Green GDP, Global Warming, and Monetary Policy:
Incorporating Climate Change and Green GDP in Monetary Policy

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1. Introduction

There are two key ideas that underlie most versions of the call for calculating and employing Green GDP. One is that our concept of depreciation should be broadened from man-made capital to include natural capital – and that the value of the depreciation of nature’s bounty should be subtracted (like capital depreciation) to achieve a more appropriate measure of our net income. The second is that the list of prices that we employ to value goods and services should incorporate externality effects, reduced when these externalities are favourable and raised when deleterious, so that our aggregates are calculated at what one could call Pigouvian market prices. Pigou called for a set of taxes and subsidies that would fully internalize externalities.

2. Depreciation Treated Properly

The first idea is ironic in a superficial way, because it proposes a different method of valuing net domestic or national product (and not “gross” domestic product at all). So in this respect “Green GDP” is really something of a misnomer. But this different method of valuing net income has much to commend it. In Value and Capital (1939), Hicks defined what he called “standard income”, an unrecognized progenitor of Friedman’s concept of permanent income, as what we can spend without getting poorer. It would be folly indeed to limit our conception of wealth to manmade objects. We customarily include the value of land among our assets, and rightly so: the land on which dwellings or other structures are built, and not just those buildings themselves. The same goes for titles to minerals in the earth’s crust, for example. Land and minerals form a major part of nature’s gift to humanity. Excluding from our perception of income any changes in their volume, due to usage, that might occur in a given interval of time seems completely unreasonable.
One can see at once why global warming matters in this context. Temperature rises imply rising sea levels. Lower lying land is threatened with inundation. A valuable asset is lost. Climate change might bring major alterations in rainfall patterns, whether across the seasons, or geographically, across different countries, or both. This may induce desertification in some areas, and grave and possibly enduring damage due to floods in others. Some land may becomes degraded, and less productive (although there could be gains as well). Storms may become more frequent, or more severe, leading to the impairment or destruction of forests, and hence, conceivably, a vicious circle, as carbon atmospheric concentrations are speeded up. Such considerations make a thorough analysis of all the policy options before us a matter of great urgency\(^2\). But it is no easy task, given the uncertainties, the awkward ethical problems, the complexities, the dynamics, and the possible non-linearities involved.

Furthermore, economic sustainability has an inescapable ecological dimension. We are apt to think of economic phenomena and policies in time frames: there is the impact effect, then the gradual transition, and then finally the long run to which the system will tend, we hope, or would, at least, in the absence of any further disturbances. This long run we identify as a steady state. In the steady state, key variables like the real interest rate – or ratios of growing variables, such as capital per head or per human efficiency unit – have become stationary.

Once the term “capital”, or wealth, is widened to embrace natural resources, as it surely should be, we are immediately confronted by the need to incorporate a role for those natural resources in our thinking about what such a long run could mean. And that will alter the way we think of the transition towards it, and of the impact effects, too, which are usually, in forward looking economic models, governed by that transition and by what is perceived to have happened to the long run itself.

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\(^2\) Fortunately, Nordhaus (2008) offers a timely and balanced analysis of many of these options.
To this extent, the thinking behind “Green GDP” should be absolutely central to the way economists, governments and central banks analyse shocks and evaluate policies. And there are further important implications of treating natural resources properly. One is to recognize that a country that sells fossil fuel, or metals like copper, is not undertaking a conventional form of exports. Actually it is selling an asset. Once one has stripped out extraction and transportation costs, at least, the transaction in question really belongs on the capital account of the balance of payments, not in fact to the current account at all.

It seems quite natural, therefore, for a large net exporter of such products to run a current account surplus on our present (and inadequate) definitions. The country should be treated as shifting one asset into others (foreign equities, or government bonds, or exchange reserves, for example). And we should think of countries that import it as buying an asset, if only to transform it into a one-time flow of energy perhaps, so their imports of such products ought to be entered on the capital account, too.

Furthermore, this train of thought does not stop at relabelling components of the national income and balance of payments accounts. Excluding at least some element of the value of fossil fuel transactions from NDP and current trade data might reinforce the case for reducing their weight in price indices, too. But does it? Firms and households that purchase electricity generated from burning fossil fuels are engaging in a form of indirect capital consumption. That means that net investment and net income are both smaller than they seem. But what we choose to do to the definition of net income has no direct bearing on the definition of consumption of goods and services, nor on the index of their prices.

Kaldor (1956) called for an Expenditure Tax, which would exempt net investment from income taxation. It would work both ways, subjecting any net disinvestment to income tax. The idea is that a key intertemporal distortion would be removed: marginal rates of substitution and transformation between consumption at different dates would be brought into equality thereby. Taxes on income as conventionally measured drive a wedge between these marginal rates, and in many settings – such as the Ramsey (1928) model of
macroeconomic evolution – they can end up being highly damaging, by taxing a factor, capital, that is in long run perfectly elastic supply. Expenditure tax gets round this problem, and typically offers a superior solution when compared with other responses, such as shifting from income tax to a wages tax\(^3\). The relevance of all this to the Green GDP debate is that using up fossil fuels, or other minerals for which recycling was impossible or incomplete, would also qualify as a form of capital consumption, which would be subject to the agent’s income tax unless compensated by net investment in another form. As a corollary, one should applaud those countries, like Norway, Chile, many Middle Eastern oil producers, and now Russia, that have established stabilization funds for transforming the proceeds of sales of oil or other minerals into other, man-made types of capital. These funds help to prevent those proceeds being frittered on a short-lived burst of private or public consumption.

The Expenditure Tax, despite its powerful, and really indisputable, long run economic benefits, has in fact yet to be applied anywhere. True, in many countries, there has been a switch from direct to indirect taxation (which has many of the benefits of an expenditure tax). And there have long been piecemeal fiscal privileges accorded to certain categories of saving by individuals or investment by companies. But a comprehensive expenditure tax awaits implementation.

Perhaps this because politicians exert a myopic bias on economic policy, rewarding voters here and now to the detriment of their successors – rather like the inflationary bias to which Barro and Gordon (1983) and others drew attention, ideas that led ultimately to the spread of operational independence for central banks and the spread of inflation targeting. Or perhaps an expenditure tax is just hard to implement and police, maybe because the boundaries between ephemeral goods, and goods that last, is so fuzzy, and net investment can be misreported. Be that as it may, environmental arguments about sustainability reinforce the arguments for an expenditure tax, so it is worth mentioning what can happen if it is brought in (unexpectedly, let us say).

\(^3\) Such as the recommendation explored by Lucas (1990).
Ultimately, capital, consumption and output per head will climb to higher levels than would otherwise obtain, and in a world with oil, the rate of sustainable growth would permanently increase, too. That is because the extraction rate would come down and stay down. In the short run, consumption would have to slip back, to make room for the net asset creation that the new fiscal regime would cease to discriminate against. And in a simple aggregate model of the whole world, agents would anticipate a transition towards lower real rates of interest, and anticipation of that should lead to a positive jump in the price of oil. In a multi-country world, countries that declined to adopt an expenditure tax would gain extra consumption early on (and all the more so if enabled to borrow more cheaply from residents in those that did adopt it), but they would pay for it later on as their consumption possibilities slipped behind, both absolutely and relatively. And it is worth emphasizing that there is a wide range of models which point to the conclusion that implementing policies to reduce fossil fuel consumption need not entail slower growth: McKibbin, Wilcoxen and Woo (2008) argue that China’s apparent official perception to the contrary may be quite gravely mistaken.

Returning to the findings in the simple one-world model, such developments would be appropriate, because they would provide the mechanism for the desired (and desirable) reduction in the rate of oil extraction. Short run output might be boosted, but only temporarily, by extra labour (this would certainly occur if agents were sufficiently averse to risk, and the tax on wage incomes low enough). But the higher income tax rate needed to balance the budget early on could conceivably push the time path of labour in the opposite direction. If the budget were not balanced, any deficit would need to be financed by net bond sales (easily achieved, given the enhanced stimulus to saving) to prevent any transient jump in the growth rates of the monetary aggregates.

3. Green Taxation and Global warming

The second strand of thinking behind Green GDP, the call for a tax-subsidy regime that would ideally correct for environmental (and presumably also non-environmental)
externalities, and for its inclusion in our statistics and policy analyses even if it has not been implemented, is considerably more problematic, and especially so in the global warming context. Why should that be? Surely the standard objection to the tax-subsidy solution to externalities, namely that Coase bargaining between individuals affected should internalize them anyway, will not apply here?

Indeed Coase bargaining between all the various affected parties is totally impracticable, particularly when one thinks of possible damage done, by burning fossil fuels today, to generations as yet unborn. That can only strengthen the case for a tax on it. One reason for scepticism, however, is that global warming is, as its name implies, a world-wide phenomenon. Higher indirect taxes on carbon emissions by one country will have an almost negligible effect on the global problem, if that country is small; but the costs will fall on its citizenry, their factor incomes and the level of welfare derived from their consumption. So however desirable such taxes may be at the world level, the incentive that such individual countries have to free ride on others, and hope that there will be cutbacks of emissions of carbon, and other noxious greenhouse gases, elsewhere while failing to implement them at home, will be overwhelming. But actually the problem lies still deeper than that.

This is no standard Prisoners’ Dilemma issue. Exhaustible resources are stocks. Quantities extracted and used up today imply less is left for future use. We must examine the resource extraction problem as an intertemporal one. Placing a higher ad valorem tax on fossil fuel burning everywhere, even if all countries could be induced to reach a cooperative equilibrium, and implement coordinated measures, might have absolutely no effect on the amount of burning, in any time period. This is because the stock is finite, and if it is all to be taken out, and used up, over some (possibly infinite) given interval, let us assume, all the tax will do is squeeze the rent the resource owner gets. The price to buyers will stand still. There will be no fall in consumption, now or in any other period.

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4 Or at least for an emissions trading scheme, such as that operated in the EU, recently reviewed by Grubb and Neuhoff (2006). See also Bosetti et al (2007).
Just as bad, if some countries tax fossil fuel consumption and others do not, this intertemporal argument implies that the second group will experience an actual reduction in the user’s price of the fuel, which balances the rise in the first group of countries. Aggregate carbon emissions will be unchanged; reductions by the first group will be neutralized by increases in the second group of countries. And to a first approximation, the time paths of the world’s distribution of temperatures, precipitation and storms, all of which are affected only by the aggregate, will be completely unaffected.

Although the level of carbon fuel *ad valorem* taxes may offer no solution to the global warming problem, the time path such taxes take can provide more hope, although the results come as something of a surprise. In small intertemporal models, Sinclair (1992, 1994) shows that a negative time trend in such taxes can indeed succeed in improving matters, by tilting the time profile of burning towards the further future. The second, 1994 paper shows that, in a suitable case, there is a particular rate of decline in fossil fuel taxation that might actually offset the global warming externality in full. So fiscal policy is not completely impotent; but fiscal responses built upon the example of a static, partial equilibrium, closed economy set up are apt to be profoundly misleading.

If fiscal policy offers some limited hope of responding to the global warming challenge, what can monetary policy offer? Should monetary policy be built on Green GDP concepts? How should monetary policy react to global warming, and to its likely or possible economic effects? And what are the implications that can follow from the uncertainties about the gravity and character of global warming, and from the possible ways such uncertainties may be resolved?

The first point to make here is that money is surely neutral in the long run, or at least approximately so. So it seems that monetary policy can have no enduring impact on real

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5 But scepticism about international agreements can sometimes be overdone: see McKibbin and Wilcoxen (2008) and Zedillo (2008), for example, on this issue.

*6 On current policies, China and the United States, presumably, among them.*
variables, such as the long term time paths of GDP (whether Green or conventional), or of carbon emissions. The sustained, average rates of growth of nominal monetary aggregates, and the rate of inflation that must almost invariably accompany them, can exert some permanent real effects under certain circumstances. But these effects are typically indirect. They are also ambiguous in sign – and possibly non-monotonic - at least for aggregate output; and they may be non-monotonic for welfare, initially improving with higher inflation, if it proceeds very slowly, before becoming damaging if it goes up more. Furthermore, no-one could seriously argue that the damage to welfare that generally accrues from prolonged faster inflation (at least at high rates) has anything directly to do with the welfare losses that global warming could induce.

In the short run, monetary policy can indeed exert pervasive real effects. With inflation sluggish, real interest rates rise and fall, for a while, with nominal policy rates set by the central bank. These real interest rate movements have substantial impact on local asset prices, particularly for the prices of assets that are largely non-traded (such as real estate). A wider class of assets may respond in countries that restrict international capital movements. All components of aggregate demand can be stimulated or held in check when real interest rates alter. In countries with less developed internal financial markets, and even in the richest countries, changes in credit supply have major repercussions.

Looking at the issue of short run monetary policy effects on carbon emissions, because the spot market prices of raw materials are highly flexible, and those of other goods and services are often not, unexpected monetary expansion may lead to a sharp rise in the relative price of oil, against a basket of all products. This can occur as a result of policy loosening in the world’s largest economies (such as the US). It can also arise in a small economy with permissive rules on international capital movements and a freely floating exchange rate. That rate can easily fall too far, further than it should in the long run, in the immediate wake of unanticipated monetary policy relaxation.

It might be that some part of the recent massive rises in real oil prices observed recently (though not in my view a large one) can be attributed to this source. The argument is
compounded by the fact that if surprise monetary loosening trims real interest rates for a while, it must tend to raise the demand price of assets fixed or nearly fixed in supply: and gold, real estate, metals and claims on subterranean or submarine oil stocks are all assets, too, no less than bonds and equities. Dearer oil must imply carbon emissions reduced\(^7\). But only briefly delayed, however - if it is monetary policy shinanigans that really gave rise to it in the first place.

A more substantial question relates to the various indirect effects that changing perceptions about global warming may have on monetary policy. At its simplest, climate change threatens to waste resources. One way of modelling this is to begin by arguing that the rate of technological progress is reduced by an increase in the rate of extraction of fossil fuels (which constitute a leading source of atmospheric carbon concentrations, and therefore, a major possible trigger for climate change).

What climate change then implies has a partly stabilizing character. With this global warming feedback effect in operation, faster fossil fuel extraction slows down productivity growth. That will lead to a reduction in the time profile of current and future real interest rates. A knock on effect of this (in a forward looking model, where relevant agents are aware of this mechanism and the general intertemporal macroeconomic model in which it operates) will be a positive jump in the (real) price of oil, at the point that perception adjust. That in turn entails some negative pressure back on the long run rate of fossil fuel extraction itself.

So dirtier extraction implies slower extraction; slower extraction entails some delay in the time profile of extraction; and delayed extraction in turn suggests a less rapid rate of increase in the mean temperatures and storm frequencies that are held to characterize the phenomenon of real concern. It also entails an immediate squeeze on the level of aggregate output (to reflect the drop in oil inputs that will inevitably accompany the jump....
in its price), but, in the longer run, some increase in the trend (or sustainable) rate of economic growth.

This line of reasoning can be extended. We are not yet certain just how dreadful global warming will turn out to be, whether in scale, or in speed, or timing, or even in the exact contribution that fossil fuel burning makes to it. It could be trivial, or it could be calamitous. The melting of glaciers and circumpolar regions currently under permafrost could speed up the process with potentially disastrous and irreversible consequences. Alternatively, the more pessimistic forecasts about this, and other aspects of the climate change phenomenon, could in fact be revealed as overdone. At this point we do not know whether either of these developments could occur. But in neither case can we assert that they are just impossible. Normatively, Pascal’s wager requires us to contrast the welfare effects of being wrong in both directions. It seems that what could be lost by underestimating the gravity of global warming is considerably greater (on pessimistic assumptions, at least) than the net sacrifices entailed by overestimating it, should we subsequently learn that it is less insidious than we feared.

Be that as it may, it makes sense to allow for the possibility that opinions about the gravity of global warming might change, and indeed in either direction. Our present beliefs can only be hazy and imprecise. Some degree of ignorance may persist, possibly for a long period; but the dispersion of our a priori probability distribution is highly likely to come down, and possibly very abruptly. The non-linearities inherent in the saddle path relationships in the model[^1] imply that even a mean preserving reduction in uncertainty could affect the spot price of oil, and the associated trajectories of all the main macroeconomic variables as well. A shift to more pessimistic mean expectations about the gravity, impact or timing of global warming should imply a change to a more downward sloping (but convex) curve for the term structure of real interest rates, and with it, a jump in the real price of oil now to make room, as it were, for more gradual, and

[^1]: Adapted from Sinclair (1992). A later paper (1994) adopts a more micro-founded approach, but with broadly similar conclusions.
gradually decelerating, rates of subsequent anticipated real appreciation along the Hotelling\textsuperscript{9} path.

So if coming years display large changes in our beliefs, and the state of our scientific knowledge, about all aspects of global warming, we need to prepare ourselves for a world where the levels of oil prices, and forward real interest rates, continue to be volatile. This means that the kinds of challenge posed for central banks – especially those that target inflation – that we have witnessed in the past two or three years, are quite unlikely to disappear. Furthermore, there could well be episodes when weakness in real energy prices, caused by moves towards greater optimism about global warming, make for phases that might resemble the “Great Moderation” or “Great Stability” that characterised much of the period from the early 1990s to the mid-2000s. These are the conclusions one may reach, at least, if global warming is seen primarily as a reduction in the rate of technological progress.

But global warming can exert other affects. It could raise the rate of depreciation of capital, for example. That would be equivalent to a reduction in the rate of capital-augmenting technical progress. So long as the ratio of net investment to national income is unchanged, earlier results carry over. But if faster capital depreciation leads to a reduced rate of capital formation, as it well might, the long term real interest rate could rise, not fall. In that case global warming would be self-exacerbating, as knowledge of this effect provoked a once-only drop in the price of oil, and subsequent increase in its rate of extraction.

Then there is the fact that awareness of the threats presented by global warming will lead to large increases in research devoted to alternative fuels – whether wave, wind, solar or nuclear – which could have the perverse side-effect of encouraging oil well owners to

\textsuperscript{9} Attributed to Hotelling, whose classic work on oil economics (1931) is the key foundation of current thinking. The simplest form of Hotelling’s model relies on perfect competition among oil sellers, certainty equivalence (or foresight), and the absence of extraction costs and taxation. But these assumptions can be relaxed in many settings; a recent paper by Ellison and Scott (2008) extends it to a model of duopoly and stochastic shocks with discounted least squares learning, for example.
pump faster, for fear of being left with a much less valuable asset once such expanded and / or cheaper alternatives are seen to have driven oil use down to much lower levels. Then there is the set of unfortunate repercussions from a gadarene rush into biofuels, which may, as Searchinger and others argue (2008), actually exacerbate carbon emissions, at least initially, as well as contributing something to a serious worldwide shortage of certain food products at the expense of which that the biofuels will have been produced. Oil markets cannot be taken in isolation; subtler, general equilibrium effects must also be allowed for. Yet a further factor that could depress oil prices, and hence hasten the ill effects of global warming, is the possibility of unexpectedly large discoveries of oil in coming years. This could well happen in response to the stimulus towards increased exploration provided by its recently elevated prices.

Technical progress is mothered by necessity. One interesting possibility, and one which all observers will hope for, takes the form of learning new and cheaper ways to capture carbon in power stations, for example, before it is emitted into the atmosphere, and then to store it at low cost\textsuperscript{10}. A major advance in this respect would reduce the urgency of research into alternative fuels (something that would tend to increase the time profile of oil prices, and delay extraction). But, given time to ensure implementation, it would also tend to mitigate the downward impact of oil extraction on the rates of technological progress, and real interest. That would be something that would imply faster-rising oil prices, from a lower initial base.

4 Concluding Observations

This paper has argued that extending the concept of depreciation from man-made structures to natural and environmental capital has much to recommend it, especially if and when this can be made the basis of taxation. The consumption of nature’s capital calls for taxation, in just the same way as running down an inheritance of claims on physical capital needs to be penalized. There would be rewards for depleting natural

\textsuperscript{10} The Stern Review (2006) has an excellent and very positive analysis of this issue (among many others).
capital more slowly, and indeed for devising ways, if we can find them, of reversing its past erosion. Implementing policies of this kind would, under neutral conditions, make immortals unambiguously better off. But given the inconvenient fact of human mortality, and the likelihood that intergenerational altruism is limited, we would have to admit that there could well be some initial suffering by one or more of the first generations to face the new fiscal regime. And this would pose a challenge for politicians in democratic polities – let alone in other systems - because posterity arrives at the ballot box far too late to affect things. From a normative standpoint, one of the key issues here, as Stern (2006) emphasizes, turns on the choice of rate (or rates) at which discount utilities of members of different generations.

This said, “green GDP” is a misnomer in that it focuses on gross income, and not on income net of depreciation in any sense. And it is fiscal policy that is centre stage here, not monetary policy – both in section 2 of this paper, and later on, in section 3 as well, where we saw that the trend of ad valorem fossil fuel taxation can have important consequences, even if intertemporal issues imply that its level may be irrelevant. Nonetheless, global warming has important implications for monetary policy, through its long run impact on rates of real interest and growth, and its short run repercussions on the level of prices of fossil fuels, which may react quite strongly to changing perceptions of the character and extent of the global warming phenomenon.

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11 And another, on how to cardinalize or compare utilities of richer and poorer members of the same generation.
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