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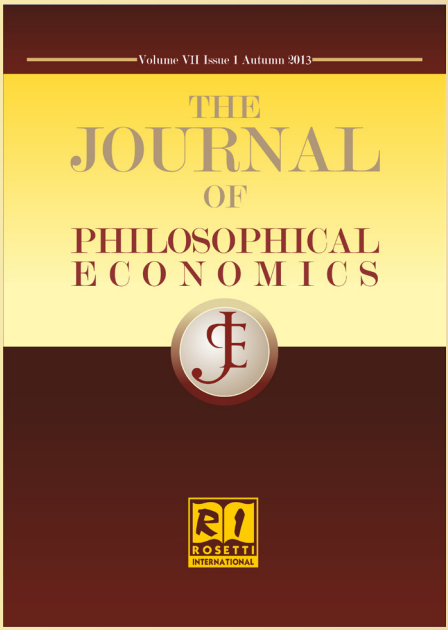

Growth theory after Keynes, part I: the unfortunate suppression of the Harrod-Domar model

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Abstract: After Harrod and Domar independently developed a dynamic Keynesian circular flow model to illustrate the instability of a growing economy, mainstream economists quickly reduced their model to a supply side-only growth model, which they subsequently rejected as too simplistic and replaced with Solow's neoclassical growth model. The rejection process of first diminishing the model and then replaced it with a neoclassical alternative was similar to how the full Keynesian macroeconomic paradigm was diminished into IS-LM analysis and then replaced by a simplistic neoclassical framework that largely ignored the demand side of the economy. Furthermore, subsequent work by mainstream economists has resulted in a logically inconsistent framework for analyzing economic growth; the popular *endogenous growth* models, which use Schumpeter's concept of profit-driven *creative destruction* to explain the technological change that Solow left as exogenous, are not logically compatible with the Solow model.

Keywords: paradigm, macroeconomics, mainstream, Schumpeter, Solow

Introduction

When Keynes published his *General Theory* in 1936, the neoclassical paradigm was well-established in the economics profession. Even though the Great Depression weighed heavily on economists' minds, economists were somewhat hesitant to jump to a new paradigm that seemed to contradict conventional mainstream economic thought. Most mainstream economists were more accepting of Hicks' (1937)

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interpretation of Keynes' *General Theory*, which omitted Keynes' more complex and radical ideas. For example, Keynes' Chapter 12 on uncertainty and his Chapter 19 on wage flexibility were not incorporated into Hicks' IS-LM framework that effectively came to be known as the 'Keynesian model.' And, Samuelson's (1948) textbook, which featured the simplified 'Keynesian cross' version of the IS-LM model, became the standard introduction for several million American students after World War II. Davidson (1984) has pointed out that Samuelson's graphic model was more in line with neoclassical methodology than it was with Keynes' *General Theory*.

In the 1970s, most mainstream macroeconomists abandoned the simplified Keynesian models in favor of macroeconomic models that were compatible with neoclassical market-based microeconomic models and which included the self-assuring assumption that humans are all rational beings who make only rational choices as well as the assumption that the economy is guided by an *invisible hand*. Within three decades, therefore, the Great Depression was forgotten and the Keynesian revolution was defeated.

Of course, intellectual resistance to Keynesian ideas was actively stoked by business and financial interests opposed to Roosevelt's *New Deal* policies, and for which *The General Theory* provided a solid justification. For example, Colander and Landreth (1996) describe how, prior to the appearance of Samuelson's watered-down Keynesian textbook, an authentically Keynesian textbook by Tarshis (1947) was driven out of U.S. universities by a business-supported campaign directed at university administrators and trustees.

While many post-Keynesians and heterodox economists have discussed how Keynesian economics was pushed out of the mainstream of the economics discipline, this article details how Keynesian ideas fared in the sub-field of economic growth and development economics. Specifically, this article examines how an insightful growth model derived from Keynesian macroeconomic foundations by Roy Harrod (1939) and Evsey Domar (1946) was marginalized. Like *The General Theory*, the Harrod-Domar model was first simplified to where it no longer reflected the authors' original intent, then the faux version of the model was criticized and replaced in mainstream economics a decade later by Solow's (1956, 1957) neoclassical supply side model. This latter model has not been very useful for development policy, but it nevertheless remains central to neoclassical growth analysis. It is often supplemented in ad hoc fashion by other models that are not only of questionable neoclassical heritage, but are logically inconsistent with the neoclassical Solow model.

A brief history of thought

According to the rules of the scientific method, new economic ideas, or hypotheses, should be objectively examined and tested, and if they prove to be accurate, they should be added to our state of knowledge. But, the model by Harrod and Domar was quietly and quickly rejected by mainstream economists despite its useful extension of Keynes' (1936) *General Theory*. There was, clearly, something other than the scientific method guiding the evolution of economic thought.

It is likely that the fate of new ideas in economics depends critically on the manner in which the new ideas are framed, that is, in what type of model they are embedded. Kuhn (1962) described the advancement of most science in these terms, concluding that new knowledge in a field was usually confined to the particular paradigm, or analytical framework, with which practitioners in a field were familiar. New ideas are more likely to be embraced if they fit the familiar paradigm. From his detailed examination of the history of science, Kuhn found that "revolutionary science," which he defined as new ideas that actually shift the paradigm, occur very infrequently. Keynes' and his followers, Harrod and Domar, were revolutionary thinkers. We must, therefore, ask why they were unable to shift the paradigm sufficiently for their ideas to be embraced by mainstream economists.

Alternative paradigms in economics

Over the past several hundred years, economic thinkers have examined the economy from a variety of perspectives. Some have sought to describe the economy as a *dynamic* system that continually changes its shape and composition, while others analyzed the economy as a *static* system consisting of a constant and stable set of interconnected parts. The latter approach is technically easier to design and manipulate, and it has conveniently enabled economists to use *partial equilibrium* models that focus on one segment of economic activity under the "all other things equal" (*ceteris paribus*) assumption. We can also distinguish between those economic thinkers who chose to construct models that *aggregated* the whole economy into a few curves in a diagram or a small set of mathematical equations, while others used less precise techniques to describe the economy as a *complex system* consisting of many parts interconnected in complex ways. Finally, economic thinkers have alternatively viewed the economy as a system with a *stable* equilibrium and one that is continuously changing and potentially unstable.

The simplest approach is to use a static aggregated model that has a stable equilibrium, as neoclassical models often assume. Keynes wanted to explain the Great Depression, so he opted to model the economy as a more complex dynamic and unstable system. To provide some context, a brief history of thought is useful for understanding the different modeling strategies.

Physiocrats, Classicals, and Marx

The eighteenth-century French Physiocrats saw the economic system as a static, unchanging system, which one of their best-known members, François Quesnay (1991[1768]), graphically depicted in the form of a *Tableau Economique*. The tableau was a type of circular flow diagram that showed how the main sectors of the economy used their income from production to demand the output produced throughout the system. Adam Smith's (1776) *Wealth of Nations*, on the other hand, described the economy as a dynamic but stable system that could continually raise human well-being. Smith's loose-knit verbal presentation did not tie the pieces together as neatly as the Physiocratic tableau economique did, but his system was more dynamic and complex. His metaphor of the invisible hand suggested that the economic system was stable.

In the early nineteenth century, the Classical School sought greater precision. They combined a model of population growth with a production function characterized by diminishing returns to natural resources into a consistent circular flow model that explained how income would be distributed and spent among various groups and producers as an economy evolved over time. The Classical economic system was, like Smith's verbal model, both dynamic and stable. The Classicals were not as optimistic as Smith: they predicted that the inevitable growth of population would undermine any increase in living standards and eventually cause per capita income to fall back towards mere subsistence regardless of how output grew in the short run. Marx (1967, 1906-1909) provided a very different prediction of the future by extending some of the logic of the Classical model of income stagnation into a complex dynamic model of social revolution. Marx described a capitalist economic system as an unstable system that involved complex interactions between the economic, social, political, and natural spheres of human existence. Not long after Marx sought more complexity and predicted economic and social instability, most economists in Western capitalist countries, in a monumental paradigm shift, began to model the economy as a system consisting entirely of competitive markets in which utility-maximizing consumers, income-maximizing workers, and profit-

maximizing producers simultaneously determined a fixed, stable equilibrium that was also optimal from a welfare perspective. This *neoclassical* paradigm is still largely in place today. The name *neoclassical* covers a paradigm that combines the marginalist ideas and the quest for modeling precision from the Classical school, without necessarily accepting the inevitable collapse back to subsistence in the long run. In fact, the implicit embrace of Say's Law and the metaphor of the invisible hand by neoclassical economists gives the paradigm a distinctly optimistic outlook.

The Walrasian Model and Neoclassical Economics

Economic historians often mention Alfred Marshall as the leading neoclassical economist, and his popular economics textbook certainly solidified neoclassical microeconomics as the dominant economics paradigm in Western countries. But, it can also be argued that the French economist Léon Walras (1874) provided the intellectual foundation for the full neoclassical paradigm. Walras modeled the market economy as a large system of mathematical equations representing each of the consumers who purchased goods and services from producers, the government agencies that purchased goods and services from producers, the producers who purchased capital goods from other producers, and the workers and capitalists who provided the factors of production. Walras specified one commodity as the *numeraire* in which all other variables are valued, which he denoted as money. He specified the market system so that the economy would simultaneously adjust prices in all markets and achieve an equilibrium at which all production was purchased and the labor market cleared to employ all willing workers. Walras claimed that as long as all individual markets moved towards their respective equilibria, the entire system would also automatically approach a stable equilibrium. To support this claim, Walras made numerous assumptions, including that the economic system consisted entirely of markets that could be represented by linear mathematical relationships, that the number of such equations was equal to the number of variables that needed to be adjusted to reach equilibrium, and that time could be stopped to permit an autonomous auctioneer to search for the full set of market-clearing prices and quantities.

Walras' model seemed to depict the economy as a complex system in which each of the many individual parts were simultaneously related to every other part, but Walras made many simplifying assumptions to fit his model into a system of linear equations. He ignored non-market household activities, human interactions within large business organizations, government, and all forms of non-market, collective,

hierarchical, and traditional economic interactions. And, because Walras specified a system of linear equations with fixed parameters, the stability of the economic system was a predetermined, rather than a proven, outcome. Walras' fixed, static system was very different from the dynamic systems envisioned by Smith and Marx.

The faith that the economic system was stable plus the complete practical impossibility of actually solving Walras' massive system of equations ended up encouraging economists to focus on the system's individual markets 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*. In sum, mainstream economists effectively combined the marginal analysis of the Classical school with the assumed systemic stability of the Walrasian system to construct a framework for scientific reductionist economic analysis that still characterizes neoclassical economics today.

Davidson (2012) explains that the many explicit and implicit assumptions behind the neoclassical paradigm effectively gave a mythical life to Smith's (1776) metaphor of the *invisible hand*, namely that the market system automatically translates self-interested individual actions into socially optimal outcomes. The many assumptions underlying neoclassical models are largely the same ones that Walras specified, such as the competitive nature of markets, the simultaneous and immediate adjustment of prices to demand or supply shifts, the neutrality of money, and the unchanging structure of the whole economic system over time. When the Great Depression developed in the 1930s, and unemployment surged in many countries, the neoclassical paradigm was clearly threatened.

Keynes' (1936) *General Theory* offered a timely explanation of why an economy could become unstable and then remain mired in high unemployment for many years. Unfortunately, most economists in the United Kingdom and the United States, two countries hard hit by the Depression, embraced the comparative static textbook 'IS-LM' version of the *General Theory* suggested by Hicks (1937) rather than the dynamic model actually developed by Keynes. The IS-LM version of the Keynesian paradigm was cut off from Keynes' General Theory (Chapter 19) discussion of why falling prices could not restore full employment. Hicks' IS-LM approach also could not explain, as Keynes' Chapter 12 could, why an economy becomes unstable and falls into a deep depression in the first place. Most students

were taught the even simpler 'Keynesian cross' version of Keynes' macroeconomic model in mainstream textbooks such as Samuelson (1948). In the 1970s, mainstream pedagogy abandoned even Samuelson's simplifications of Keynesian economics in favor of macroeconomic models that were compatible with microeconomic models of competitive markets and the assumption that people are fully rational self-interested individuals.

The need for a growth theory

Instability and high unemployment were not the only economic concerns that orthodox neoclassical economics was unable to address. After World War II, there was renewed interest in economic growth. People in the war-torn countries expected policymakers to generate economic growth to not only raise standards of living above those of the Great Depression, but to restore the continual economic progress that preceded the Depression. Also, during the Cold War communist leaders publicly challenged the capitalist economies to a contest to see which system would more rapidly raise its citizens' standards of living. Finally, the independence of former colonies in Africa and Asia after World War II increased awareness of the huge income differences that existed in the world. Most Western governments publicly acknowledged the obligation of rich countries to provide foreign aid to the world's poor countries. Economists needed a model of economic growth to guide policymakers seeking economic growth and to justify foreign aid to developing countries. Orthodox neoclassical economics, which focused on resource allocation within a static and stable system, did not offer a model of economic growth.

The Harrod-Domar growth model

Harrod (1939) and Domar (1946) independently developed what turned out to be identical growth models, which we now refer to as the *Harrod-Domar model*. That two economists would independently produce the identical model was not surprising; their models were logical extensions of the same Keynesian macroeconomic model. In analyzing how macroeconomic policy could restore full employment, Keynes had focused on aggregate demand, especially the potentially volatile component called investment. Harrod and Domar pointed out that investment changed the economy's supply side as well as the demand side, and full employment could be maintained only if investment and the other sources of aggregate demand grew just fast enough to exactly absorb the increased output that the new investment made possible.

The supply side of the Harrod-Domar model

To capture the potential inconsistencies between investment's dual effects on aggregate demand and the economy's productive capacity, Harrod and Domar specified separate demand and supply sides in their model. Because they wanted to make a fundamental point about the potential dynamic inconsistency between aggregate demand and aggregate supply, not provide a general growth model, they hypothesized a very simple supply side model in which investment was the only contributor to economic growth. They also assumed a production function with a constant marginal product of capital to keep things linear. Harrod and Domar made little effort to justify these assumptions; they wanted to show how investment directly increases productive capacity and not clutter their abstract model with features unrelated to the purpose at hand.

A constant marginal product of capital means the economy exhibits a constant capital-output ratio $K/Y_S = \gamma$, and the supply of output, Y_S, is proportional to the stock of capital, K:

$$Y_S = (1/\gamma)K \tag{1}$$

Also, the change in output is proportional to the change in the capital stock:

$$\Delta Y_S = (1/\gamma)\Delta K \tag{2}$$

If capital does not depreciate, then the change in the capital stock is exactly equal to investment. Assuming that the savings rate is a constant σ, and all savings are invested productively, it follows that:

$$S = \sigma Y_S = I = \Delta K \tag{3}$$

Then, combining the results from equations (1), (2), and (3):

$$\Delta Y_S = (1/\gamma)\Delta K = (1/\gamma)\,\sigma Y_S = (\sigma/\gamma)Y_S \tag{4}$$

Dividing both sides of equation (4) by Y_S leaves a very simple formula for the rate of growth of the economy's supply of goods and services, which we denote as G_{Ys}:

$$G_{Ys} = \Delta Y_S/Y_S = \sigma/\gamma \tag{5}$$

The supply side of the Harrod-Domar model thus suggests that the rate of economic growth is a constant and equal to the ratio of the savings rate to the capital-output

coefficient. The supply-side of the model made growth predictions easy to calculate; all one had to do was insert their assumed savings rate and the capital-output ratio.

The simple model was convenient for economic planners seeking a specific target growth rate; the formula could be used to justify the foreign aid and government taxation if private domestic saving was not sufficient. In practice, however, the savings rate and the capital-output ratio were almost never constant, and development economists quickly found the simple supply-side formula of the Harrod-Domar model to be a very inaccurate predictor of future economic growth. But, it is not fair to judge the supply side model as a stand-alone model; Harrod and Domar intended the simple suppy-side equation to be used in combination with a demand side model in order to provide a valuable insight into the dynamic behavior of an economy.

The demand side of the Harrod-Domar model

Like Keynes, Harrod and Domar focused on investment as a source of instability in the circular flow of aggregate output and income. In his *General Theory*, Keynes argued that investment was always a potential source of instability because the decision to invest could not be based on a precise comparison of estimated future returns and current opportunity costs of investment. In reality, no one has enough information about the future to perform such a deterministic exercise. 'Only a little more than an expedition to the South Pole, is it [investment] based on exact calculation of benefits to come,' Keynes (1936, p. 162) wrote in Chapter 12 of the *General Theory*. Fundamentally, future events cannot be accurately estimated from past events because the economy is not *ergodic*, that is, the world is not a stable, unchanging system in which variables in time-series and cross-section data have the identical statistical characteristics.

Because investment is based on so little solid information, Keynes argued that investment was driven by 'animal spirits,' by which he meant the complex combination of confidence, optimism, and unsubstantiated faith in the future of the economy. From years of experience in the financial markets, Keynes noticed that investors tend to pay more attention to events of the recent past as opposed to the distant past, largely because investors were more familiar with the more recent information. He also noticed that as long as most investors' expectations were approximately validated, investment would tend to continue to occur despite the lack of any 'exact calculations of benefits to come.' If a growing proportion of investments

failed to meet expectations, however, confidence in the future eroded and investment declined.

Consistent with Keynes' insightful discussion of how investor confidence depends on recent real outcomes, Harrod and Domar hypothesized that investment demand was a function of recent growth in the aggregate demand for output, Y_D:

$$I = b(\Delta Y_D) \tag{6}$$

The parameter b relates new investment to the change aggregate demand, which Harrod and Domar assumed aggregate demand consisted just of consumption and investment:

$$Y_D = C + I = (1 - \sigma)Y_S + b(\Delta Y_D) \tag{7}$$

The economy is in equilibrium when desired investment equals actual savings, or when:

$$b(\Delta Y_D) = \sigma Y_S \tag{8}$$

Manipulating (8) suggests that in equilibrium the demand side, the following holds:

$$\Delta Y_D / Y_S = \sigma / b \tag{9}$$

But it is difficult to maintain this equilibrium because dynamically the growth of aggregate demand is equal to the growth of aggregate supply only if:

$$\Delta Y_D / Y_D = \sigma / b = \Delta Y_S / Y_S = \sigma / \gamma \tag{10}$$

Thus, the economy continues on a given growth path only as as long as $b = \gamma$. This equality is unlikely to hold, however. As discussed above, in the real world γ is not a constant, and the parameter b is dependent on the volatile state of investor confidence, or what Keynes called animal spirits.

If intended investment, I_D, declines, say because something happens to undermine confidence in the future, then b effectively falls and intended investment falls below the savings available for investors:

$$I_D = b(\Delta Y_D) < \sigma Y_S \tag{11}$$

In this case, aggregate demand does not grow fast enough to absorb the increased output created by the previous period's investment. Investors' animal spirits are not confirmed, and therefore in the subsequent period of time desired investment will

fall further, thus reducing demand for output further, which then causes a further decline in intended investment, and so forth. The animal spirits variable b may also decline further in light of the recent disappointing events. In sum, a cumulative downward spiral in aggregate demand develops, unemployment grows, and economic output spirals downward.

On the other hand, if for some reason a bout of optimism raises b so that $b(\Delta Y_D) > \sigma Y_S$, an economic boom develops and, once the economy's capacity is reached, an inflationary spiral develops. This instability of the dynamic economy described by Harrod and Domar is often referred to as the *knife's edge* of the Harrod-Domar model; anything that drives the economy out of equilibrium causes a continuous spiral away from equilibrium. The model's unstable equilibrium suggests there is a need for active policy interventions to raise or lower demand for output and keep aggregate demand in line with the economy's capacity and thus keep the economy on its precarious knife's edge.

Neoclassical economics' White Knight: the Solow model

For many reasons, mainstream economists were uncomfortable with the Harrod-Domar model. There is no doubt that Keynesian economics in general, and the Harrod-Domar model in particular, were seen as threats to capitalism because they suggested a need for active government policies to guide the economy. But such an ideological fear of the model, which was seldom openly admitted by mainstream economists, did not comprise an objective and intellectually justifiable reason for rejecting the model. However, a more compelling reason was provided in a more subtle fashion when textbooks on economic growth and development chopped off the demand side of the Harrod-Domar model and presented only the supply side relationship. This truncation of the model eliminated the objectionable knife's edge outcome, but it also left only the very simplistic supply side-only model shown in equation (5) that still linked the model to economic planning, another anathema during the 1950s McCarthy era that fueled the ideological distrust of the model.

Another reason for the Harrod-Domar model's rejection was that its prediction of *instability* clashed with the neoclassical culture that had come to see the economic system as set of markets with stable equilibria. While many mainstream economists, still impressed by the Great Depression and its high rate of unemployment, accepted some of Keynes' macroeconomic policy suggestions, they did not necessarily agree that a growth model should reflect what they viewed as short-term disequilibria.

Mainstream neoclassical economists still believed that, in the long run, an economic system of competitive markets moves towards full employment. By cutting off its demand side and eliminating its circular flow logic, the truncated supply side-only version of the Harrod-Domar was completely cut off from its *General Theory* roots. Then, without the underlying logic of Keynes' *General Theory*, neoclassical reasoning could be applied to reject the Harrod-Domar model, as Solow did in 1956 and was done again most recently by Easterly (2001). Note that the Harrod-Domar model's vulnerability to the neoclassical critique from mainstream economists was not due to any inherent weakness in the model given its original intent. Rather, the Harrod-Domar model's weakness was the result of being diminished to a supply side-only growth model, being deprived of the *General Theory's* full theoretical support for the model's mission of explaining dynamic instability, and then being judged as an all-purpose growth model.

Harrod-Domar replaced by Solow

Robert Solow's (1956) neoclassical growth model consisted of an aggregate production function in which investment was subject to diminishing returns and the entire capital stock was subject to depreciation. Solow thus presented a slightly more complex supply side-only model, not a complete general equilibrium growth model. In contrast to Harrod and Domar's constant returns production function, Solow's model permitted the capital-output ratio to adjust, thus giving the model a stable equilibrium. Solow thus eliminated the knife's edge, one of the alleged justifications for macroeconomic policy activism and a source of discomfort among orthodox economists taught to believe in the invisible hand. However, Solow also showed that in the long run, investment alone cannot sustain economic growth, no matter how high the economy's rate of saving. According to the Solow model, the economy will gradually settle in a steady state of zero growth unless innovation and technological change continually raise the economy's aggregate production function. But, technology entered the model as an exogenous variable, determined elsewhere.

It is appropriate to ask why was there so much enthusiasm for the Solow model among mainstream economists, given its many shortcomings. First of all, most mainstream economists were only familiar with the supply side-only version of the Harrod-Domar model, so for them the Solow model, with its stable equilibrium as opposed to the depression-prone Harrod-Domar model, seemed to be a clear improvement. Secondly, neoclassical economists and their belief that a market economy always moved towards full employment seemed to imply that only the

supply side of the economy mattered in the long run anyway. And, of course, Solow's model was neoclassical in nature, which meant that it met little cultural resistance in the mainstream. Finally, the fact that the Solow model made technological change the key determinant of economic growth greatly appealed to a Western culture that had, at least since the Enlightenment, idealized human knowledge and scientific discovery as capable of solving any and all problems faced by humanity. Where the Harrod-Domar model suggested a need for government policies to increase saving, raise taxes to fund government investment, and build publicly-owned infrastructure and industries, the self-equilibrating Solow model suggested that 'economic reforms' like business deregulation, flexible labor markets, privatization, and lower taxes on income and profit were called for in order to increase innovation and technological change. Also, at the height of the Cold War, Solow (1956, 1957) used this result 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. As long as Americans were more inventive and clever, which, or course, they would be with their free markets and rational individuals, the rigid centrally-planned Soviet economy would not overtake the capitalist U.S. economy.

The lack of empirical support for the Solow model

It is important to note that the Solow model was adopted without much convincing empirical evidence to support it. Early 'tests' of the model consisted of listing observed characteristics of economic growth, or what economists called the *stylized facts* of growth, and then examining whether the Solow model was compatible with those 'facts.' These early exercises were somewhat inconclusive, largely because 1950s and 1960s historical data reflected wars, depressions, and other major disruptions that the Solow model could not incorporate.

With the development of econometrics and the increase in computing power, more evidence has been presented in recent decades. Easterly and Levine (2001) show that the model seems to explain a set of stylized facts of growth after World War II, and the statistical test by Mankiw, Romer, and Weil (1992) is often presented as definitive confirmation of some of the model's basic predictions. However, statistical confirmations remain difficult to interpret because it is practically impossible to quantify the technological change that the model concludes is the fundamental driver of economic growth. The most common method involves finding the residual between the growth of economic output and a weighted average of known inputs like capital, labor, resources, etc. using a standard neoclassical production function. This

method is doomed not only by the impossibility of accurately measuring economic inputs such as labor, human capital, physical capital, and real output, but also by the fact that the residuals are derived using the very same neoclassical production function that the Solow model assumes.

Growth regressions also inevitably suffer from omitted variable bias because there are so many possible variables that should, but cannot, be included in the analysis. When Sala-i-Martin (1997) addressed this problem by using Leamer's (1983) sensitivity analysis to test all 62 of the causal variables used in one or more growth regressions published over the prior decade, he found that only 22 significantly explained GDP growth at least 95 percent of the time. Those variables included many cultural variables, political variables, legal institutions, and geographic dummy variables, the latter of which reflected various regional institutions.

In short, the Solow model's focus on capital enables it, at best, to only partially explain economic growth. The mere fact that *some* of the evidence is supportive of the Solow model seems to have been enough to justify adopting the ideologically-preferred Solow model as the fundamental textbook model of economic growth. Challengers that do not fit the dominant culture of economics have not been given such an easy pass.

How the Harrod-Domar model was eliminated

In summary, the Harrod-Domar model was eliminated from mainstream economic thought and substituted in a very systematic, if unplanned, manner. First, the full Harrod-Domar model was taken out of its complete framework and reduced to its supply side only. It was easier to justify substituting the more 'elegant' neoclassical Solow supply side model for the truncated Harrod-Domar supply side-only model than it would have been to directly replace the full Harrod-Domar framework, especially since the Solow model was only a supply side-only model too. The Harrod-Domar model was thus driven out of mainstream economics using, effectively, the same strategy with which it turned back the Keynesian macroeconomic revolution: (1) misrepresent the new challenging paradigm with a simplistic model (e.g., a truncated version of Harrod-Domar and the IS-LM model, respectively) that was easy for mainstream economists to grasp, (2) rely on the mainstream neoclassical economics mindset to spur economists to actively and systematically critique the misrepresented challenging paradigm after it was effectively cut off from its logical foundations (such as the circular flow and the

instability of investment), and (3) wait for the arrival of a new model that was compatible with mainstream beliefs and traditions.

This is not to say neoclassical economists were entirely comfortable with the Solow model and its exogenously-imposed rates of savings, depreciation, and technological progress. Routine research by Cass (1965) and Koopmans (1965) endogenized the savings rate by using Ramsay's (1930) aggregate welfare function to determine the relative gains from saving and consumption. Of course, the endogenization of the savings rate only affected the determination of the steady state in the Solow model, not the long-run growth rate. For this reason, growth economists also began to search for ways to endogenize innovative activity and technological change. It proved to be impossible to do this in a neoclassical model that assumes perfect compeitition and zero long-run profit. In fact, innovation is a costly activity, and the assumption of perfect competition underlying the Solow model meant that in equilibrium the value of output exactly covers the cost of the variable inputs in the production function. How could costly innovation be carried out if there was no prospect of earning enough profit to cover the up-front costs? Growth theory languished for more than a decade awaiting a solution to this problem.

The endogenous growth model

Mainstream growth economists began to seek complementary models to explain the Solow model's exogenous technological change, rather than building technological change directly into the perfectly competitive model. The most popular complementary models, such as those by Romer (1990), Grossman and Helpman (1991), Rivera-Batiz and Romer (1991), and Aghion and Howitt (1992), among others, draw on the work of Joseph Schumpeter (1934) and his concept of *creative destruction*. There are subtle differences between the various *endogenous growth models*, but all incorporate the following five fundamental ideas:

1. Innovations are the result of employing costly productive resources to create new products, ideas, methods, etc.
2. Profit-seeking innovators compete with producers to employ the economy's scarce, and therefore costly, resources.
3. Innovation creates new products or techniques that are better, cheaper, more attractive, or in some other way superior to existing products, which gives the producer of the new products a market advantage over existing producers and products and, thus, profit.

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

5. In deciding how many resources to employ, 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 into a neoclassical maximization problem, albeit a dynamic maximization problem. In the process, Schumpeter's vast works and wide-ranging ideas were compressed into a mathematical maximization problem with a stable equilibrium.

The entrepreneur

Schumpeter (1934) gave individual *entrepreneurs* a central role in the innovative process, which seemed to fit the neoclassical paradigm's emphasis on individual choice very neatly. However, Schumpeter (1934, p. 85) distinguished between *risk* and *uncertainty*, and he depicted the entrepreneur not as a manger of risk, but as an adventurer willing to face the uncertainty of the unknown, like Keynes' aforementioned 'expedition to the South Pole':

> '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 thus rejected the neoclassical assumption, rigorously stated by Arrow and Debreu (1954) and Debreu (1959), that investment is characterized by risk with a known probability distribution, and that this risk can be diversified away if enough financial markets are created.

Also unlike most neoclassical economists, Schumpeter emphasized the importance of social and economic cultures within which entrepreneurs operate. Although he

clearly recognized that the rate of technological change of an economy depends to some extent on how many costly resources profit-seeking entrepreneurs employ, Schumpeter (1934) also explicitly discussed how entrepreneurs faced many barriers and incentives that tempered their urge to innovate. Schumpeter identified culture and other social institutions, such as 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, in fact, described entrepreneurs as 'social deviants' who often clash with tradition and act against the interests of vested business and social interests. Schumpeter noted that entrepreneurs were often immigrants and minority groups, such as, for example, the Jews throughout Europe, Chinese in Southeast Asia, and Indians throughout the British Empire, because they were less bound by tradition and social norms than natives.

The complexity of innovation

Schumpeter tempered his emphasis on entrepreneurs by simultaneously highlighting the role of corporations in the innovation process. He noticed that a growing portion of R&D activity was carefully managed within large business organizations in the same way they managed routine production. Wrote Schumpeter (1934, pp. 85-6):

> '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 influence of entrepreneurs.

Later in his career, Schumpeter (1942, p. 185) predicted that the improvements in technology and knowledge that entrepreneurs and corporations 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.' Schumpeter seems to expand on Kuhn's (1962) finding that most innovation is routine rather than revolutionary (paradigm shifting) by predicting that routinization was becoming even more entrenched as corporations increasingly dominated innovative activity. Thus, reminiscent of Marx, Schumpeter suggested

that the dynamic process of economic development continually evolves, and inconsistencies arise to weaken the system and block the continuous renewal of the creative destruction process.

Schumpeter also recognized the financial sector's role in the creative destruction process. This contrasts sharply neoclassical economics' tendency to ignore transactions costs and assume that the financial sector somehow costlessly channels savings to the most productive investment and innovative activities. Schumpeter's inclusion of finance into the analysis puts him 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, and the potential for fraud, and 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 that he clearly recognized that innovation is a complex process. Policymakers seeking to promote economic growth must take care to create a state of tolerance and freedom that enables productive *social deviance* while also maintaining the economic and social stability necessary to support *routinized* innovation, for example. 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 entrepreneur to shift the paradigm in the first place.

Many of the subtle points made by Schumpeter over the course of his writing do not appear in the mathematical endogenous growth models. These models simply set up maximization problems in which entrepreneurs carefully weighed the costs and potential gains from employing productive factors to engage in developing new products and processes that expanded the firm's profits.

Inconsistency between Solow and the endogenous growth models

Modern growth theory effectively combines the Solow and endogenous growth models like Romer's (1990) into a single explanation of economic growth. But, not only are Schumpeter's original ideas not compatible with the neoclassical mindset

that underlies the neoclassical Solow model, but the mathematical endogenous growth models that just incorporate Schumpeter's creative destruction process are not logically compatible with the Solow model either. The Solow model describes the economy as always moving towards a stable equilibrium, while the endogenous growth models reflect the dynamic creative destruction process that repeatedly pushes the economy away from the status quo. Also, the Solow model aggregates output into a single production function while the creative destruction process assumes that old industries are continually replaced with new industries, which implies a continually changing industrial structure that is likely to require different types of technological innovations. Finally, Solow assumed perfect competition in product markets while the endogenous growth model distinguished the pursuit of monopoly profit by large business firms as the driver of innovation.

Conclusions and further questions

It is appropriate to ask why the Harrod-Domar model was so quickly rejected by development economists for its alleged inconsistencies, only to be enthusiastically replaced by a pair of mutually inconsistent models. Perhaps the mainstream economics culture was so threatened by the Keynesian revolution and the Harrod-Domar model that mainstream economists were willing to accept any model or set of models that omitted the most objectionable aspects of the Keynesian paradigm. In a sense, the Harrod-Domar model represented a true paradigm shift from the idea that the invisible hand and free markets would continue to efficiently allocate society's economic resources as an economy developed over time. When the Solow model proved too simplistic to explain long-run growth or provide insight into which policies could promote long-run growth, the addition of an endogenous growth model seemed to shore up the former's weaknesses, thus protecting the reigning neoclassical paradigm. Such models suppressed Schumpeter's ideas into a traditional neoclassical maximization problem, albeit a dynamic one. Perhaps more important, the Solow/Romer combination covered only the supply side of the economy, which thus permitted the continuation of the belief in the invisible hand and, therefore, that government policies and institutions to coordinate the supply and demand sides of the economy were not necessary. Romer's (1990) mathematical growth model specifically defined a stable path of technological change. Today's 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.

Explaining *how* the dominant neoclassical paradigm was maintained in the face of challengers is only the first step in ultimately explaining the demise of the Harrod-Domar growth model, however. There is still the question of *why* the economics profession was so willing to sustaining the neoclassical paradigm in the face of the reality-based challenges by Keynes, Harrod, Domar, and, as discussed just above, Schumpeter. More to the point: Why was the neoclassical paradigm so powerful in the face of glaring real-world anomalies that should have been readily apparent to growth economists, especially when the anomalies were better dealt with by the challengers? We can find some answers to this question in the history of science, sociology, and political science. That discussion will be covered in Part II of this essay, which will follow in the next issue of this journal.

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