A Proposal for the Greening of Textbook Macro.: 'IS-LM-EE'

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Abstract

The celebrated ecological economist Herman Daly asked: "Is there not a neglected connection between the environment and the macroeconomics we teach? If there is no such thing as environmental macroeconomics in our textbooks should there be? If so, what would it look like?" (Daly (1991: 255)). Emphasising the need to breach widely-used undergraduate texts - such as Begg, Fischer and Dornbusch (1997), Abel and Bernanke (1998), Blanchard (1997) and Sloman (1997) - we show that an 'environmental equilibrium' (EE) line can be added to the standard IS-LM diagram which remains the workhorse of undergraduate macro teaching and is widely used for applied policy analysis. The familiar comparative static analysis of fiscal and monetary policy are reworked. It is argued that chapter sections detailing the environmental extension should be incorporated into all IS-LM-using texts.

1 Introduction

The environment has become a huge policy issue over the last couple of decades. Daly (1991) laments the failure of an 'environmental macroeconomics' to emerge. This is not to say that environmental considerations

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have not occasionally featured in discussion of macro policy issues. The efforts of John Hartwick and others to develop techniques for 'green' national accounting is one sign that the links between the environment and macro-variables are being thought about. Rather, that the major macroeconomic models - those familiar from any major textbook and used in day-to-day policy analysis - have yet to be adapted incorporate environmental objectives or constraints.

It is conventional to treat environmental policy as a self-contained topic in microeconomics. So doing means failing to recognise that the environmental health of a country or region will, to a great extent, be determined by the scale and composition of economic activity in that country or region and hence by predominantly macroeconomic variables.[1] On macro-scale Daly has a lot to say:

> "How big can and should the economy be? Optimal scale of an individual activity is not a strange concept to economists - indeed microeconomics is about little else. . . When we move to move to macroeconomics, however, we never hear about optimal scale again. Optimal *allocation* of a given scale of resource flow within the economy is one thing (a microeconomic problem). Optimal *scale* of the whole economy relative to the ecosystem which supports it is entirely different. The micro-allocation problem is analogous to allocating optimally a given amount of weight on a boat. But once the best relative location of weight has been determined there is still the question of the absolute amount of weight that the boat can carry. Optimally loaded boats will still sink under too much weight - even though they may sink optimally !! (Daly (1991: 257 - 258).

Ecological economics emphasises that the natural environment has an aggregate carrying capacity - putting a constraint on the maximum sustainable level of economic activity.[2] In this paper we present a version of the familiar IS-LM model which incorporates such a macro-environmental constraint.

[1] As Daly notes: "My own search through the indexes of three leading textbooks in macroeconomics revealed no entries under and of the following subjects: environment, natural resources, pollution" (Daly (1991: 255), italics in original).

[2] The sinking boat is reminiscent of Kenneth Boulding's notion of 'spaceship earth'. Marxsen (1992) takes this analogy further: "The major task of environmental macroeconomics is to design an economic institution analogous to the Plimsoll mark - to keep the

We use the extended model to think about the design and implementation of environmentally neutral stabilisation and macro-development packages.

The rationale for starting from IS-LM - rather than any of the more sophisticated models around - is essentially pragmatic. It is the one used in a range of popular textbooks and is at the heart of undergraduate macro teaching. In arguing that environmental objectives can be embodied in conventional macro-analysis it is important that that embodiment be in familiar and widely used constructs.

Even in its crudest form the IS-LM model remains " . . the workhorse of modern macroeconomics . . such that despite criticism IS-LM remains in very common use well past its fiftieth year" (Blanchard and Fischer (1989: 506 and 529). It retains considerable currency in policy circles - underpinning, for example, almost all of the major macroeconometric models - and is likely to continue to be a staple analytic and expositional tool.[3] From the point of view of this paper the fundamental validity or otherwise of IS-LM is of secondary importance, and we make no particular attempt to defend it. It is of interest here because of the prevalence of its use in widely-used textbooks (Begg, Fischer and Dornbusch (1997), Sloman (1997), Abel and Bernanke (1998), Blanchard (1997) and Branson (1989) are examples) and in policy analysis.

The flaws of IS-LM identified by critics - most compellingly (i) the assumption of a perfectly elastic supply curve for goods and (ii) the failure to give the IS and LM curves sufficient micro-foundations - are, according to Blanchard and Fischer (1989: 532) "flaws of only the simplest textbook version". The construct can readily be extended to meet such criticism. Blanchard's (1981) long-run, flexible price version of the IS-LM model incorporates expectations formation, risk aversion and a positively sloped aggregate supply curve, and it is this version that we work with here. For

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weight, the absolute scale, of the economy from sinking our biospheric ark" (Marxsen (1992: 241)). The lack of proper dynamics in the model make us reluctant to use the term 'sustainability', preferring 'environmental neutrality'. The correspondence between the two should, however, become apparent.

[3]Mankiw (1990) concludes his well-known *Journal of Economic Literature* survey by noting that: "(T)he textbook IS-LM model, augmented by the Phillips curve, continues to provide the best way to interpret discussions of economic policy in the press and amongst policy makers. The observation that recent developments have had little impact on applied macroeconomics creates at least the presumption that these developments are deemed to be of little use by applied macro-economists". For an empirical assessment see Gali (1992). For a sceptical view see King (1995).

the purposes of comparative statics the extended IS-LM can be manipulated exactly 'as if' it were one of its primitive cousins.

2 Model - The Existing Basics

For the purposes of exposition we adopt Blanchard's (1981) long-run version of the IS-LM model. The notation is standard;

$Y \equiv$ real output

$A \equiv$ aggregate demand for goods

$R \equiv$ long-term real interest rate

$r \equiv$ short-term real interest rate

$i \equiv$ short term nominal interest rate

$F \equiv$ index of fiscal stance

$\pi \equiv$ rate of inflation

First recognise that investment, as well as consumption, should be affected by R. The demand for goods can then be written as $A(R, Y, F)$ where $A_R < 0$ and A_Y, $A_F > 0$. Adjustment of output to movements in demand is assumed to be sluggish -

$$\frac{dY}{dt} = \Phi[A(R, Y, F) - Y] \equiv \Phi(R, Y, F) \tag{1}$$

where Φ is decreasing in R and Y, increasing in F. Equilibrium in the goods market requires that $\Phi = 0$ such that $A \equiv Y$ implicitly defines the IS curve. The slope of the IS curve in $\{Y, R\}$—space is simply $(-\Phi_Y/\Phi_R)$ which is negative. Increases in F (expansionary fiscal policy) generate rightward shifts in it.

Money market equilibrium is also characterised from conventional portfolio considerations. Assuming rational expectations (and risk neutrality) arbitrage equalises the rates of return on short nominal bonds and real consols such that

$$R - \frac{dR/dt}{R} \equiv i - \pi^* \tag{2}$$

Money market equilibrium requires equation between the supply and demand for money balances: $(M/P) = L(i, Y)$. Substituting for i in Equation 2 yields the LM curve:

$$\frac{M}{P} = L\left(R - \frac{dR/dt}{R} + \pi^*, Y\right) \tag{3}$$

It is straightforward to confirm that the LM curve is upward-sloping in the usual space, and that a monetary expansion shifts it downwards.

Though derived from firmer foundations, this long-run model looks and handles like its simpler counterpart - at least insofar as comparative static inference is concerned. Any point above and to the right (below and to the left) of the IS curve is associated with excess supply (excess demand) for real goods such that Y is falling (rising) at a rate described by Equation 1. Any point below and to the right (above and to the left) of the LM means excess (inadequate) demand for money balances. Equilibrium is defined by the intersection of the curves. A monetary expansion induces a rightward shift in the LM and a new equilibrium is established with R lower and Y higher. A fiscal expansion shifts the IS rightward such that a new equilibrium is established with both R and Y higher.

3 Building in the Environmental Constraint

Just as Mundell and Flemming superimposed a third line onto the textbook IS-LM diagram to capture open economy constraints (albeit in a highly stylised way), it is similarly possible to include a line to reflect the constraint imposed by environmental considerations.

Let e be the environment-intensity of economic activity in the economy - the 'amount' of some composite commodity called the 'environment' used in the production of an average unit of output. The variable e is best thought of as the emission of some generic pollutants ('smoke'). The waste disposal service provided by the environment can be thought of as an input into the production process such that in equilibrium e, a factor intensity, will be determined by aggregate choice of technique. We will write e as a function of R and Λ, where $0 \geqslant \Lambda \geqslant 1$ is an institutional parameter capturing the state of development of environmental regulation in the economy or, more concretely, the fraction of environmental services (damage) for which the user

pays.[4] Thus $e = e(R, \Lambda)$ where we assume that $e_R > 0$, $e_\Lambda < 0$ and $e_{R\Lambda} < 0$. The environment-intensity of economic activity is increasing in the cost of capital and decreasing in the extent to which environmental costs are internal to the user.[5]

The factor-intensity measure e, then, captures choice of technique. The story it tells corresponds to that often made anecdotally in political debate, the media, World Bank discussion documents and elsewhere. The environmental impact of economic development in, say, Poland will depend not just upon the level of output attained, but also upon the selection of technologies with which that output is produced. The key assumption is that capital and environmental services are substitutes. Polish producers choose between cleaner but more capital intensive industrial plant and dirtier but less capital-intensive alternatives. A high value of R and/or low values of Λ push the choice of technique, *ceteris paribus*, in favour of the latter.

The total employment of environmental services by the economy is, then, $e(R, \Lambda).Y$ by construction. Let E_t denote the physical stock of the composite variable 'environment' at time t and assume that it self-renews at a rate $s.E_t$. Using E as a measure of environmental quality then the net rate of environmental degradation is simply

$$-\left(\frac{dE}{dt}\right) = e(R, \Lambda).Y - s.E \tag{4}$$

Environmental equilibrium (steady-state) in a simple model of this sort will require that $dE/dt = 0$ such that an 'environmental equilibrium' (EE) locus is implicitly defined in the usual $\{Y, R\}$-space by setting the expression equal to zero.

The EE locus is superimposed on the familiar IS-LM diagram in Figure 1. Implicit differentiation of the expression in 4 implies that EE has slope

$$\left.\frac{dR}{dY}\right|_{dE/dt=0} = -\frac{e}{e_R.Y}$$

[4]Putting R rather than r as an argument in the e function is not crucial. A fuller model of choice of technique under a term structure of interest rates could be derived but would not much add to insight.

[5]Capital and the environment are gross substitutes in the aggregate production process: an increase in the price of the former induces an increase in the (output compensated) use of the latter. It is a standard assumption in general equilibrium analysis and holds for lots of functions. It is an n-good analogue to the familiar dictum that the substitution effect of a (relative) price change is always positive.

which is negative. For any point on EE the associated $\{Y, R\}$ pair is such that the rate at which the economy is using environmental services is exactly equal to the natural environment's ability to supply them. If we are thinking about the exploitation of a renewable resource (such as timber) then the rate at which it is being harvested equals the rate of replenishment. In the case of the emission of pollutants, the aggregate rate of emission must exactly equal the rate at which the environment is able to absorb and and assimilate those emissions without net diminution of its future assimilative capacity.[6] At any point above and to the right of EE it is true that

$$s.E > e(R, \Lambda).Y$$

- the combination of level of economic activity and economy-wide choice of technique are such that the rate of pollution exceeds the assimilative or regenerative capacity of the natural environment implying net environmental degradation. Conversely, any point below and to the left is associated with net environmental enhancement.

The macro-environmental constraint can be represented, then, as a downward sloping locus on the familiar IS-LM diagram. Figure 1 has been drawn for the case in which EE is steeper than IS though this will not necessarily be the case. It will be more likely when the environmental intensity of production is comparatively insensitive to changes in R. Note that an increase in Λ induces a leftward shift in EE. For any specified Y and R the economy-wide choice of technique will be 'greener' when the prevailing regulatory and legal structures are such that a comparatively high proportion of pollution costs are incident upon the user ($(1 - \Lambda)$ can usefully be thought of as an *ad valorem* subsidy on the use of environment as an input).

Before moving on to the textbook comparative statics which are the focus of the paper, it is also worth noting that E - the current state of the environment - is itself a shift parameter for the EE locus for $s > 0$. The absorbtive capacity of an environmental sink (for example) is itself related to its past treatment (enhancement or degradation). Under discrete repetition, for example, for each period that the economy spends to the right of EE the aggregate environment is being degraded which implies the EE shifting leftward. Interestingly this yields the possibility of hysteresis whereby short-run

[6] Of course reality is more subtle than this. The strictures of a model of this sort prevent more detailed specification of the underlying natural systems dynamics.

economic development beyond the ecological carrying capacity reduces the long-run sustainable development potential of the economy.

4 Fiscal and monetary policy in IS-LM-EE

The main use to which IS-LM is put in textbooks and in policy discussions is the comparative static analysis of fiscal and monetary policy packages.

The discussion here will focus on macroeconomic development packages for LDC's but can obviously be interpreted more generally. The commitment of the World Bank to supporting only environmentally neutral ('sustainable') development - together with the widespread use of IS-LM within that organisation - makes the model developed here a particularly appropriate one to use to think about World Bank policy and structural adjustment advice.

Suppose, for exposition, that the economy is initially in an equilibrium such as that marked 0 in Figure 2.

A fiscal expansion is described by an increase in F and induces a rightward shift in the IS. The point 1 is not, however, consistent with environmental equilibrium. In order to respect the macro-environmental constraint - to keep the economy on the EE locus - the fiscal expansion must be accompanied by a monetary *contraction* sufficiently large to place the economy at the point 2. At point 2, note, Y is lower than it was initially.

Abstracting from possible shifts in EE it is apparent that the environmental constraint it embodies dictates that any policy which implies higher R - inducing substitution towards more environmentally intensive methods of production - must be accompanied by a lower Y if environmental equilibrium is to be maintained.

From the same initial point, labelled 0, a monetary expansion is described by an increase in M and induces a rightward shift in the LM locus (Figure 3). Again, however, the point 1 is not consistent with environmental equilibrium. In order to respect the macro-environmental constraint - to keep the economy on the EE locus - the monetary expansion must be accompanied by a fiscal *contraction* sufficiently large to place the economy at the point 2. At point 2, note, Y is higher than its initial level.

The combination of monetary expansion and fiscal contraction allows an increase in Y to be made compatible with environmental neutrality because the increase is accompanied by a fall in the interest rate which induces a substitution towards less environmentally intensive methods of production.

4.1 The role of institutional reform in facilitating sustainable development

In these two comparative static manipulations we have assumed that the EE locus did not move. There are, as noted, two ways in which the macro-environmental constraint might itself change. Firstly, endogenously in response to periods of disequilibrium. Secondly, the policymaker might actively manipulate Λ. The study of the first is outside of the scope of the current paper. We focus on the second.

The parameter Λ captures, recall, the extent to which the cost of environmental use is incident upon the user. An increase in Λ would be generated by institutional, legal or other reforms which move the economy in the direction of the polluter pays principle, and would be associated with a rightward shift in EE.

Examples of such policies are manifold; implementation of charges for natural resource exploitation, social-cost pricing (SCP) of electricity, fuller enforcement of environmental liability laws *etc.*. Whilst the implications of such policies - each of which is often advocated by development organisations such as the World Bank - are commonly analysed with microeconomic tools, the model presented here emphasises the interaction between such policies and the macroeconomic potential of the economy. Starting from a point of equilibrium such as that marked 0 in Figure 3, it is apparent that a package of reform that induces a rightward shift in EE constitutes a relaxation of the macro-environmental constraint and creates the opportunity for an environmentally sustainable expansion in Y.

5 Conclusions

The aim of this paper has been simple - to present a way in which environmental concerns can be injected into the type of textbook macroeconomics taught to undergraduates and used in policy discussions in international organisations and elsewhere. This, we have argued, is an important thing to do because of the substantial linkages between environmental performance and macroeconomic variables. Pragmatism dictated IS-LM as the foundation on which to build.

The analysis is, of course, incomplete in a number of ways. To save clutter we stuck with the closed-economy version of IS-LM, though a BP line

could readily be superimposed on Figures 1 through 3. We also have paid little attention to shifts in EE - though the potential for institutional reform to facilitate sustainable macroeconomic expansion has been identified and in some ways formalises ideas familiar to anyone who follows policy speculation in this field. We do believe, however, that IS-LM-EE provides a useful way of thinking about and teaching the role of environmental constraints in macroeconomic policy-making, and think that chapter sections detailing the environmental extension could usefully be incorporated into all IS-LM-using introductory and intermediate texts. It could encourage and inform policy-level discussion of the linkages between macro policy and the environment.

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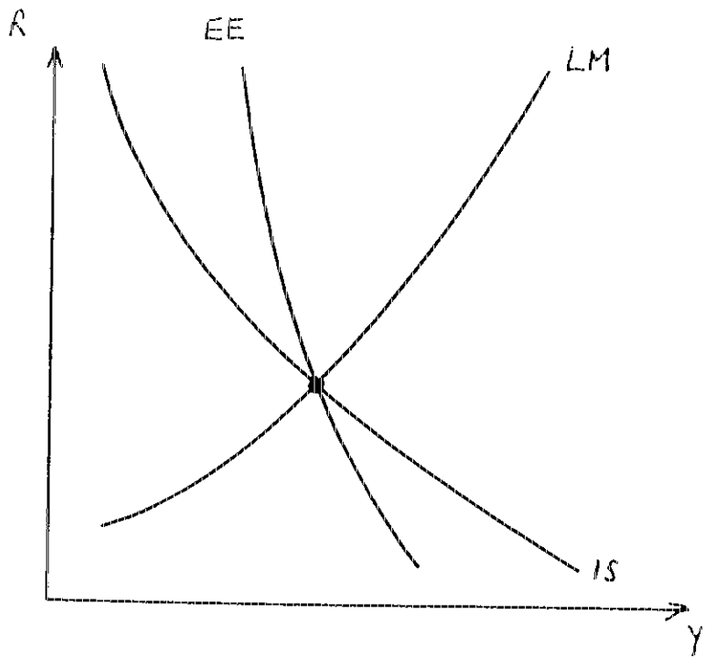

Figure 1

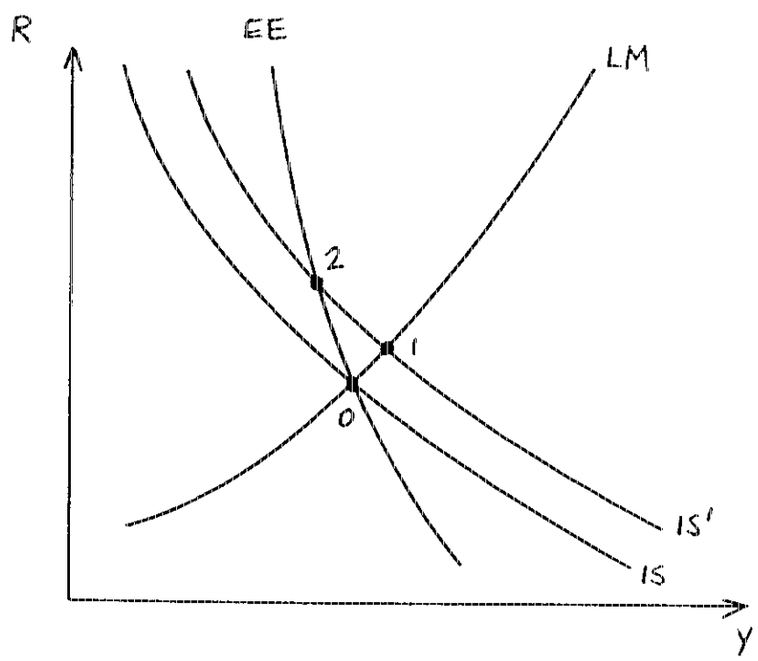

Figure 2

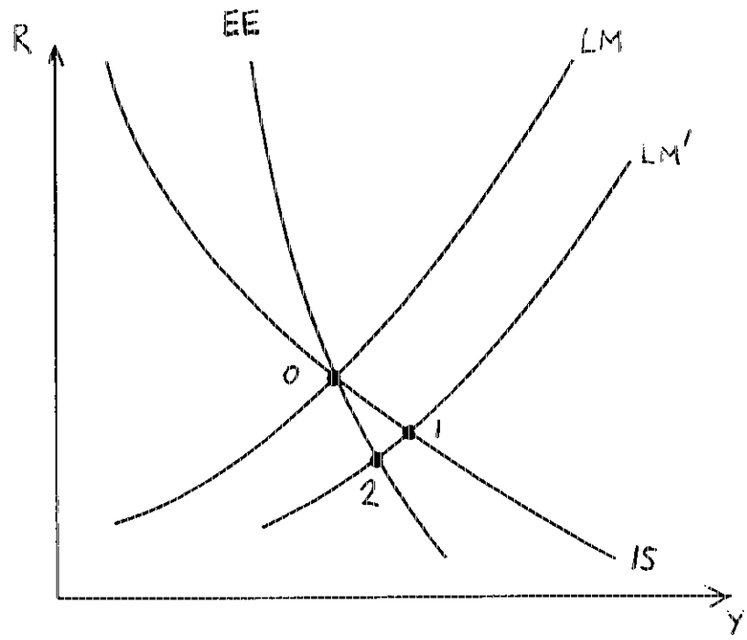

Figure 3