From Cycles to Shocks: Progress in Business-Cycle Theory

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Early analysts of business cycles believed that each cyclical phase of the economy carries within it the seed that generates the next cyclical phase. A boom generates the next recession; that recession generates the next boom; and the economy is caught forever in a self-sustaining cycle. In contrast, modern theories of business cycles attribute cyclical fluctuations to the cumulative effects of shocks and disturbances that continually buffet the economy. In other words, without shocks there are no cycles.

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The evolution of thought about business cycles from an emphasis on self-sustaining behavior toward one in which random shocks take center stage is a significant development in macroeconomics, and it is an especially important one for policymaking institutions like the Federal Reserve. The view that cycles are self-sustaining implies that a market economy cannot deliver stable economic performance on a sustained basis. Generally speaking, this view points to aggressive countercyclical policies or institutional reform as the appropriate response to cyclical fluctuations.

In contrast, the view that shocks are the ultimate sources of business cycles does not point to a particular policy stance. Whether a countercyclical policy should be pursued depends on the nature of the shocks. If shocks can be eliminated, macroeconomic policy should endeavor to do so because a more stable economic environment is preferable to a less stable one. But if shocks cannot be eliminated, it may be in the long-run interests of society to adapt to the shocks. To the extent that countercyclical policies interfere with the necessary adaptations, they may do more harm than good.[1]

Not surprisingly, the shift of professional opinion toward the shock-based view of business cycles has been accompanied by increasing debate about the sources of cyclical volatility. Few macroeconomists doubt that random shocks underlie business cycles, but they have been unable to agree on which random shocks, historically, have been the main causes of cyclical volatility.

To a person not versed in business-cycle theory (including economists who are not macroeconomists), this situation must seem somewhat paradoxical: How can macroeconomists be certain that shocks cause cycles, yet not agree on *which* shocks are responsible for cyclical volatility? Moreover, if a person is told that despite this ignorance, macroeconomists have made great strides in understanding business cycles, his or her perplexity can only increase. How can there be any understanding of business cycles (let alone an improvement in it!) if economists don't know the causes of cyclical volatility?

This article will answer these questions by sketching the historical evolution of the shock-based theory of business cycles. The answer to the first question delineates the key discoveries that led macroeconomists away from the self-sustaining view of business cycles and toward the shock-based view. The impetus for the shock-based view of business cycles came in the 1920s when mathematicians made a major breakthrough in the statistical description of cyclical phenomena. They established that many kinds of irregular cyclical phenomena (in fields as diverse as economics, geology, and physics) are best explained by random shocks.

This discovery set economists on the search for a shock-based theory of business cycles. Initially, economists thought that observable random events, such as an unexpected increase in government spending or a financial panic, would turn out to be the shocks causing business cycles. And to some extent they are. But they are not the major source of cyclical volatility. The major source appears to be shocks that manifest themselves as deviations of macroeconomic variables from their model-predicted values. Such shocks cannot easily be connected to observable real-world events. The unobservable nature of these shocks is the fundamental reason macroeconomists disagree about the ultimate causes of cyclical fluctuations. Yet, most macroeconomists agree that some set of unspecified shocks must be ultimately responsible for business cycles.

Although macroeconomists lack firm knowledge about the ultimate sources of cyclical volatility, they do understand how these shocks, once they occur, contribute to business cycles. Thus, the answer to the second question is that advances in business-cycle theory have provided a better understanding of how industrial economies respond to random shocks. One outcome of these developments is a new appreciation of the role that erratic changes in business-sector productivity play in cyclical fluctuations. According to the real business cycle, or RBC, theory (arguably one of the most successful shock-based business-cycle theories to date), random variation in business-sector productivity is the key *proximate* cause of post-WWII U.S. business cycles.

Let's now examine the historical process by

[1]For instance, a boom in residential construction could reflect speculative excess or changing demographics. An increase in the interest rate can eliminate speculation, but it cannot change demographics. Thus, policy action is desirable in the former case but probably not in the latter.

which business-cycle theorists have come to this conclusion.

THE STATISTICAL THEORY OF RANDOM WAVES

The fact that random disturbances may underlie business cycles was clearly demonstrated by the Russian statistician and economist Eugen Slutzky. In an article published in Russian in 1927 (and reprinted in English in 1937), Slutzky described in compelling detail how chance events could generate cyclical movements in economic data.[2]

Slutzky began with a series of many random numbers, each an integer between 0 and 9. If such numbers are plotted on a graph, they produce a line that moves up and down without displaying any particular pattern (Figure 1). This simply reflects the fact that the numbers, being drawn at random, don't bear any relationship to each other. Next, Slutzky constructed a new series by adding the random numbers 10 at a time in the following way. The first number in the new series was the sum of the first 10 random numbers; the second number in the new series was the sum of the second through the 11th random number, and so on. Thus, each member of the new series was a 10-item sum of random numbers. In the new series, the difference in value between adjacent members could be at most nine, but the difference between widely separated members could be much larger.

Slutzky recognized that this combination of facts—adjacent members of the series are likely to be similar in value, and widely separated members are *un*likely to be similar in value—implies wavelike, or cyclical, movement. Indeed, when plotted as a graph, the 10-item moving sums of the random numbers shown in Figure 1 display an unmistakable wavelike pattern (Fig-

FIGURE 1

Numbers Between 0 and 9 Drawn at Random

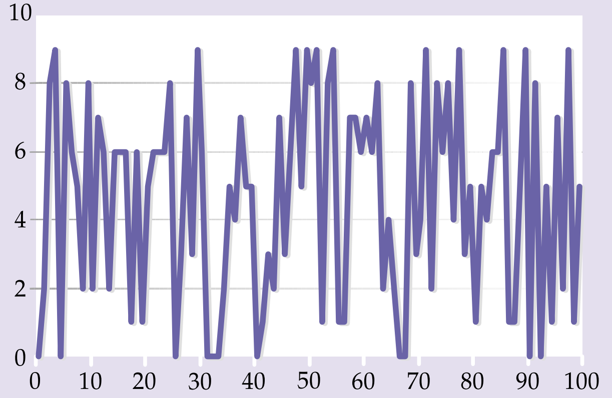
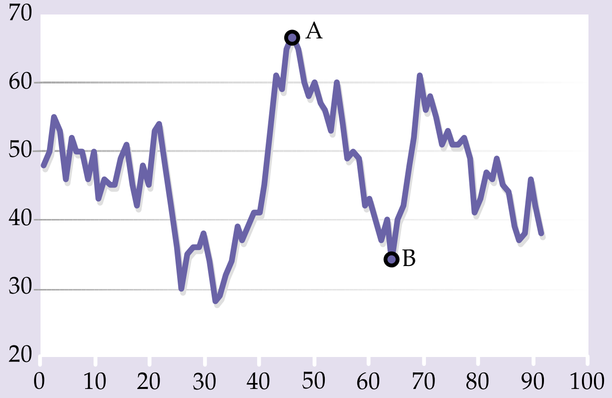


FIGURE 2

Ten-Item Moving Sum of Random Numbers Displayed in Figure 1



[2]Priority of discovery is attributed to the British statistician G. Udny Yule, who made this point in the early 1920s. However, Slutzky went much further than Yule in showing how random shocks could lead to apparently cyclical movements in economic (and other) data.

ure 2). While widely separated members of the series may be quite different in value, such as members A and B, the movement from A to B must be gradual because adjacent members of the series cannot be too different from each other. To persuade his readers that random numbers may underlie business-cycle movements, Slutzky compared a segment of his 10-item moving-sum series to an index of English business cycles. As we can see in Figure 3, the similarity is indeed remarkable!

Following Slutzky's pioneering work, mathematicians further developed the statistical theory of random waves. This development revealed that Slutzky's random-number-based explanation of irregular cyclical patterns was, in fact, the most compelling explanation of such patterns. This discovery persuaded business-cycle theorists to seek an explanation of business cycles in the cumulative effects of various random shocks hitting the economic system.

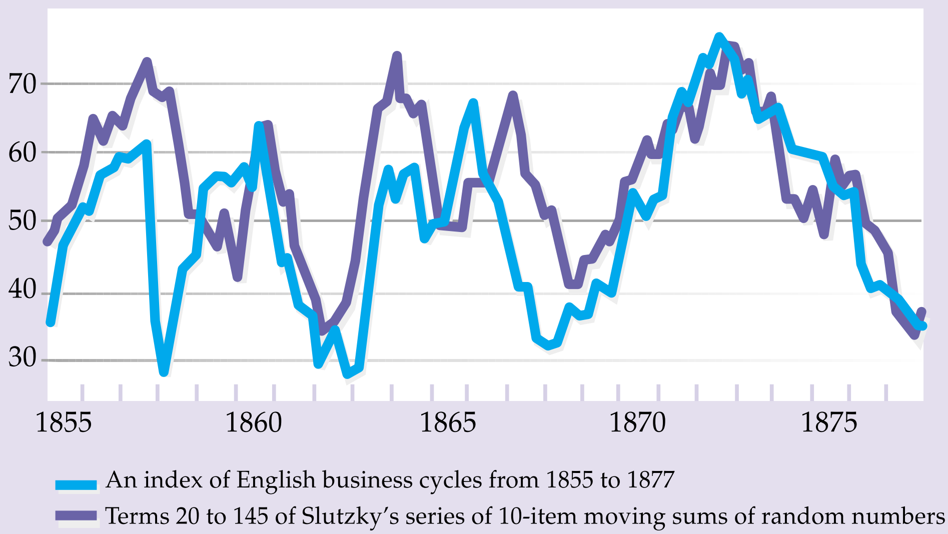
THE GENESIS OF SHOCK-BASED BUSINESS-CYCLE THEORY

Although Slutzky showed that moving sums of random numbers could display business-cycle-like patterns, he didn't provide any *economic* theory as to why macroeconomic variables might behave like moving sums of random numbers. However, he did point to examples of mechanical systems, such as a pendulum, whose motion under the influence of random shocks was, mathematically, a moving (weighted) sum of random numbers.

Imagine tapping with a hammer a pendulum whose motion is hampered by friction. If the hammer strokes vary randomly in strength, they'll cause the pendulum to swing about in an irregular way. A time-plot of the displacement of the pendulum from its (vertical) resting position (with displacement to the right measured as positive numbers and to the left as negative numbers) will show an irregular wavy line. The key

FIGURE 3

English Business Cycles and Slutzky's Random Series



Adapted from Slutzky, Eugen, *Econometrica*, 5 (1937).

point is that mathematically (and experimentally!), the displacement of the pendulum at any given point in time is a weighted moving sum of random numbers, the random numbers being the strength of each hammer stroke up to that point in time.

In an article published in 1933, the Norwegian economist and Nobel laureate Ragnar Frisch described a simple macroeconomic model in which the evolution of output, investment, and consumer spending resembled the motion of a swinging pendulum. Frisch's model implied that if some transient random event raised output above the economy's normal level, all macroeconomic variables (output, investment, and consumer spending) returned to normal in a *cyclical* fashion. In other words, the initial periods of above-normal economic activity (analogous to displacements of the pendulum to the right) were followed by periods of below-normal economic activity (analogous to displacements to the left). These swings in economic activity gradually diminished in strength and eventually died.

Frisch didn't work out the behavior of his model economy for a sequence of random shocks, but the analogy to the swinging pendulum suggested that the resulting behavior would resemble that of business cycles. In any event, by adopting the swinging pendulum as an analogy for the evolution of a capitalistic economy, Frisch took a step back from the prevailing view that business cycles were self-sustaining. Recall that without the hammer strokes, the force of friction brings the pendulum eventually to rest. And so it is, claimed Frisch, with an economic system: without shocks, there are no cycles.

Still, by basing his economic model of business cycles on an analogy to a swinging pendulum, Frisch gave inherently cyclical behavior (i.e., pendulum-like movements) a prominent place in business-cycle theory. However, the influence of the pendulum in business-cycle theory received a severe setback when Irma and Frank Adelman published an article in 1959 showing that shocks, rather than pendulum-like movements, lie at the center of cyclical volatility.

THE DEMISE OF THE PENDULUM AND THE RISE OF SHOCKS

By the mid-1950s, advances in econometrics (the use of statistical methods to determine quantitative economic relationships from economic data) had progressed to the point where equations describing various sectors of the economy could be inferred from economic data. The Klein-Goldberger model of the U.S. economy was one such model.[3] It contained 25 equations describing the evolution of 25 macroeconomic variables for the U.S. economy and was much more detailed than the simple economic model used by Frisch.

The question that the Adelmans asked was whether the Klein-Goldberger model could generate business cycles. First, they simulated the model on a computer to see if it displayed inherently cyclical behavior. They found that the model did *not* display appreciable pendulum-like movements. If some small to moderate transient shock temporarily raised economic activity, most economic variables simply returned to normal *without* experiencing any periods of below-normal activity.[4]

Next, the Adelmans turned to assessing the role of shocks in cyclical fluctuations. The first type of shock they considered was one affecting observable causal factors. In the Klein-Goldberger model, the list of observable causal factors included changes in short-term and long-

[3]The model was developed by Lawrence Klein and Arthur Goldberger, two well-respected econometricians (Klein received the Nobel Prize in economics in 1980). The model is described in their book published in 1955.

[4]In their simulations of the Klein-Goldberger model, the Adelmans did find pendulum-like behavior for very large shocks to the economic system. But these shocks were much larger than those actually observed for the U.S. economy.

term interest rates, an index of hours worked by those employed, government employee compensation and government expenditures, agricultural exports and agricultural subsidies, and population and labor-force variables. The Adelmans noted that these causal factors didn't evolve steadily but tended to jump around their respective trend paths "more or less erratically." The Adelmans treated these erratic movements in causal factors as random shocks and simulated the Klein-Goldberger model to see how macroeconomic variables behaved in response to such shocks. They found that these shocks didn't "produce the sort of cyclical behavior observed in the actual economy." Thus, shocks to observable causal factors did not seem to be responsible for business cycles, either.

The Adelmans then turned to a second type of random shock: the random discrepancies between the predictions of the Klein-Goldberger model and the actual values of macroeconomic variables. These discrepancies arise for several reasons, the most important being that any macroeconomic model is likely to omit some relevant factors. For instance, the Klein-Goldberger equation for predicting consumer spending takes into account only the influence of income; the stock of liquid assets (cash as well as checking and savings accounts) held by people; population; and consumer spending from the previous year. It ignores any effects resulting from, say, shifts in the distribution of personal income. If a shift in the distribution of personal income is an important factor in some year, that shift will contribute to the discrepancy between the predictions of the model and the actual value of consumer spending for that year. Macroeconomists refer to such deviations of model-predicted values from actual values as *residuals.*

When the Adelmans treated the residuals of the Klein-Goldberger model as random shocks, they found that the behavior of macroeconomic variables in the Klein-Goldberger model closely resembled actual U.S. business cycles. In other words, they found that residuals were the prime source of cyclical volatility!

These results were counter to prevailing views about the role of shocks in cyclical volatility. Recall that Frisch and his contemporaries believed that business cycles resulted from observable shocks impinging on an economy prone to pendulum-like movements. But the Adelmans found that business cycles resulted from unexplained shocks (i.e., residuals) impinging on an economy that displayed no strong tendency toward pendulum-like movement.

Why does the Klein-Goldberger model generate business cycles even without any strong tendency to pendulum-like movement? The answer lies in the fact that in the Klein-Goldberger model, values of macroeconomic variables are determined, in part, by moving sums of random numbers. For instance, the Klein-Goldberger equation for consumer spending holds that the level of consumer spending during the previous year has a positive influence on consumer spending in the current year. Thus, if some shock raised consumer spending in the past year, that same shock will raise consumer spending during the current year as well, although not by as much. By the same logic, a shock that raised consumer spending two years ago will also have raised consumer spending during the past year (again, not by as much) and, therefore, will raise it during the current year as well. In other words, since consumer spending in any year is affected by consumer spending in the previous year, consumer spending in any year is determined, in part, by a weighted sum of random shocks affecting consumer spending in all previous years.

Now recall Slutzky's demonstration that a quantity that's a moving sum of random numbers will display wavelike movement. Thus, in the presence of random shocks, the link between consumer spending in consecutive years becomes a source of wavelike movements in consumer expenditures.

Most modern macroeconomic models incorporate links between consecutive values of macroeconomic variables. These links imply that values of macroeconomic variables are determined, in part, by moving sums of random numbers, and those random numbers are past unexplained shocks to macroeconomic variables, i.e., past residuals.[5] Thus, while it's true that macroeconomists don't know *which* factors cause business cycles, they do understand *how* the changes brought about by those factors combine to generate cyclical fluctuations.[6]

Nevertheless, the fact that residuals cause business cycles is unsettling for business-cycle theory. Macroeconomists would prefer to explain business cycles in terms of observable shocks or, failing that, to develop theories that make minimal use of residuals.

THE POWER OF RESIDUALS

Since the 1960s, the evolution of business-cycle thought has been linked to theoretical developments in economics in general. In particular, advances in dynamic economic theory provided new and powerful tools for tackling problems in business-cycle research. Initially, these new ideas held out hope of reducing the importance of omitted factors in business-cycle models and correspondingly raising that of included factors. Consequently, professional attention turned to re-assessing the role of factors included in business-cycle models. A great deal of energy was spent in assessing the role of monetary shocks. As it turned out, this assessment failed to produce a compelling case for monetary shocks as an important factor in postwar U.S. business cycles. It also failed to produce compelling evidence in favor of other easily identifiable shocks.[7] Since the early 1980s, interest has again shifted to consideration of the role of residuals in cyclical fluctuations. Armed with the new advances in dynamic economic theory, Finn Kydland in collaboration with Edward Prescott developed a residual-driven business-cycle model called the real business cycle (RBC) model.[8]

Recall that a residual is the deviation of a macroeconomic variable from its model-predicted value. In RBC theory, the residual that generates business cycles is the quarterly deviation of labor productivity from its model-predicted value. The model of labor productivity used in RBC theory was developed by growth theorists in the 1940s and 1950s. This model holds that average labor productivity (output per worker) is positively related to the amount of capital per worker in the economy. The difference between growth in actual labor productivity and its model-predicted value is called the Solow residual, in honor of Nobel laureate Robert Solow, who developed this idea. A positive Solow residual, i.e., growth in labor productivity in excess of what can be explained by growth in capital per worker, indicates an improvement

[5]In principle, random shocks to observable causal factors can also be a source of wavelike movements. However, the shocks to observed causal factors are too small to generate realistic business-cycle fluctuations in the Klein-Goldberger model.

[6]For evidence on the importance of residuals for cyclical volatility in modern macroeconomic models, see John Cochrane's article. Can the omitted factors be discovered by relating residuals to observable historical events? Perhaps, but scholars are not sanguine about the prospects. To quote the eminent economic historian Peter Temin: "If the goal is to find events that can be represented by the residuals, it may be possible to find events to explain one set of residuals as easily as another. But the variety of models extant today makes that kind of exercise unrealistic as a way to identify causes of multiple cycles."

[7]Pre-WWII fluctuations are another matter. In that case, monetary shocks may well have been the decisive factor.

[8]Prescott's 1986 article contains an influential statement of the RBC model. The antecedents of this article appeared in an earlier 1982 publication by Finn Kydland and Edward Prescott. Two other authors, John Long and Charles Plosser, published a closely related article in 1983; they coined the term real business cycles.

in the economy's technological capability (brought on by new inventions). In the theory of economic growth, positive Solow residuals are seen as a major cause of economic growth; in RBC theory, *fluctuations* in the Solow residual are seen as a major cause of business cycles.[9]

Two properties of the Solow residual make it possible to base a business-cycle theory on it. First, when the Solow residual rises above its trend path, indicating better-than-average growth in the economy's technological capability, firms are motivated to invest in new plant and equipment at a faster-than-average rate. To meet the increased demand for investment goods, businesses hire more than the average number of workers. Above-average employment growth leads, in turn, to faster-than-average growth in consumer spending. Thus, a rise in the Solow residual above its trend path makes investment, employment, and consumer spending rise above their respective trend paths as well. This comovement of key macroeconomic variables is a central feature of business cycles.

Second, as was the case with consumer spending in the Klein-Goldberger model, there is a strong link between the value of the Solow residual in consecutive years. Therefore, the value of the residual in any given year is determined, in part, by a weighted sum of random shocks affecting the residual in past years. Thus, the observed movements of the Solow residual around its trend path resemble Slutzky's moving sums of random numbers. Since RBC theory predicts that macroeconomic variables will take on values that are almost proportional to the Solow residual, all macroeconomic variables in the RBC model behave like moving sums of random numbers as well. Thus, RBC theory can also explain the observed wavelike movement of macroeconomic variables.

[9]For a detailed description of the RBC model and some of its implications, see my 1995 and 1999 articles.

RBC theory has had considerable success in explaining cyclical fluctuations. As shown in Charles Plosser's 1989 article, values predicted by RBC theory (given the observed movements in the Solow residual) are close to the actual values of key macroeconomic variables during the post-WWII period. For instance, as predicted by the theory, a decline in consumer expenditures, hours worked, investment, and output accompanied the decline in the Solow residual in 1970. More recently, the faster-than-average growth of the U.S. economy since 1995 has accompanied a faster-than-average growth in the Solow residual. Between 1995 and 1997 (the last year for which the residual can be calculated), the growth in the Solow residual exceeded its average growth rate since 1959 by more than 15 percent.

Still, a natural question to ask about the RBC model is whether it offers a more satisfactory explanation of business cycles than the one offered by the Adelmans using the Klein-Goldberger model. After all, given that both explanations are residual-based, are there any reasons to prefer one to the other?

Quantitatively, the RBC model explains cyclical fluctuations at least as well as the Klein-Goldberger model, as Robert King and Charles Plosser demonstrated in a 1994 article. However, many macroeconomists prefer the RBC explanation for two reasons. First, RBC theory relies on only one residual to generate business cycles whereas the Adelmans relied on a consumer spending residual, an investment residual, and other assorted residuals. Second, the RBC model is based on straightforward economic ideas whereas the theory underlying the Klein-Goldberger model is much more complex and subtle.

WHITHER BUSINESS-CYCLE THEORY?

The pioneers of RBC theory have steadfastly maintained that fluctuations in the Solow residual result from technological and institutional changes. Generally speaking, business-cycle theorists don't view their job as explaining changes in technology or institutions. So, if the omitted factors that cause fluctuations in the Solow residual are truly technological or institutional in nature, then in one important sense, RBC theory is complete. The phenomenon left unexplained, namely, fluctuations in the Solow residual, falls outside the scope of business-cycle theory and therefore doesn't need to be explained by it. The intellectual journey begun in 1927 on the pages of an obscure Russian journal has come to an end!

But has it really? Economists, after all, are a curious lot. Confronted with a residual that can explain business cycles, they will want to dig deeper into its ultimate causes. One reason researchers are motivated to dig deeper is that some aspects of the Solow residual seem inconsistent with the assertion that only technological or institutional changes cause the residual to fluctuate. For instance, during recessions, the residual usually declines. The strict RBC interpretation would hold that some factor caused a decline in the productive potential of the economy and led to the recession. In some cases such an interpretation seems plausible (as it does for the decline in the Solow residual during the energy crisis in 1974). However, in other cases (for instance, in 1970) the reason for the decline is not clear. Most macroeconomists find declines in the Solow residual during recessions puzzling, although many now believe the declines are real and not simply the consequence of measurement error.

The future development of shock-based theories of business cycles is almost certainly going to be influenced, in part, by attempts to resolve such puzzles. Indeed, both critics and proponents of RBC theory have focused increasingly on the reasons why the Solow residual fluctuates.

For instance, critics of RBC theory have proposed models in which the Solow residual moves in response to cyclical fluctuations caused by unexplained shifts in investment or consumer spending. In these models, a higher rate of production enables businesses to produce at a lower unit cost, which implies that the Solow residual rises during booms and falls during recessions. These induced changes in the Solow residual magnify the effects of the initial change in investment or consumer spending and may lead to excessive cyclical volatility.[10]

On the other hand, proponents of RBC theory point to evidence from U.S. manufacturing plants that seems to indicate that technological change is an important determinant of fluctuations in the Solow residual. If new plants adopt technological improvements, RBC theory predicts that such improvements will induce old and obsolete plants to cease production. As the new technology comes into use, both the Solow residual and national output will rise. U.S. data show that, as theory predicts, plant closings precede increases in the Solow residual. Then, as the Solow residual rises, new plants open and national output increases.[11]

As research on RBC theory progresses, we may expect it to shed light on the questions that vex policymakers. Is there a policy trade-off between the rate of economic growth and its cyclical volatility? How can policy contribute to reducing cyclical volatility? What role do existing countercyclical policies play in promoting economic growth and reducing cyclical volatility? It is to the credit of shock-based business-cycle theories, and to the RBC theory in particular, that progress on these traditional policy concerns can now be made by learning about the factors that underlie fluctuations in the Solow residual.

SUMMARY

Early analysts of business cycles believed that cyclical fluctuations are self-sustaining. But in

[10]See, for instance, the article by Marianne Baxter and Robert King and the article by Roger Farmer and Jang-Ting Guo.

[11]This theory is described in Jeffrey Campbell's article.

the 1920s, statisticians and economists realized that business cycles could result from purely random causes. This discovery moved economists away from the self-sustaining view of business cycles and toward a shock-based view. The first shock-based business-cycle model gave prominence to both random shocks and inherently cyclical behavior as sources of business cycles. But later research demonstrated that shocks were the major source of cyclical fluctuations.

However, these shocks turned out to be peculiar in nature in that they couldn't easily be connected to observable real-world events. They appeared, instead, as deviations of macroeconomic variables from their model-predicted values (i.e., residuals). Then, in the early 1980s, a group of economists greatly refined shock-based (more precisely, residual-based) business-cycle theories by linking cyclical fluctuations to deviations in labor productivity, the so-called Solow residual. Using the advances made in dynamic economic theory in the 1960s and 1970s, these economists demonstrated that fluctuations in the Solow residual were powerful enough to generate fluctuations in output that closely resembled post-WWII U.S. business cycles. This remarkable demonstration strengthened the links between business-cycle theory and simple microeconomic principles and reduced the number of residuals from several to just one. For both reasons, RBC theory represents a significant improvement over first-generation shock-based theories.

Nevertheless, RBC theory doesn't settle the issue of the ultimate sources of cyclical volatility because the random shocks in the RBC model result from variations in unspecified factors that cause erratic movements in business-sector productivity. However, by focusing attention on the role of the Solow residual in cyclical fluctuations, RBC theory has laid a foundation for better understanding the causes of such fluctuations. As business-cycle researchers look for reasons why the Solow residual fluctuates, they may gain knowledge that will help policymakers fashion better macroeconomic policies.

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