, R.M. (1986) On the Intergenerational Allocation of Natural Resources, *Scandinavian Journal of Economics*, 88: pp. 141-149.

Thampapillai, D.J. (1995) Environmental macroeconomics: towards filling an empty box. *The Indian Economic Journal*, 42(4): pp. 43-58.

Thampapillai, D.J. and Uhlin, H-E. (1997) Environmental capital and sustainable income: basic concepts and empirical tests. *Cambridge Journal of Economics* , 21(3): pp. 397-394.

Thampapillai, D.J. and Uhlin, H-E. (1995) Internalising the Environment in a Keynesian Model of Income Determination: Empirical Tests and Further Concepts. Paper presented to the *Annual Meeting of the Canadian Economic Association*, University of Quebec at Montreal, June.

World Resources Institute (1993) *World Resources 1993-94*. Oxford University Press: NY.

World Resources Institute (1994) *World Resources 1994-95*. Oxford University Press, NY.