Toward a New Chapter in Macroeconomics – Literally

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Abstract

Intermediate macroeconomics textbooks (Blanchard, 2003, for example) have started to expand their treatment of growth and integrate it a bit more into the model, if only by putting the chapter in the middle and not at the end. Jones and Burda and Wyploz even write their books backwards from what it would have been in the 1960s: economic growth, then Aggregate-Supply-Aggregate-Demand, then the Keynesian model, then monetary theory, then the ISLM model, and so forth.

The economy is, however, embedded in the ecological system, so our models of the economy need to be embedded in models of the ecological system as well. Before the chapter on economic growth, there needs to be one on the environment in which economic activity takes place. The limits to growth, both from depleting resources and from carbon emissions, should be addressed early. To the circular flow, for example, there need to be added a source and a sink; the flow comes from somewhere and goes to somewhere.

I attempt to outline such a chapter. I define a variable $Y_G$, which depends not only on the usual factors of production but especially on the quantity of depletable resources used and is related to the quantity of emissions in the environment from the past. There is a level $Y_G^*$ beyond which the environment of the planet is irreversibly damaged. Note that Mother Nature does not care about prices or reductions in per capita GDP.

I also indicate how this chapter affects the rest of a typical macroeconomics textbook. Jonathan Harris’s classification of consumption and other variables into non-durable, human-capital intensive, energy-intensive, etc., would appear in this chapter and in the ones on measurement and the components of aggregate demand. But for the moment it should be enough to put them in this new chapter. That way it can be slipped into the typical macroeconomics course without requiring very much revision of the instructor’s lecture notes.

This chapter should be compatible with whatever approach is used in the textbook: New Classical, New Keynesian, Post-Keynesian, or radical, though perhaps with a few revisions here and there. For example, a New Classical model would have a vertical Aggregate Supply curve, a New Keynesian model would use a partly horizontal one, and a radical textbook would omit the part on Aggregate Supply and Aggregate Demand.

Ideally we would rewrite macroeconomics textbooks completely. In the meantime, we can at least supplement them in a useful way.

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Toward a New Chapter in Macroeconomics – Literally

Several events should have prompted a rethinking of macroeconomics: the 2000 post-autistic movement, the 2007 climate trilogy (IPCC, Gore, Stern), and the 2008 Great Recession. They should have, but they did not.

The intermediate macroeconomics textbooks of the 1960s started with the Keynesian cross and the components of aggregate expenditure: consumption, investment, and government purchases. Then came the chapters on money, ISLM analysis, fiscal and monetary policy, and perhaps one on the Phillips Curve. At the end, carefully designed so that they could be skipped for lack of time, were the chapters on foreign trade and, last but not least, economic growth. That last chapter continued to be completely separable from the rest of the economic model. Then came the 1970s, and the failure of a model that stressed only demand was exposed.

In the 1980s not only were new chapters added, but the older ones were rearranged. Now the text leaped into ISLM and money, a chapter on aggregate supply was added, and another combining aggregate demand and aggregate supply, and international trade was incorporated into the model. Economic growth, however, was still outside the structure of the model, except for an occasional nod to a special vertical “long-run aggregate supply curve,” formerly called the full-employment line.

By now, some textbooks – Blanchard (2003), for example – have started to expand their treatment of growth and integrate it a bit more into the model, if only by putting the chapter in the middle and not at the end. Jones and Burda and Wyploz even write their books backwards from what it would have been in the 1960s: economic growth, then Aggregate-Supply-Aggregate-Demand, then the Keynesian model, then monetary theory, then the ISLM model, and so forth. The chapters on consumption and investment are now the ones that can be skipped for lack of time.

Strangely, however, none of the textbooks I recall using ever mentioned scarcity: growth was assumed to be able to continue forever, or at least within the relevant range, like unlimited tastes.

Looking at ecological economics textbooks is trickier: some of them are written at the introductory level, even though they would normally fit in the curriculum at the level requiring an economics prerequisite. Common and Stagl (2005) have three chapters on macroeconomics, one on the national income accounts and input-output analysis and two on economic growth. There is nothing in between. Daly and Farley (2004) also have three chapters on macroeconomics (not counting the one on distribution) on measurement, money, and ISLM analysis. These are the only two books I have found after an exhaustive search that include the notion that growth has limits. Common and Stagl show simulations of aggregate production functions, and Daley and Farley somewhat apologetically introduce a vertical curve in the ISLM model.

I do not think we should wait for the textbooks to change. David Colander says that could take 10 to 20 years. I think we can help change the courses before changing the textbooks, by writing a lecture and then a model textbook chapter that fits into the syllabus of an intermediate macroeconomics course just after the chapter on measurement of the GDP.

Why not just ask professors to assign a textbook on ecological macroeconomics? First, because none exists; the ecological economics books cover both micro and macro at an introductory level. Second, because it is easier and faster to add a lecture to an existing syllabus than to adopt an entirely new textbook, as most of us already know. This lowers the cost of incorporating ecology into macroeconomics, on the off chance that conventional economists, and the greater chance that ecologically-minded economists in conventional departments that impose textbooks on instructors, wish to do so.

True, what is said in the added chapter should influence every other chapter in the textbook, but as a first approximation one could just drop a chapter or lecture in that is self-contained.

Part I is an outline of what such a chapter or lecture should contain. First, it should extend the well-known critiques of the GDP with more ecologically-oriented discussions. Second, it should provide a short history of economic growth and the ecology over the last 400,000 years or so, including a description of climate change, sustainability, and the limits to growth. Third, it should set up an aggregate production function (or a set of them, if you will) that decomposes both inputs and outputs according to their effects on the environment. Jonathan Harris (2008) does this in an intuitively appealing way. All this sets the stage for the last section, the introduction of what I call the Daly constraint: the maximum quantity of resources (especially carbon) that can be used to produce GDP in a given year without permanently harming the environment.
Part II contains what could be either a single chapter toward the end of the course or sections scattered throughout the rest of the book. These are the areas that are most affected by the introduction of the ecological considerations covered in Part I.

I THE CHAPTER

The macroeconomy is embedded in the natural and societal environment. We start with modifications to GDP and continue with a simple way to show the constraints imposed on the economy by that environment. First we look at the way in which GDP is measured; it is the fundamental variable in macroeconomics. Second we look at the science behind climate change and sustainable development. Third we construct an expanded Aggregate Production Function, making explicit the inputs and outputs that are energy intensive. Finally we show the relation between GDP and carbon-dioxide emissions and indicate the limit beyond which such emissions damage the ecology. We do not specify the value of that limit, but we do incorporate it as a variable in the general model.

Measurement

The real problem with the GDP as a measure is not what it includes or leaves out, but what it has come to represent. Fundamentally, GDP is a measure only of output. It is the macroeconomic equivalent of the measure of, say, the quantity of rice produced; no one seems to complain that the output of rice does not take into account pollution, using up of precious water, women’s work serving rice, or the satisfaction people get from eating Rice-a-Roni. These are recognized to deserve their own measures. Yet people expect the GDP to measure those things, when it is no more than the measure of the total quantity of everything produced. Presumably this is because it is more convenient to have a single number to tell us how well things are going than to have to balance the values of several of them.

Nonetheless there is serious work on measuring the relation between GDP and an economy’s well-being. Various approaches include welfare economics, happiness economics, and augmented measures such as the Index of Economic Well-Being (Thiry, 2015), the Index of Sustainable Economic Welfare – now called the Genuine Progress Indicator (Harris, 2013, Chapter 3, note 18), or the Human Development Index (United Nations Development Programme. Any year). Many of these are directly relevant to the incorporation of ecological considerations into macroeconomics. (See Harris, 2013, Chapter 3.)

In general, there are several issues concerning these alternative measures. In some cases, they move with GDP. Since economics is the study of changes rather than levels, there is no need to use another measure if it changes in the same way. In other cases, they move differently from GDP, in which case it is necessary to explain why and to explain why those changes are more important than the changes in GDP.

But there is a more fundamental question here: what do these alternative measures measure? Consider a production-possibility frontier between consumption and investment. Also show a set of “community indifference curves” (Samuelson, 1956) one of which is tangent to the PPF at an optimum corresponding to the “bliss point” in utility space. A line tangent to both curves indicates the GDP, and its slope is the price ratio between consumption and investment. The alternative measures to GDP either are substitute measures of output or substitute measures for community indifference curves or something else entirely, and economists and others sometimes get confused. Happiness indicators are on the community-indifference side, and the Human Development Index is on the production side, with an extended view of what is being produced. This could either be the original Bergson (1938) social welfare function (which included noneconomic variables), a set of Lancasterian characteristics (Lancaster, 1966), or a hedonic price function. When other numbers are added and subtracted in, however, to account for pollution, household production, etc., it is difficult to tell where the social preferences leave off and the social possibilities come in.

Since intermediate macroeconomics textbooks stick to GDP, however, it is best that this chapter do the same. Especially since the point of the chapter is to show the connections among production, resource depletion, and pollution.

The Environment of Economic Behavior

The economy is embedded in the ecological system, so the chapter needs to indicate the connection. Begin with the history of the world economy for the last few hundred thousand years, much as is done by Common and Stagl (2005, Chapter 3). The stress would be on the climate temperature when it was last this high, and on the exponential growth of carbon pollution that has accompanied the industrialization process since 1800. At this point
it would remind students of the production-possibility frontier. That model applies even if we do not know what the quantities of the resources are or when they will run out. It is a bit like a keg at a fraternity party far from town: if the partiers wake up and find the keg is still partly full but they do not know by how much, what price should they charge now for the beer?

**Global climate change**

The scientific evidence shows that (1) climate change is happening, (2) it is partly caused by humans, (3) it is serious, and (4) it is almost too late to do something about it. In my syllabi for other courses I have included a challenge:

I will give a free A to any student who can find three articles attacking the idea of global warming. They have to meet the following criteria:

1. They have to have been published in respectable scientific journals. I’ll go as far as *Scientific American* or maybe *Science et Vie*, but not Fox News or the *Journal of Intelligent Design*, if there is one.
2. They have to have been published in the last five years.
3. They have to attack either the fact of global warming, or the fact that it humans are causing it, or that it is serious, or that it is almost too late. Now I do not mean an article that says for example that the crisis will occur in forty years rather than thirty or that Jane Doe’s figures are off by a decimal point. I mean someone who says that global warming is a myth and that the scientific evidence does not support the idea that it is happening.

I did not say a free A in what, but of course I never had to make good on this promise anyway.

The chapter and lecture for the intermediate macroeconomics course would address each of these questions briefly, taking the climate scientists’ word for it in the same way that we take the word of the mathematicians about marginal analysis, the logicians about the fallacy of composition, or the historians on the dates of the Great Depression. Since all scholars are bound by the same rules of research, which in the natural and social sciences are the scientific method, we assume they have done their job the way they assume we have done ours.

**Climate change is happening**

I would open with the chart of CO$_2$ for the last few hundred thousand years and the earth’s temperature for the same length of time. The spike at the right hand side should lay to rest the ideas about how present climate change is just a normal fluctuation.

![Carbon Dioxide vs Temperature: past 400,000 years](http://www.skepticalscience.com/co2-lags-temperature.htm)
It is partly caused by humans

The second chart would show that even though humans do not of course account for all the increase in global temperature, they account for most of the increases since 1960.

![Separating Human and Natural Influences on Climate](chart.png)

Plait (2014)

It is serious

A chart from the Stern Review shows the consequences of increasing global temperature from the baseline of 1800. I would point out that some of the predictions, e.g. disappearance of glaciers and increased forest fires, are coming true.
Figure 2 Stabilisation levels and probability ranges for temperature increases

The figure below illustrates the types of impacts that could be experienced as the world comes into equilibrium with more greenhouse gases. The top panel shows the range of temperatures projected at stabilisation levels between 400 ppm and 750 ppm CO₂e at equilibrium. The solid horizontal lines indicate the 5 - 95% range based on climate sensitivity estimates from the IPCC 2001 2 and a recent Hadley Centre ensemble study 3. The vertical line indicates the mean of the 50th percentile point. The dashed lines show the 5 - 95% range based on eleven recent studies 4. The bottom panel illustrates the range of impacts expected at different levels of warming. The relationship between global average temperature changes and regional climate changes is very uncertain, especially with regard to changes in precipitation (see Box 4.2). This figure shows potential changes based on current scientific literature.

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It is almost too late

*Scientific American* reports, “Currently the atmospheric concentration of CO2 (the leading greenhouse gas) is approximately 398.55 parts per million (ppm). According to the National Oceanic and Atmospheric Administration (NOAA), the federal scientific agency tasked with monitoring the health of our oceans and atmosphere, the current average annual rate of increase of 1.92 ppm means we could reach the point of no return by 2042.” (“Have We…”)

**Sustainable development and the limits to growth**

The temptation is overwhelming to use an enhanced circular flow diagram based on Herman Daly’s work, and to tell the story of Herman Daly vs Larry Summers. According to Daly (1997, p.6), he presented the following diagram to a gathering at the World Bank, stressing that the economy is embedded in the ecology and is growing so large that it threatens to burst it.

**The Daly Version of the Circular Flow of Income**

Larry Summers then got up and said, “That’s not the way to look at it,” and proceeded to draw the following diagram
It seems clear that the Summers view should be superseded by the Daly view: the economy is part of the ecosystem, not the other way around.

**Aggregate Production**

Following this would be a description of the aggregate production function, which would include variables for resources:

\[ Y_F = F(D, L, K, R, H, A, \ldots) \]

where

\[ Y_F = \text{full-employment GDP (or whatever it is called in the textbook in question)} \]

**Outputs**

Later of course the Y term, that is GDP, would be broken down into consumption, investment, etc., in the usual way. Jonathan Harris’s classification (2008, p.11) of outputs is useful here:

- \( C_g \) = consumption of non-durable goods and energy-intensive services
- \( C_h \) = consumption of human-capital intensive services
- \( C_m \) = household investment in consumer durables
- \( I_{ne} \) = investment in energy-intensive manufactured capital
- \( I_{nc} \) = investment in energy-conserving manufactured capital
- \( I_n \) = investment in natural capital
- \( I_h \) = investment in human capital
- \( G_g \) = government consumption of non-durable goods and energy-intensive services
- \( G_h \) = government consumption of human capital-intensive services
- \( G_{ne} \) = government investment in energy-intensive manufactured capital
- \( G_{nc} \) = government investment in energy-conserving manufactured capital

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1. “Full employment” was the original name. For reasons discussed elsewhere in the macroeconomics textbook, the term has been replaced several times: “high employment,” or, to turn it around, “natural rate of unemployment,” NAIRU (“non-accelerating inflation rate of unemployment”), and so on. Full-employment GDP is the maximum level of output that can be efficiently produced by the existing stock of resources in an economy.
$G_n = \text{government investment in natural capital}$
$G_h = \text{government investment in human capital}$

**Inputs**

D = land and natural resources. Harris and others call this “natural capital.” I resist this here for two reasons: first, I see no reason to rename things that already have a name just because the word “capital” may have more cachet. Second, some economists use N for population.

L = labor and human capital
K = physical capital made by humans
R = renewable resources
H = exhaustible resources
$A_T = \text{technology; can be D-augmenting, K-augmenting etc.}$
A = etc. (Solow residual)

These variables should be broken down in the same way as above. Based on Harris (2008), each would have a subscript e for “energy-intensive” or c for “energy-conserving.” Government statistics in general do not as yet break down these variables this way, but they should. Also, later chapters should include these subscripts, but for the moment it should be enough that they are mentioned here. I have still not incorporated resource depletion into the model; I suspect it is rather straightforward for someone who has more experience than I.

It might be of interest to point out that several other standard relationships come from this function: marginal product, production-possibilities, and isoquants. Solow’s formulation, often found in principles texts, also comes from here. The standard textbook rendition is more accurately called an “aggregate total product curve,” of which the Solow diagram is a variation. Of course, the coefficients and elasticities of substitution change as the technology adjusts -- unless you are a Post-Keynesian. See below.
Daly constraint

Next there would be an equation for emissions as a function of GDP:

\[ E_m = E(Y) \]

The inverse function of this would show the GDP associated with each level of emissions. From climate science we get the maximum safe level of carbon emissions \( E_G \) and the maximum GDP associated with those emissions:

\[ Y_{G*} = E^{-1}(Y) \]

The slope has been estimated at 0.38:

![Global Carbon Dioxide Emissions versus Global GDP: 1990-2006](http://thebreakthrough.org/archive/carbon_dioxide_and_the_global)

From climate science we get \( Y_{G*} \) which is the limit beyond which the emissions from the production of \( Y \) in the given year produces irreversible damage to the environment. The constraint is imposed by nature, but it can be enforced only by humans. That is, unless you count the prospect of total collapse of the human environment.

It should be stressed that Mother Nature cares about quantities, i.e., the total \( \text{CO}_2 \)e in the atmosphere. She does not care about prices, or GDP per capita, or tax rates, or oil-company profits, or someone’s election or re-election. This is one of the purposes of the IPAT identity (impact = population x affluence x technology; Common and Stagl, 2005, p.211); the PA in IPAT is a total, not an average.

This follows Daly and Farley (2004, p.302):

How might the … model be adapted to ecological economics? Remembering our basic vision of the macroeconomy as a subsystem of the finite and nongrowing ecosystem, the most obvious suggestion would be to impose an external constraint on the model representing the biophysical limits of the ecosystem. For example, we could assume a fixed throughput intensity per dollar of \( Y \) (i.e., GNP), so that a given \( Y \) in money terms implied a given physical throughput. Then we could estimate the maximum ecologically sustainable throughput, convert that into the equivalent \( Y \), and impose that as an exogenous constraint on the model. [1] It would be represented by a vertical line at the \( Y \) corresponding to maximum sustainable throughput. ...
II THE REST OF THE BOOK

Incorporating ecological considerations into macroeconomics affects other parts of the model as well. Here are some important examples.

The Aggregate Production Function

The aggregate production function could be a simple Cobb-Douglas or a fancier one like a CES function, or even a Romer-style function with “endogenous growth,” but the point is to include variables that take scarcity into account. There can be increasing returns to knowledge and diminishing returns to the other variables, but it needs to be acknowledged that knowledge other than oral tradition uses physical objects to create, store, and transmit it.

A carbon tax would raise the price of inputs that include carbon as an ingredient and thus reduce the relative price of other inputs. In other words, with a carbon tax firms would have the incentive to substitute labor for carbon-based inputs whenever possible (Harris et al, 2015, p.31).

In an intermediate macroeconomics course, it may be necessary only to indicate that there is a function, not necessarily to specify it. The mathematics could be in an appendix, though I have always wondered what students think about that. The appendix is there to show that what is stated verbally an also be stated mathematically, but would not students think that if it can be stated verbally, why is it necessary to do it mathematically at all? With the mathematics should be an indication that this is sometimes how the economics is developed by real economists.

Post-Keynesians object to the use of a neoclassical aggregate production function, preferring some sort of Leontief function for input-output analysis. A major argument of the Post-Keynesians is that distribution is arbitrary and politically determined, and that firms do not change demand for inputs according to changes in input prices. If so, then how can we limit carbon use in production? Whether by cap-and-trade or by taxation or by any other means, limiting carbon use in production is supposed to translate into, well, limited carbon use in production. How can that happen if firms ignore relative input prices? I asked several colleagues about this and was mostly referred to Peter Dorman. I emailed him, and he said he had not used a Leontief function for over thirty years. On the other hand, there are ways in which input-output analysis can take price changes into account (Carter, 1974, p.4; Munasinghe, 2009, p.141). Fortunately it may not be necessary to include these issues in an intermediate macroeconomics course.

The Economy as a Whole

There are at least three different diagrams in intermediate macroeconomics with Y (GDP) on the horizontal axis: the Keynesian cross, the ISLM model, and the Aggregate-Demand-Aggregate-Supply model. Some textbooks might also use a modified version of the Phillips Curve with Y on the horizontal axis, but that is rare. In each case, however, one can just insert the YG line somewhere and go on with the regular analysis.

Daly and Farley (2004, pp. 303-304) do a good job of YE ≤ YF ≤ YG. They also stress that there is no automatic mechanism by which the equilibrium is made to approach the constraint. This is in contrast to the mechanisms sometimes described for full employment.

It would be easy therefore to use the YG Daly constraint in a textbook regardless of the approach: for example, the New Classical model would use a vertical Aggregate Supply curve, New Keynesian a partly horizontal one that eventually curves and turns vertical around the full-employment line.

Aggregate Supply and Aggregate Demand

Some textbooks, especially a radical one, however, might reject the ASAD framework entirely. I find this astonishing, since I have always thought this was the greatest teaching aid since Marshall’s scissors. Though not a specialist in macroeconomics, I did have the most comprehensive course in the country in graduate school,2 so I was taken aback when I found such scathing critiques of the model. The arguments seemed to veer between incomprehensible and equally applicable to every other model in economics. Fortunately one can simply omit the model, as Daly and Farley do (2004), and still have a logical system. Unfortunately, it means that the only thing explicitly representing the supply side of the economy is the Daly constraint.

Carbon-based inputs are pervasive in advanced economies. Thus during the oil crises of the 1970s, the rise in the price of carbon-based fuels (mainly oil) pervaded the entire economy, shifting the Aggregate Supply curve

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2 I took three hundred pages of lecture notes, not counting summaries, detailed tables of contents, etc. It was 25-30 years before anything surprised me in macroeconomics.
upward and to the left. This could be prevented or at least lessened by subsidizing and otherwise encouraging alternative energy sources, and by following the European policy of the time rather than the American: reducing unemployment and letting inflation go where it may. Proper income redistribution and indexing would reduce the burden on the poor. Harris et al. (2015, pp.31-32) even quote Dower and Zimmerman (1992) saying that consumer adjustment and substitution of lower-carbon products for higher-carbon ones would lessen the price increase in any case. This would be a long-run solution however.

**Policy**

Economic policy has several different facets, to address several different sets of problems. Aggregate Demand policy is the most well-known macroeconomic policy: monetary policy is suitable for fighting inflation, fiscal policy for fighting recession. These are to bring $Y_E$ as close to $Y_F$ as possible.

Aggregate Supply (“supply-side”) policy came into view in the 1970s, and aspects of it are clearly controversial. Nonetheless, research and development policy can twist the production function away from energy- and carbon-intensive inputs and outputs and allow $Y_F$ to stay the same.

The new category of macroeconomic policy covered here would be ecological policy: Set the scale of $Y_G$ equal to what would not destroy the environment. Within that constraint, economic policy can proceed in a normal way.

Some of these goals can be achieved through microeconomic policy: cap and trade, for example, can implement the decision on scale. Income redistribution toward the lower-income groups through tax and transfer policy could increase aggregate demand without fiscal and monetary policy.

One could argue that a final category would be necessary: political and social policy. This would involve the creation of new institutions to strengthen the implementation of the other policies. That however is a matter for another course.

**III CONCLUSION**

It is past time for intermediate microeconomics textbooks to incorporate ecological considerations into their models, but the nature of the publication process prevents their quick modification. Ideally we would rewrite macroeconomics textbooks completely. In the meantime, we can at least supplement them in a useful way. Here I outline a chapter or lecture that can be inserted into a standard course. It sketches the problem of climate change and indicates the constraint that the problem imposes on an economy’s ecologically sound output. One might also wish to incorporate limits to growth from resource depletion (à la Club of Rome), distributional considerations (à la Kalecki or someone else) and radical uncertainty (à la Davidson and Minsky) into the mix. Knock yourself out.
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