Mainstream Growth Theory:
Are Pro-Growth Conclusions Driven by Models or Mindset?

By Hendrik Van den Berg*

Abstract

Most mainstream economics textbooks present economic growth in a capitalist market economy as a stable and continuous process. The neoclassical Solow growth model and more recent dynamic mathematical endogenous growth models are used to explain growth and justify the optimistic conclusion about economic growth. Other schools of thought reach different conclusions: Marxist models predict that in a capitalist economy growth will inevitably collapse, American Institutionalists see continuous economic growth as just one of many possible economic outcomes, Post Keynesian models suggest that recessions/depressions occur with great regularity in market economies, and environmental economists present models suggesting that economic growth as we have known it in the past two centuries is not sustainable. The apparent differences in economic outcomes derived from alternative models have led some heterodox economists to attribute mainstream's optimism about long-run growth to the inherent pro-growth bias in mainstream neoclassical models. However, this paper shows that under many realistic assumptions and conditions, mainstream growth models can used to predict economic collapses as well as persistent growth. For example, when the neoclassical Solow growth model is disaggregated into separate market and natural sectors, the model can predict an economic collapse. Similarly, when Romer's well-known endogenous growth model, based on Schumpeter's process of creative destruction, is disaggregated, the model can be used to show that it is very difficult to generate the continuous flow of new technologies necessary to sustain economic growth. The fact that disaggregated models can generate economic collapses but mainstream economists have avoided disaggregating their models suggests that mainstream's optimistic predictions about capitalist growth is more likely to reflect a particular mindset than a modeling bias.

*Hendrik Van den Berg: Professor, Department of Economics, University of Nebraska–Lincoln, Lincoln, NE 68588-0489; hvan-den-berg1@unl.edu; 402-202-6997.

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INTRODUCTION

Mainstream economists routinely use neoclassical models and modeling methods to argue that capitalist economies, if left alone, can grow indefinitely. On the other hand, Keynes (1936) and Post Keynesian economists such as Minsky (1978, 1982) have suggested that an unregulated capitalist economy is prone to major booms, deep depressions, or even long reversals of economic growth. Ecologically-sensitive economists such as Daly (1980), Victor (2008), and Harribey et al. (2012) as well as ecologists such as Meadows et al. (2004) argue that there are indeed natural limits to economic growth. Marx (1906-9, 1967) and twentieth-century Marxists such as Baran and Sweezy (1966) suggest that capitalist economic systems inevitably face collapse; Burkett (2009), Foster (2000), and Magdoff (2014) combine Marxist models with ecological concerns to argue that modern capitalist economic systems will collapse. Since different schools of thought are identified with specific sets of models, those who question mainstream economists' optimism about long-run growth (and their failure to anticipate the 2008-2009 global recession) tend to focus on the inherent pro-growth bias in the neoclassical models that mainstream economists use. Given the severe environmental problems human society faces, it is certainly quite important to avoid a pro-growth bias in economic analysis.

To put things in perspective, we should examine the great variety of models, stories, metaphors, heuristics, and assorted other theoretical constructs that economic thinkers have developed to interpret the complex economic and social structures that humans have evolved over time and to predict economic outcomes. In focusing on the details and mechanics and

details of the different models, we often lose sight of the conceptual frameworks or belief systems that underlie the models, or what the science historian Kuhn (1962) describes as the *paradigm* that guides economists' thinking, shapes formal analysis, prescribes the methods used, determines the topics analyzed, and influences how the results are presented. Sociologists refer to such a belief system and the preferred models as the *culture* of an intellectual field.

Bourdieu (1977, 2001, 2005) splits culture into *doxa* (beliefs) and *habitus* (tools, procedures, methods, perspectives, models, etc.). In accordance with this framework, it is fair to say that the majority of economists educated at Western universities embrace the *neoliberal* doxa of individualism and private property, and neoclassical models have become the standard tools in the mainstream economic culture's habitus. Their culture then pushes economists to use their neoclassical models to derive optimistic conclusions about long-run economic growth. But, how much of the growth bias is due to the models that have come to make up the habitus, and how much is due to how the underlying doxa leads mainstream economists to use the models?

Economists outside the mainstream culture, such as Post-Keynesians, Institutionalists, and Marxists use different models that better fit their particular prior beliefs and perspectives, and they reach less optimistic conclusions about future economic growth. These non-neoclassicals often conclude that it is the neoclassical models that bias mainstream analysis. This paper questions that assertion and shows that, in fact, the most popular mainstream growth models do not always show economic growth to be a stable and continuous process. Neoclassical growth models can be applied to generate growth reversals and even economic collapses. Mainstream economics' pro-growth bias may, therefore, not reflect a modeling bias but a bias in how models are applied, and critics of mainstream economics pro-growth bias should contest the neoliberal doxa rather than the neoclassical models in the mainstream habitus.

SOME THOUGHTS ON MODELING

In general, all models are simplified patterns that humans perceive in the complexity that they actually observe. First, perceptions differ from reality for the simple reason that the economic, social, and natural realities are too complex to comprehend. Secondly, as Frederick (2005) shows by means of various experiments, the human brain often jumps to false conclusions because it fits reality into pre-conceived patterns. Human perceptions of reality inevitably reflect human culture, which means that economic models inevitably have built-in biases that end up shaping conclusions about how the world works.

Understanding how social thinkers view the economy is critical to interpreting their conclusions. For example, if a social scientist assumes that every economy has the same stable and constant structure, she may feel justified to use simpler *partial equilibrium* models that focus on one segment of economic activity under the "all other things equal" assumption. Such a preconception of structural stability can also lead to the use of models that represent the *aggregate* economy by means of a few curves in a diagram or a small set of mathematical equations under the assumption that the composition of the aggregates does not vary much over time. It is probably easiest to model the economy as an isolated static and stable system, as neoclassical models usually do, although it takes a very large set of assumptions to construct such logical models; once constructed, such models easily generate conclusions about how changes in an exogenous variable or a policy parameter affect the relatively small number of endogenous variables.

Models can also be constructed with a specific set of circumstances in mind or they can be intended for general applications across all circumstances. For example, in the of the U.S. Institutional school or the German historical school, particular economic and social institutions

are given prominence in economic analysis, and because institutions differ greatly over time and across countries, there is no simple model that applies to all economies. Neoclassical models are usually used as having universal applicability because they are built under a common set of assumptions that mainstream economists believe apply (or should apply) to all economies.

Mainstream economists often find it convenient to model the economy as a self-contained organism, distinct from the social and natural systems in which humans also live and act. In contrast, social thinkers and those economists who recognize the complexity of the real world often prefer to model an economy as an interdependent system within broader social and natural systems; this will usually motivate the development of less precise models that depict the economy as a *complex system* consisting of many parts interconnected in complex ways. Because such interactions between the economic, social, and natural systems are unlikely to be linear or unchanging, this "holistic" perspective suggests that models be dynamic, evolutionary, and potentially unstable or lacking a single definable equilibrium.

The preference for neoclassical models in mainstream economics requires some explanation. After all, it is not entirely clear why, after Classical economists and Marx devoted great effort to explaining the dynamic development of economies, economists in the late nineteenth century stopped looking at the economy as an evolutionary, changing organism, to instead focus on the allocation of a fixed set of resources, precisely when the capitalist system was generating unprecedented economic growth and structural change. It was around that time that Walras (1874) provided the intellectual foundation for the Neoclassical school with his static mathematical general equilibrium model. Walras specified a system of linear equations with fixed parameters, which effectively pre-determined the stability of his hypothetical market system. Walras' fixed, static system was very different from the dynamic capitalist systems

envisioned by Smith and Marx. The faith that a market system was stable combined with the practical impossibility of actually solving Walras' massive system of equations to effectively push economists towards using neoclassical models to analyze the system's individual markets (what we know as microeconomics today) instead of trying to use the model to analyze the overall performance of the economic system. The *ceteris paribus* assumption became standard operating procedure for analyzing individual and firm behaviors. The practice of focusing only on individual parts in order to understand the whole of a complex system is referred to as *scientific reductionism*. Seabright (2010), perhaps more accurately, describes the practice as *tunnel vision*. Analysis of the aggregate (macro)economy generally assumed Say's Law or the invisible hand applied, which meant that an aggregate supply-side production function would suffice to represent the entire economy.

The neoclassical modeling framework was occasionally challenged in the mainstream, as, for example, during the Great Depression when Keynes (1936) provided a new macroeconomic paradigm for modeling macroeconomic policy that quickly gained a wide, but shallow, acceptance. Also, there was renewed interest in economic growth after World War II, when people in the more democratic war-torn countries demanded that policymakers generate economic growth not only to raise standards of living above those of the Great Depression, but to restore the economic growth that had preceded the Depression. At that same time, the Cold War resulted in a competition of systems, and even free marketers in the capitalist economies sought further insight into policies to increase economic growth. Finally, the independence of the European colonies in Africa and Asia after World War II increased awareness of the huge income differences that existed in the world. Economists needed models of economic growth to guide policymakers, but mainstream neoclassical models provided little insight.

THE RISE OF THE SOLOW GROWTH MODEL IN THE MAINSTREAM

While orthodox neoclassical economics, which focused on resource allocation within a static and stable system, did not offer a ready model of economic growth, some Keynesian economists did have a growth model ready after World War II. Harrod (1939) and Domar (1946) independently developed identical dynamic logical extensions to the Keynesian macroeconomic modeling framework that had gained popularity during the Great Depression. In analyzing how macroeconomic policy could restore full employment, Keynes had focused on aggregate demand and especially the potentially volatile component, investment. Harrod and Domar pointed out that this volatile investment changed the economy's supply side as well as the demand side, and full employment could be maintained only if aggregate demand, including investment, grew just fast enough to absorb the increased output that the new investment made possible. A mismatch could easily lead to an extended boom or bust.

There is no doubt that Keynesian economics in general, and the Harrod-Domar model in particular, were seen as threats to capitalism because they denied Say's Law and the invisible hand. Worse yet, the suggested a need for active government policies to keep the economy on a stable growth path. So, the mainstream rejected Harrod-Domar and, instead, embraced a neoclassical supply side-only model offered by Solow (1956, 1957). Solow's model consisted of an aggregate production function in which investment was subject to diminishing returns, and the capital-output ratio adjusted as the economy moved towards its stable equilibrium. Solow thus seemed to eliminate the Harrod-Domar model's potential instability and the need for active macroeconomic policies.

Interestingly, Solow's model also showed that diminishing returns to investment would cause the economy to gradually settle in a steady state of zero growth unless there was continual

economy-wide innovation and technological change to continually shift up the aggregate production function. By explicitly making technological change the key determinant of economic growth, the Solow model appealed to Western culture that, according to Moreau (2005), had since the Enlightenment idealized human knowledge and scientific discovery as capable of solving all problems humanity faced. By reasoning that there were no technical limits to human ingenuity, mainstream economists concluded that economic growth was also limitless. Solow's model also seemed to justify neoliberal "economic reforms" like business deregulation, flexible labor markets, privatization, and lower taxes on income and profit in the name of increasing innovation and technological change.[1]

It appears that, even though many mainstream economists accepted some of Keynes' macroeconomic policy suggestions as useful for dealing with the Great Depression's persistently high levels of unemployment, they were reluctant to accept a growth model built around short-term disequilibria. Mainstream economists still believed that, in the long run, the invisible hand guides the economic system of competitive markets towards full employment.

In reference to the neoliberal doxa, we should not forget that at the height of the Cold War, Solow (1956, 1957) explicitly used his model to argue that the Soviet Union would not be able to use its high rate of forced saving to catch up to the U.S. in terms of per capita income; innovation drove growth in the long run, and the Soviet Union was not generating the necessary new technologies. Solow's conclusions thus mirrored neoliberal notions of American and capitalist exceptionalism: since Americans were inherently more inventive and clever, and they also had a capitalist free market system in which to bring their ideas to fruition, the rigid centrally-planned Soviet economy would never overtake the capitalist U.S. economy.

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[1] The role of ideology in the downfall of the Keynesian model has been described more broadly by Colander and Landreth (1996).

Within these favorable circumstances and the strong neoliberal/neoclassical culture of the field, the Solow model was adopted despite the lack of convincing empirical evidence to support it. Early tests of the Solow model consisted of distinguishing some "stylized facts" [observed regularities] of growing economies, and then examining whether the Solow model accurately predicted those "facts." These early exercises were inconclusive, largely because in the 1950s and 1960s there was not much historical data that was not influenced by wars, depressions, and other major disruptions not captured by the Solow model. The Solow model's fundamental conclusion, namely that technology is the fundamental driver of economic growth, was especially difficult to prove because technology is difficult to quantify. The common method of estimating technology as the residual between economic output and a weighted average of known inputs like capital, labor, resources, etc. is doomed by the impossibility of accurately measuring true economic output and the production functions hypothesized inputs.

Statistical growth regressions generally have exhibited strong omitted variable biases because the complex process of economic development involves so many variables that cannot be included in the statistical analysis. Estimates thus vary greatly across studies. In short, the Solow model's focus on capital enables it, at best, to only partially explain economic growth. But, the mere fact that *some* of the evidence is supportive of the Solow model was enough to justify the Solow model as the fundamental textbook model of economic growth. Models that do not fit the neoliberal/neoclassical culture of economics have not been given such an easy pass.

DISAGGREGATING THE NEOCLASSICAL SOLOW MODEL

The Solow model's stable equilibrium seems to rule out economic instability, and mainstream economic interprets it in that way. However, a simple disaggregation of the model into separate

economic, social, and natural sectors makes it surprisingly easy to apply the logic of the model to situations that then lead the model predict a sudden collapse of economic growth.

The textbook version of the Solow model begins with a simple aggregate production function, $Y = f(K, L)$, in which Y is total output, K is the economy's stock of capital, L is the number of workers, and the function $f(\ldots)$ represents the economy's state of aggregate technology. Solow assumes *constant returns to scale* and *diminishing returns* to individual inputs. Solow also assumed that capital *depreciates* at a constant fraction, δ, of the stock of capital, K. Hence, the stock of capital is equal to the difference between total new investment, I, which is equal to the savings rate, σ, times the level of income, and the amount of existing capital that depreciates, or:

$$\Delta K = I - \delta K = \sigma f(K) - \delta K. \tag{1}$$

The Solow model is often shown diagrammatically in output-capital space, as in Figure 1. Diminishing returns to capital means the production function slopes upward at a decreasing rate, and a constant savings rate means that the savings/investment function $I = \sigma f(K)$ is a diminished version of the production function $f(K)$. The constant rate of depreciation implies that depreciation is a straight line function of capital, δK. The economy's capital stock automatically adjusts toward the stable equilibrium level K* where investment just equals depreciation.[2]

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[2] It should be obvious that the Solow model presented here is an extreme example of simplification. It is not realistic to describe all economic output with one general production function, and the well-known Cambridge debate reminds us that the aggregate capital stock cannot be represented as a single variable input; see, for example, Kalecki (1971) and Robinson (1962). Capital takes on many forms, such as private factories and public infrastructure, hand tools and locomotives, and factories and residential homes. Thus, there is also no unique depreciation function, as Solow hypothesizes. More generally, there are many social variables that affect the supply of labor. Natural resources are also important inputs; these vary across exhaustible resources, such as petroleum and iron ore, and renewable services of nature, such as air, wind, soil, water, pollination, plants, etc. Finally, the aggregate saving function is not defined because it varies with the distribution of income from varying forms of production.

We seek to find out whether the model that is used so often in mainstream growth theory always shows positive economic growth to be the long-run equilibrium. The fact that the model's equilibrium is called the *steady state* suggests some other outcome than permanent growth is quite possible. Indeed, we find that if we disaggregate, technological progress in the economic sector will not sustain growth or even sustain a steady state of zero growth.

It is straightforward to extend the Solow model and its basic logic to include renewable natural resources as a separate category of inputs, thus creating a three-dimensional graphic model. Suppose that instead of assuming the world consists only of a market economy, as represented by the standard Solow model, humans also depend on an ecosystem that continually provides a flow of natural inputs. That is, there is another dimension to human economic activity beyond those in the model given in Figure 1.

Figure 1
The Solow Equilibrium
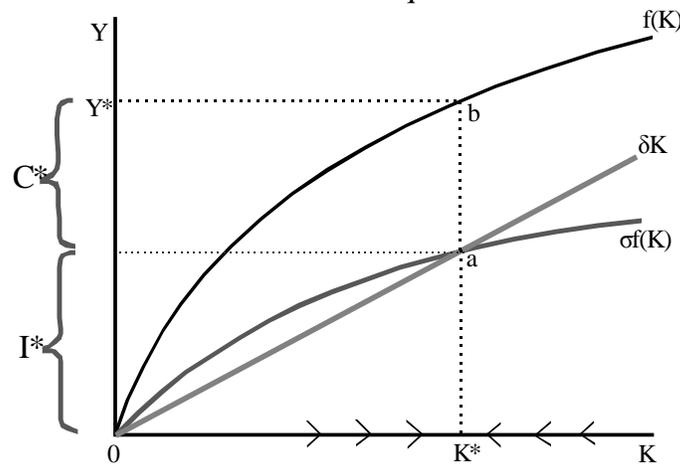
Suppose output depends on the renewable resources, S, as well as labor and capital:

$$Y = f(K, S, L) \tag{2}$$

For ease of presentation on a two-dimensional screen, it is easier to split the model into two separate two-dimensional diagrams, one for the traditional relationship between capital and

output and the other showing the relationship between natural inputs and economic output. Unlike the depreciation function of capital in Figure 1 above, depreciation of the ecosystem that supplies the flow of renewable natural inputs is not linear. The quantity of nature's provision of renewable resources is limited by the ecosystem's capacity to replenish itself, which depends on how intensively humans exploit the ecosystem. For example, in the case of Earth's atmosphere, if CO_2 emissions from human fossil fuel use exceed the atmosphere's capacity to dissipate them, then atmospheric temperatures rise and the climate no longer conforms as closely to the needs of Earth's living organisms and the amount of natural inputs available as inputs in the economy is reduced. In general, the more intensively humans use renewable resources, the more likely that nature will not be able to keep up. Costly conservation efforts, such as planting more trees to capture the carbon emissions, filtering waste water, cleaning up contaminated soil, installing catalytic converters, etc., can compensate to some extent, but those require the use of resources that could otherwise be used in the production of goods and services in the economy.

Figure 2 depicts nature's depreciation function, or better, its *conservation function*, along with the production function of natural inputs. The conservation function reflects the need to engage in explicit conservation activities when nature is stressed. In neoclassical terms, nature can provide additional renewable resources, say from S_1 to S_2, at virtually zero marginal cost, in which case output can increase from Y_1 to Y_2 without impacting the flow of natural inputs. However, when economic output rises to Y_3, conservation activities with an economic cost of $c(S_3) > 0$ are required to sustain such resource use. The steep slope of the conservation function after S_3 reflects the likelihood that once nature is stressed, it cannot expand its provision of natural inputs very much before running into absolute limits.

Figure 2
Economic Growth in the Natural Sector
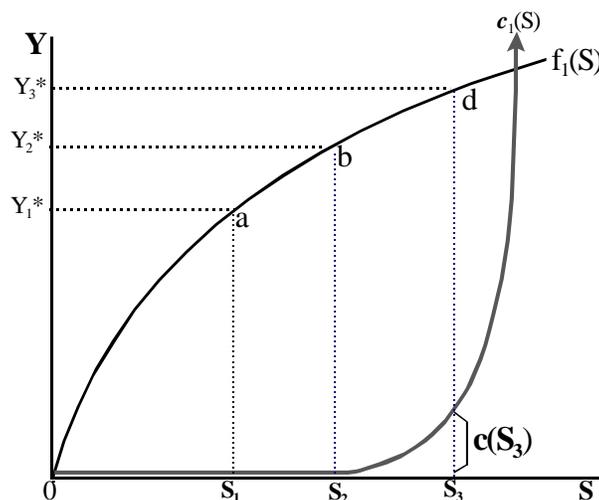
THE UNSTABLE TWO-SECTOR SOLOW MODEL

In Figure 3, both the market and natural dimensions are shown side-by-side. In the case where technological progress in the economy increases output from Y_1 to Y_2, all other things equal, the required increase in inputs of natural services such as rainfall, oxygen, dissipation of air pollutants, absorption of water runoff, etc. incurs no additional conservation costs because the ecosystem's capacity has not been reached.

However, if further technological change in the economic sector shifts the relationship between capital and output further to $f_3(K)$, there will be costly consequences. Figure 3 shows that economic output Y_3 requires natural inputs equal to S_3. To maintain this supply of renewable resources, conservation costs of $c_1(S_3)$ are necessary.

Figure 3
Economic Growth when the Natural Sector Comes under Stress

Natural Sphere　　　　　　　　　　　　　**Economic Sphere**
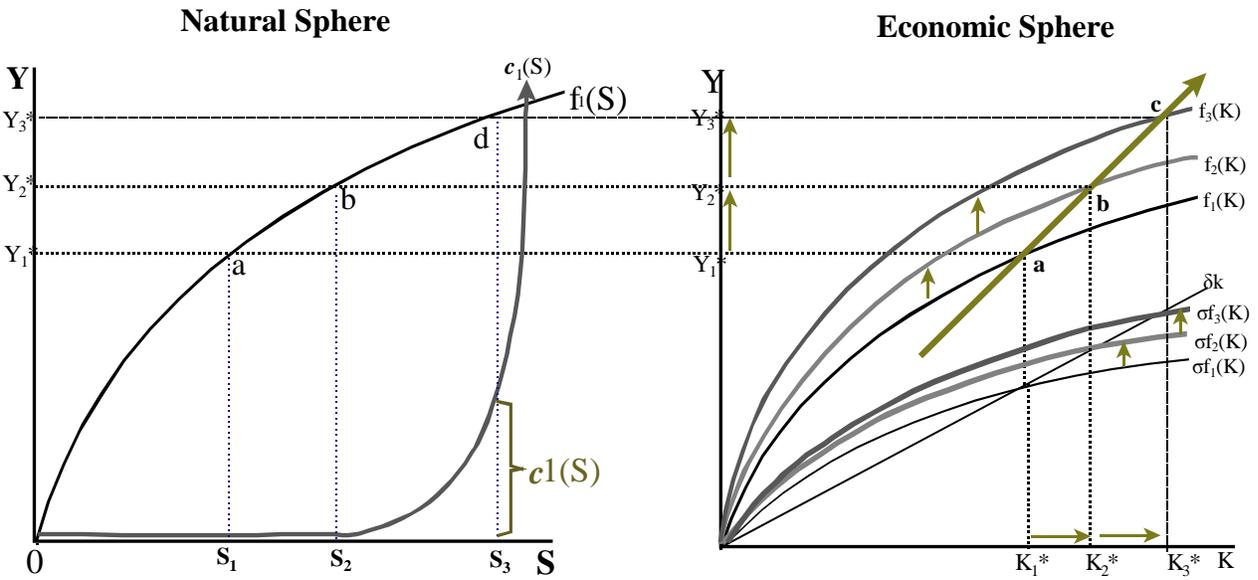
If conservation activities are not undertaken, the ecosystem will be diminished and the stream of services and products will decline. Soil will be depleted, lakes will dry up, and air pollution will reduce the amount of clean air. As shown in Figure 4, the conservation curve shifts to the left. The leftward shift of the conservation curve means that now costly conservation activities are now required at levels of use of renewable resources below S_2, and unless human society engages in higher real conservation activities in period 2 costing $c_2(S_2)$, there will be even further deterioration of nature's capacity to provide water, air, warmth, carbon sinks, flood control, etc. The ecosystem enters a downward spiral of productive deterioration, and with the conservation curve at $c_3(S)$ output level Y_3 can no longer be produced. Wackernagel et al. (2002) estimate that the world has already surpassed the sustainable level of usage of nature's services.

Figure 4
From Economic Growth to Economic Decline

Natural Sphere

Economic Sphere

Most important, Figure 4 shows that the economic system will decline, not just settle in a steady state equilibrium. If the downward spiral described above is permitted to continue because society continues to ignore, or is incapable of responding to, the decline in nature's capacity to provide renewable resources, output in the economy will continue to fall further. If only humans had left "good enough" alone and been satisfied with output Y_2! Diamond (2010), for example, describes many historical examples of such combined environmental and economic collapses. Such outcomes contrast sharply with the single-sector aggregate Solow model, which generates only incremental (marginal) adjustments towards a stable equilibrium. The traditional aggregate (single-sector) Solow model, therefore, is biased towards predicting future economic growth because it ignores the ecosystem as an additional source of diminishing returns.

Figure 5
Technological Change in Both Spheres
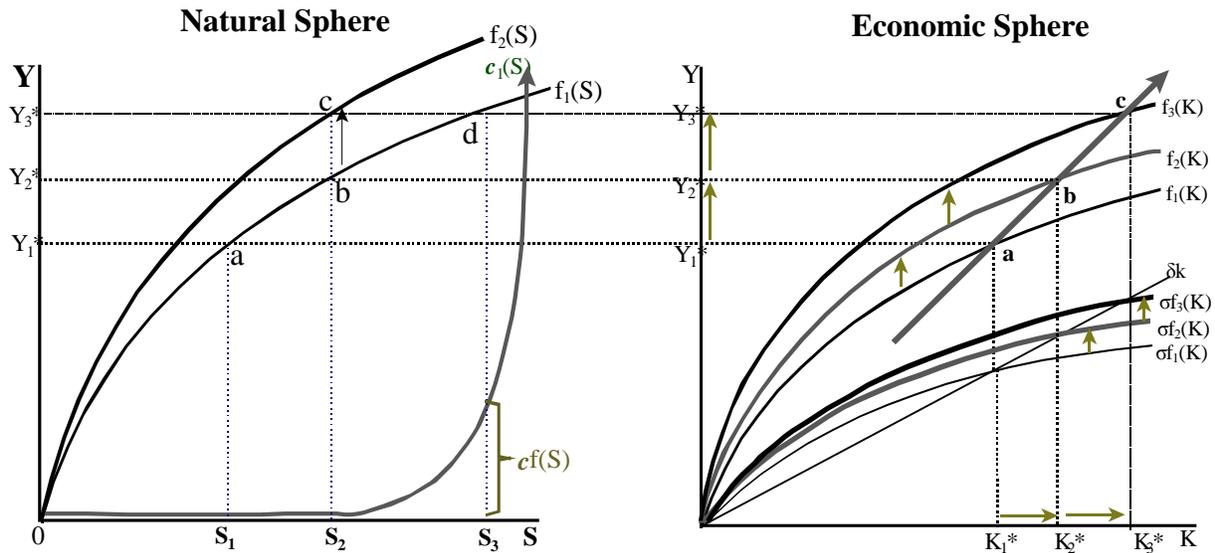
The disaggregated two-sector Solow model reaches another conclusion that it shares with the aggregate model: the growth of economic output can be sustained if innovative activities raise the production function with respect to the provision of renewable resources as well as capital. In Figure 5, a shift in nature's production function from $f_1(S)$ to $f_2(S)$ in the natural sphere when $f_2(K)$ shifted to $f_3(K)$ in the economic dimension enables the increase in output to Y_3 without requiring any additional use of nature's services beyond its self-regulating sustainable level of S_2. Note, however, that now sustainable growth requires not only technological progress in the economic sphere, but also technological progress in the natural sphere. The basic logic of the Solow model effectively suggests that technological change must occur across all sectors; otherwise, diminishing returns will set in and long-run economic growth is not possible. Limits on the exploitation of the ecosystem function much the same way that a fixed supply of labor does in the traditional aggregate Solow model.

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The problem of how to generate the required technological change in the disaggregated Solow model is thus much greater than the aggregate model let on because the technological change needed in the natural sphere is quite different from technological change in the economic sector. Technological change in the natural sphere involves such things as farming more intensively, substituting drip irrigation to save water, and generating electricity with solar or wind power so that fewer greenhouse gasses are emitted into the air. More subtle technological changes that enable society to achieve more welfare-enhancing output from the eco-system are improvements in food storage, improving transportation and packaging to reduce product losses and spoilage, and new farming methods such as crop rotation and no-till planting. More generally, humanity will have to change the way it lives and produces. People will need to use more public transport and fewer private vehicles, they will have to produce fewer material products and more services, and they will have to consume more collectively provided public goods and fewer individually owned private goods. These types of technological change are very difficult because they imply changing human cultures and conventional perceptions of the meaning of life, not to mention the need to change the organization of the economic system. Hence, diminishing returns in the economic sector are likely, and economic growth by means of technological change will not be as easy to achieve as the aggregated single-sector Schumpeter/Romer model suggests.

THE DISAGGREGATED SOLOW MODEL WITH POPULATION GROWTH

Textbooks show that population growth shows up in the simple Solow model as an upward shift of the depreciation line. The reason for this is that population growth effectively imposes a need to invest to provide additional members of society with the same amount of capital as is already

provided to each existing member of society. But, that aggregate model ignores the natural sector, and population growth most certainly affects, and is affected by, what changes in the natural sector.

To show the effect of population growth on the natural sphere, we begin with the Solow model in per worker terms and the assumption that the population growth rate $\omega > 0$, as illustrated in Figure 6. First, note that population growth shifts the depreciation function up from δk to $(\delta+\omega)k$, which lowers the economy's steady state from y_1^* and k_1^* to y_2^* and k_2^*. In Figure 6, both these levels of output per worker are sustainable if the ecosystem's capacity is reflected in the conservation function $c_1(s)$. At per worker natural resource use of s_1 and s_2 the ecosystem can replenish itself, and both output levels appear to be sustainable.
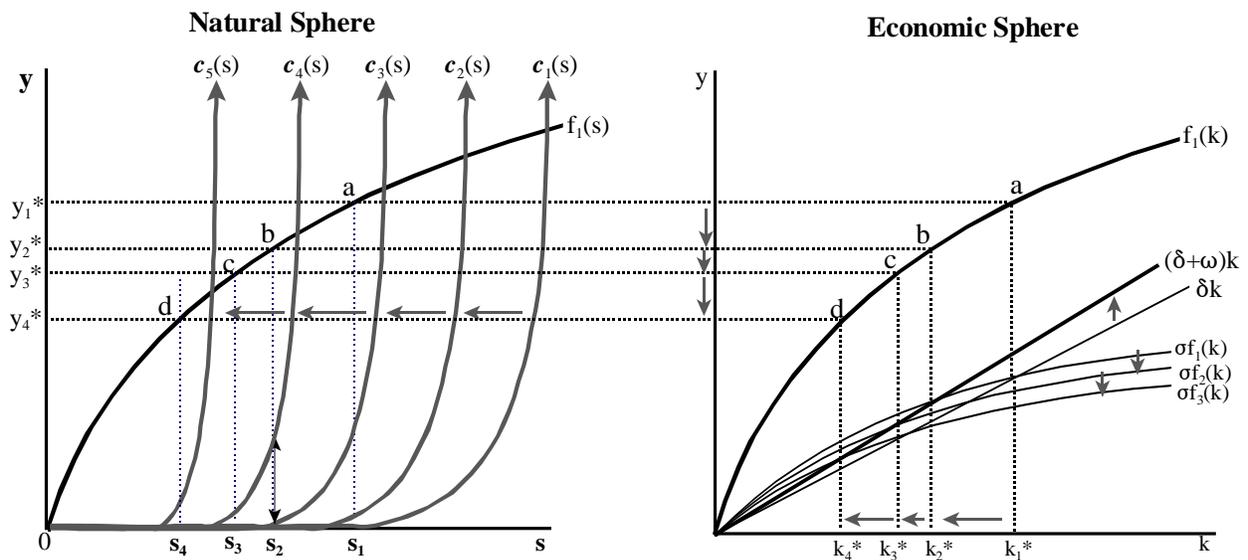
Figure 6 Economic Growth, Population Growth, and Stress in the Natural Sphere

Population growth eventually undermines the ecosystem's resilience, however. The capacity of the ecosystem to provide its services is an absolute quantity, not a per capita quantity, which means that in the model in per worker, or per capita, terms, population growth causes the

conservation function to continually shift to the left. In effect, the human use of nature's services depends on the per capita use *times* the number of people. Therefore, if population growth shifts the conservation function to $c_2(s)$, the combination of y_1^* and s_1 at point a on the natural sector's production function is no longer sustainable without devoting some of society's resources to conservation activity. Of course, this is not an immediate concern because population growth had already established society's steady state at y_2^*, which even after the shift of the conservation function to $c_2(s)$ is still below the point where the ecosystem's capacity to replenish itself is surpassed. But, continued population growth continues to shift the conservation function gradually to the left, and by the time the conservation function reaches $c_4(s)$, there is a large gap between the ecosystem's capacity and its exploitation. Hence, with continued population growth, even the lower per capita income of y_3^* eventually becomes unsustainable.

Population growth seems to have pushed the economy into a downward spiral. In this model, individual actors are assumed to ignore the long-run ecological effects of a birth rate that exceeds the death rate. The two-sector Solow model suggests that the burden of population growth is substantially greater than the single-sector Solow model lets on. And, note that this Solow model still ignores the social costs of economic growth and change. What are the costs of maintaining social stability and generating the necessary new institutions in a three-sector model? It is likely that population growth strains the social sphere as well as the economic and natural spheres. Economists have yet to devote much thought to population growth's environmental and social effects, however. Even studies of sustainable growth focus on reducing carbon emissions from economic production, and little attention is given to the growth of the number of humans. Note that the continuation of the current population growth rate for 700 years results in each person having just one square meter of land to stand on.

ENDOGENIZING TECHNOLOGICAL CHANGE

The manner in which mainstream economics dealt with the recognized failure of the Solow model to explain the technological progress also helps to explain the way culture affects economic analysis. After Solow introduced his model, some growth economists sought to *endogenize* innovative activity and technological change into the neoclassical Solow model, but it proved to be theoretically impossible to explain technological change as a maximization problem within the neoclassical model Solow framework. Innovation is a costly resource-using activity, but production under perfect competition does not generate profits that can cover the up-front cost of innovation. No one would employ resources for research and development activity if there was no prospect of earning enough profit to cover those up-front costs. The endogenization of technological change thus remained near-dormant for two decades, until in the 1980s a number of mainstream economists recognized that they could only model technological change as an activity undertaken by imperfectly competitive firms that had market power that permitted them to earn enough surplus to recover the up-front costs through excess profits. The currently most popular *endogenous growth models* are those by Romer (1990), Grossman and Helpman (1991), Rivera-Batiz and Romer (1991), and Aghion and Howitt (1992). Most of these models claim to draw on Schumpeter's (1934) concept of *creative destruction*, which described how repeated waves of innovators, by *creating* new products, methods, procedures, and technologies, *destroy* their competition and gain monopoly profits until they themselves see their profits destroyed by subsequent creations. In the process, the economy grows. Schumpeter described growth as a process of creative destruction carried out by large business enterprises.

There are subtle differences between the various *endogenous growth models*, but all incorporate the following five fundamental ideas:

1. Innovations are generated by employing costly (scarce) productive resources to create new products, ideas, methods, etc.

2. Profit-seeking innovators compete with producers to employ the economy's scarce, and thus costly, resources.

3. Innovation creates new products or techniques that are better, cheaper, more attractive, or in some other way superior compared to existing products, which gives the producer of the new products a market advantage over existing producers and products.

4. Just as their "creation" of innovations "destroyed" earlier innovators' profits, innovators also know that further innovations by competing innovators will eventually eliminate the profits of their innovations.

5. In deciding how many resources to employ in R&D activities, innovators rationally weigh the costs of innovation, the likely success of their innovative efforts, and the discounted expected future profits of innovation.

Romer (1990) and the other endogenous growth models converted Schumpeter's ideas to a typical maximization problem. These models have gotten a life of their own, and few contemporary users of these models recognizes that they compressed by mainstream economists into a mathematical maximization problem that actually ignored many complexities that Schumpeter had included in his original description of the creative destruction process.

SCHUMPETER'S IDEAS

It is well-known that Schumpeter (1934) gave individual *entrepreneurs* a central role in the innovative process. But, Schumpeter (1934, p. 85) also distinguished between *risk* and

uncertainty, and he explicitly depicted the entrepreneur not as a manger of risk, but as an adventurer willing to face the uncertainty of the unknown:

> Carrying out a new plan and acting according to a customary one are things as different as making a road and walking along it....How different a thing this [entrepreneurship] is becomes clearer if one bears in mind the impossibility of surveying exhaustively all the effects and counter-effects of the projected enterprise. ....As military action must be taken in a given strategic position even if all the data potentially procurable are not available, so also in economic life action must be taken without working out all the details of what must be done. Here the success of everything depends on intuition, the capacity of seeing things in a way which afterwards proves to be true, even though it cannot be established at the moment, and of grasping the essential fact, discarding the unessential, even though one can give no account of the principles by which this is done.

Schumpeter, therefore, did not exactly match the orthodox neoclassical paradigm, which largely takes into consideration only risks characterized by known probability distributions that can potentially be diversified away by financial markets [See Arrow and Debreu (1954) and Debreu (1959)].

Like the German Historical School and the American Institutional School, but unlike mainstream economists today, Schumpeter emphasized the importance of social and economic institutions. Schumpeter also explicitly recognized that innovators faced many barriers and incentives that tempered their urge to innovate, such as culture, society's attitude toward business success, the education system's preparation of potential entrepreneurs, and the legal freedoms entrepreneurs have to pursue their ambitions or urges. Schumpeter even went so far as

to note that entrepreneurs were often immigrants and minority groups because they were less bound by tradition and social norms than natives.

Schumpeter's emphasis on entrepreneurs was not as great as recent growth theorists seem to suggest. He also highlighted the role of corporations in the innovation process. Anticipating much current analysis of industrial organization, Schumpeter (1934, pp. 85-6) noted that R&D activity within large business organizations was increasingly managed in the same way that routine production was managed:

> The more accurately...we learn to know the natural and social world, the more perfect our control of facts becomes; and the greater the extent, with time and progressive rationalisation, within which things can be simply calculated, and indeed quickly and reliably calculated, the more the significance of this function [entrepreneurship] decreases.

Such *routinization* of innovation effectively reduced the role of entrepreneurs that Schumpeter also distinguished as a driver of innovation.

Later in his career, Schumpeter (1942, p. 185) predicted that the improvements in technology and knowledge that entrepreneurs brought about would ultimately undermine capitalism: "...the modern corporation, although the product of the capitalist process, socializes the bourgeois mind; it relentlessly narrows the scope of the capitalist motivations; not only that, it will eventually kill its roots." Reminiscent of Marx, Schumpeter effectively suggested that the dynamic process of economic development continually evolves, and inconsistencies arise to weaken the system and slow the continuous renewal the system requires for its survival.

Schumpeter explicitly recognized the financial sector's role in the creative destruction process. Schumpeter's inclusion of finance into the analysis opens up many potential

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difficulties, and this puts Schumpeter at odds with neoclassical economics in the same way that Keynesian analysis clashes with neoclassical economics' assumption of the neutrality of money. Schumpeter, who lived through the Great Depression of the 1930s, was keenly aware that financial sectors often fail to connect savers with innovators because of information gaps, adverse incentives, fraud, and macroeconomic conditions; he also recognized that a collapse of the financial sector quickly stops investment and innovative activity.

This brief discussion suggests, first of all, that Schumpeter had a very creative intellect and ever-evolving ideas that were not bound even by his own earlier thinking. And, it also suggests he clearly recognized that innovation takes many forms. Policymakers seeking to promote economic growth must take care to create a state of tolerance and freedom that enables creative destruction while also maintaining the economic and social stability necessary to support *routinized* innovation. Schumpeter's distinction between *destruction* and *routine* is not unlike Kuhn's (1962) separation of science into *routine science* that occurs continuously within a paradigm and *revolutionary science* that occasionally shifts the paradigm. Also, the issue of how the gains from innovation are shared becomes important because an entrepreneur is only successful when others do the many types of routine work that ultimately makes the paradigm shift a success. On the other hand, there must be incentives for the innovator to shift the paradigm in the first place. Finally, mainstream endogenous growth models have greatly oversimplified, to the point of misinterpretation, Schumpeter's ideas on economic development.

MAINSTREAM ECONOMICS' INCONSISTENT GROWTH FRAMEWORK

Modern growth theory effectively combines the Solow and endogenous growth models, like Romer's (1990), into a single explanation of economic growth. Popular economic growth

textbooks, such as Jones (2002), Barro and Sala-i-Martin (2004), and Weil (2009), first teach the Solow model, followed by one or more versions of "Schumpeterian" endogenous growth models. But the discussion here makes it clear that the Solow (1956) and the Schumpeterian Romer (1990) models make an odd couple: the Solow model and the real Schumpeter simply cannot be logically combined. The Solow model describes the economy as always moving towards a stable equilibrium, but the endogenous growth models reflect the dynamic creative destruction process that persistently pushes the economy away from the status quo. Also, the Solow model aggregates output into a single production function while Schumpeter's technological change is a process of replacing old industries with new industries, which implies a continually changing set of industries that require different technological innovations. Furthermore, Solow assumed perfect competition in product markets while Schumpeter distinguished the pursuit of monopoly profit by large business firms as the driver of innovation.

It is interesting to contemplate why mainstream economists so enthusiastically replaced earlier models of economic development, such as the dynamic circular flow analysis of Harrod-Domar or even the Marxist model of capitalist development, with the combination of a simplistic supply side neoclassical model and a mathematical maximization model that misrepresents Schumpeter's dynamic, inter-disciplinary, and complex process of disruptive innovation and structural change. Perhaps the mainstream economics culture felt so threatened by Marx, the Keynesian revolution, and the Harrod-Domar model that mainstream economists were eager to accept any model or set of models that omitted these alternative models' most objectionable aspects. The Harrod-Domar or the Marxist models effectively required the rejection of the neoliberal/neoclassical culture that dominated economics since the late nineteenth century, but the Solow model supplemented by the Romer model fit within the existing culture. Perhaps the

doxa of the mainstream culture just clashed too directly with Harrod and Domar's instability or Marx's clarification of capitalism's inherent contradictions.

This examination of the how mainstream economics augmented the Solow growth model with an incompatible model of technological change shows that mainstream economists are not reluctant to go adjust the scope of their models. But they only used adaptions that supported the pro-growth conclusions. Disaggregation into separate market and natural sectors introduces new sources of diminishing returns that slow down or prevent economic growth, but mainstream economics textbooks like as Jones (2002), Barro and Sala-i-Martin (2004), and Weil (2009), do not extend their analysis beyond the aggregate Solow and Romer models. These models assume there is only one kind of capital and one general type of technology, both of which are assumed to react to the same market incentives in an economy that, in the tradition of neoclassical analysis, consists entirely of competitive markets. Hence, the impression remains that economic growth is the normal and permanent state of affairs in modern capitalist economies. This impression seems to be based on a very selective use of mainstream growth models, however.

CONCLUSIONS

In this paper, we have first of all provided some examples of how standard neoclassical growth models can be used to predict something other than permanent growth. Specifically, when the neoclassical Solow model is disaggregated into separate economic and natural sectors, it can be used to generate economic collapses as well as economic growth. Such a collapse in output may be due to insufficient technological advancement, an unwillingness to recognize the importance of the ecosystem in economic production, or it be simply be caused by normal population growth. The popular endogenous growth models based on Schumpeter's creative destruction

hypothesis, in combination with the Solow model, introduce additional sources of economic instability, mainly the obvious difficulty of generating technological advancement in the natural sector and the likelihood of institutional failures.

The important point is that we have produced potential economic collapses using neoclassical models. We have not used a Marxist or post-Keynesian model, both of which are well-known for predicting economic and social instability. This observation seems to undermine the claim that mainstream economics nurtures an overoptimistic perspective on the potential for economic growth because of the bias in the neoclassical models it relies on. That is, the mainstream implicit support of capitalism as an exceptional generator of economic growth and continued improvements in human welfare is due to mainstream economists' very selective applicationsuse of their neoclassical models rather than the inherent bias in the models per se. Criticizing the neoclassical models is not necessarily going to eliminate the pro-growth bias of mainstream economics.

Why did mainstream economists not increase the number of sectors in their widespread use of the Solow model? Why have they seldom examined the pace of technological change across different sectors? Why were they willing to make very biased use of Schumpeter's heterodox ideas to shore up a theoretical weakness of the Solow model, but only to emphasize the role of technology and not to address less growth-friendly economic issues? We suggest that it is the neoliberal belief in the rational individual economic man [gender intended], the natural role of private property over collective action and ownership, and the ubiquity of competitive markets that pushes economists to apply their largely neoclassical models in ways that generate conclusions compatible with those beliefs. In short, the failure of mainstream economics to incorporate issues such as global warming, the deterioration of the ecosystem, or social

phenomena such as trust, peace, and security is not so much due to the reliance of the neoclassical modeling framework in the habitus of mainstream economics culture, as it is due to the neoliberal doxa that influences how the tools of the habitus are applied. We have, first and foremost, an attitude problem in mainstream economics.

Of course, we also have a political problem. The power of culture to sustain itself and to induce conformity is well understood by powerful special interest groups such as the financial industry and large business organizations. Gramsci (1971) noted early in the twentieth century that powerful interest groups can easily maintain their privileged position even in a fully democratic society as long as they control ideology. We can think of Gramsci's "ideology" as similar to Bourdieu's doxa. In this regard, the former chief economist of the International Monetary Fund (IMF), Simon Johnson (2009), recently explicitly wrote that the financial industry "gained political power by amassing a kind of cultural capital—a belief system," the result of which was that "faith in free markets grew into conventional wisdom…." And, Wisman (2013, p. 922) points out that financial and business lobbyists and public relations officers actively manipulated the economics culture in order to induce economists to furnish "…support to free-market ideology, thereby lending 'scientific' support to right-wing policies." In short, the neoliberal doxa of mainstream economics was to a substantial degree an intentional consequence of outside manipulation by special interests who wanted to ensure that economists wouls provide "friendly" intellectual support for our system of monopoly capitalism.

The main implication of our finding that the neoliberal bias in economic analysis and the policies such analysis cannot be eliminated by only attacking the specific models or modeling methodologies that comprise the habitus of the mainstream culture. A pluralistic approach to modeling will not eliminate bias while the underlying doxa remains well-entrenched in the

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culture of the field. The individualist philosophy underlying the neoliberal doxa is likely to continue to bias economic analysis even if, for some unimaginable reason, mainstream economists were open to substituting institutionalist or Keynesian models for the neoclassical models in the mainstream habitus. This is evidenced, for example, by how Keynes' (1936) macroeconomic model as presented in his *General Theory of Employment, Interest, and Money* was gradually transformed into the pseudo-neoclassical New Keynesian model. More vivid is the self-proclaimed "Keynesian" Paul Krugman repeatedly arguing that policies to stimulate economic growth are necessary to reduce unemployment, apparently in complete ignorance of the environmental effects of such a resumption of traditional energy-based economic growth. Today, only a few Post Keynesians remain loyal to Keynes' original ideas. Similarly, today's New Institutionalists are quite compatible with the neoliberal doxa, unlike the original American Institutionalists. Perhaps environmental economists will always reach different conclusions about future economic growth because their doxa drove them to become environmental economists in the first place, but it is troubling to see many environmental economists arguing for "market-based" policies such as carbon offsets, carbon exchanges, and carbon taxes. The neoliberal doxa of the mainstream economics culture is so powerful that even schools with a different habitus and doxa end up conforming to the mainstream doxa. Such conformity cannot shift economic thinking; it only further embeds the neoliberal doxa in the mainstream culture.

In general, one remains hopeful that the reality of environmental decay, social decline, and social inequality will induce a paradigm shift away from our individualistic and materialistic capitalist economic system. However, such as shift must overcome a well-established culture and very powerful economic and political interests; criticizing mainstream models will probably not make economics more effective in dealing with environmental destruction or social decline.

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