Nobel Lecture: The Transformation of Macroeconomic Policy and Research

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I. Introduction

What I am going to describe for you is a revolution in macroeconomics, a transformation in methodology that has reshaped how we conduct our science. Prior to the transformation, macroeconomics was largely separate from the rest of economics. Indeed, some considered the study of macroeconomics fundamentally different and thought there was no hope of integrating macroeconomics with the rest of economics, that is, with neoclassical economics. Others held the view that neoclassical foundations for the empirically determined macro relations would in time be developed. Neither view proved correct.

Finn Kydland and I have been lucky to be a part of this revolution, and my address will focus heavily on our role in advancing this transformation. Now, all stories about transformation have three essential parts: the time prior to the key change, the transformative era, and the new period that has been affected by the change. And that is the story I am going to tell: how macroeconomic policy and research changed as a result of the transformation of macroeconomics from constructing a system of equations of the national accounts to an investigation of dynamic stochastic model economies.

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Macroeconomics has progressed beyond the stage of searching for a theory to the stage of deriving the implications of theory. In this way, macroeconomics has become like the natural sciences. Unlike the natural sciences, though, macroeconomics involves people making decisions based on what they think will happen, and what will happen depends on what decisions they make. This means that the concept of equilibrium must be dynamic, and—as we shall see—this dynamism is at the core of modern macroeconomics.

Before proceeding, I want to emphasize that the methodology that transformed macroeconomics is applicable to the study of virtually all fields of economics. In fact, the meaning of the word *macroeconomics* has changed to refer to the tools being used rather than just to the study of business cycle fluctuations.

As a result of the transformation, these are exciting times in economics. The methodology that Finn and I developed for the study of business cycle fluctuations is being used to advance learning not only in the area of business cycles but also in virtually all areas of economics. By using this methodology, researchers are able to apply theory and measurement to answer questions, define puzzles, and determine where better measurement is needed before specific questions can be answered.

Over the last five years, I have addressed the following questions using this methodology: What is the fundamental value of the stock market, and do fundamentals account for the large movements in the value of the stock market relative to gross domestic product that have occurred over time? Why did hours worked per adult fall by one-third in Western Europe, and not in Canada and the United States, in the 1970–95 period? Why were market hours in the United States at the end of the 1990s 6 percent above what theory predicts? Why did Japan lose a decade of growth beginning in 1992, a decade in which growth was at trend in the other advanced industrial countries?

Much of this recent research originates from my undergraduate teaching that began in the late 1990s. Until then, I had never taught a course in which this methodology was used to address economic questions. The undergraduate course I taught was Quantitative Analysis of the Macroeconomy. I chose to teach this course because I felt there was a need to develop material that could be used in teaching at the undergraduate level what macroeconomics has become. I felt there was this need because Finn's and my work on the time consistency problem and developments in agency theory led me to the conclusion that having good macroeconomic policy requires having an educated citizenry that can evaluate macroeconomic policy. A second reason why I thought there was this need is that if talented undergraduates were introduced to the excitement of modern macroeconomics, some would be influenced to pursue careers in economic research and would make important advances to economic science.

In the course I introduced the real business cycle model economy, which is the single-sector growth model in which people decide how much of their income to consume and save and how much of their time endowment to allocate to the market. Motivated by Ragnar Frisch's (1970) Nobel address, I call this model the neoclassical growth model because it incorporates the willingness of people to substitute as well as their ability to substitute.

One decision that people must make is how to allocate their time endowment, which is the most precious resource an individual has. Indeed, as my undergraduates figure out, the present value of their time endowment is approximately (current) US$5 million, which makes them all multimillionaires. Another crucial feature of any real business cycle model is that the model people decide how much to consume and how much to invest or equivalently save.

The course requires students to carry out quantitative analyses to address specific questions. They use the methodology that Finn and I developed for the study of business cycles to address policy issues. A typical exercise is to determine whether a proposal made by a public opinion leader or government official will have the intended consequence. One question they were assigned concerns financing of transfer payments. Their finding was totally counter to then-conventional wisdom. I will return to this finding later because it is an implication of Finn Kydland's and my business cycle theory.

II. The Transformation of Macroeconomic Policy

In this section I first describe what macroeconomic models were before the transformation and what they are after the transformation. Then I describe policy selection before and after the transformation. Before the transformation, what is evaluated is a policy *action given the current situation*. Policies were discussed in terms of questions such as what will happen if the money supply is increased by some amount. In his 1976 critique, Robert Lucas established that questions such as this one are not well posed in the language of dynamic economic theory.

After the transformation, what is evaluated is a policy *rule*. A policy rule specifies the current policy action as a function of the current economic situation. As Finn and I found, no best policy rule exists. It is true that typically a policy rule exists that is best given that it will be followed in the future. Any such rule is by definition time-consistent but, except in empirically uninteresting cases, not optimal; indeed, such rules typically lead to bad outcomes. There is a fundamental problem in defining what "best" policy means. This led us to the conclusion that all that can be hoped for is to follow a good, but time-inconsistent, policy rule, and this requires economic and political institutions that sustain such a rule.

A. *Macroeconomic Models before the Transformation*

Macroeconomic models were systems of equations that determined current outcomes given the values of the current policy *actions*, values of predetermined variables, and values of any stochastic shocks. Thus physical models and pretransformation macro models have the same mathematical structure. The basic mathematical structure has two sets of equations. One set of equations is the law of motion of the state variables:

$$x_{t+1} = f(x_t, u_t, \epsilon_t).$$

The state or position of the dynamic system at the beginning of period t is x_t, the control or policy variables are u_t, and the stochastic shocks are ϵ_t. The second set of equations specifies the values of all the other variables including national account statistics as a function of the same set of variables.

With the system-of-equations approach, each equation in the system is determined up to a set of parameters. The simple prototype system-of-equations macro model has a consumption function, an investment equation, a money demand function, and a Phillips curve. Behind all these equations were a rich empirical literature and, in the case of the consumption function and investment equation, some serious theoretical work. The final step was to use the tools of statistical estimation theory to select the parameters that define the functions.

I worked in this tradition. In my dissertation, I formulated the optimal policy selection problem as a Bayesian sequential decision problem. The problem is a difficult one because the policy actions taken today affect the distribution of the posterior distribution of the values of the coefficients of the equations.

The macroeconometric models organized the field. Success in macroeconomics was to have your equation incorporated into the macroeconometric models. Indeed, Lucas and I were searching for a better investment equation when in 1969 we wrote our paper "Investment under Uncertainty," a paper that was published two years later in 1971.

A key assumption in the system-of-equations approach is that the equations are *policy invariant.* As Lucas points out in his critique, a draft of which I read in 1973, this assumption is inconsistent with dynamic economic theory. His insight made it clear that there was no hope for the neoclassical synthesis, that is, the development of neoclassical underpinnings of the system-of-equations macro models.

Fortunately, with advances in dynamic economic theory, an alternative set of tractable macro models was developed for drawing scientific inference. A key development was recursive competitive equilibrium theory in Lucas and Prescott (1971) and Lucas (1972). Representing equilibrium as a set of stochastic processes with stationary transition probabilities was crucial to the revolution in macroeconomics.

B. *Macroeconomic Models after the Transformation*

Models after the transformation are dynamic, fully articulated model economies in the general equilibrium sense of the word *economy*. Model people maximize utility given the price system, policy, and their consumption possibility set; firms maximize valuation given their technology set, the price system, and policy; and markets clear. Preferences, on the one hand, describe what people choose from a given choice set. Technology, on the other hand, specifies what outputs can be produced given the inputs. *Preferences and technology are policy invariant.* They are the data of the theory and not the equations as in the system-of-equations approach. With the general equilibrium approach, empirical knowledge is organized around preferences and technology, in sharp contrast to the system-of-equations approach, which organizes knowledge about equations that specify the behavior of aggregations of households and firms.

C. *The Time Inconsistency of Optimal Policy*

Before the transformation, optimal policy selection was a matter of solving what the physical scientists called a control problem. This is not surprising, given that the system-of-equations approach was borrowed from the physical sciences. With such systems, the principle of optimality holds; that is, it is best to choose at each point in time the policy action that is best given the current situation, which is summarized by the value of a suitably selected state variable, and the rules by which policy will be selected in the future. The optimal policy is time-consistent, and dynamic programming techniques can be used to find the optimal policy as in the physical sciences. This is true even if there is uncertainty in the model economy.

Finn and I had read the Lucas critique and knew that an implication of dynamic economic theory is that only policy rules can be evaluated. This led us to search for a best policy rule to follow, where a rule specifies policy actions as a function of the state or position of the economy. We had worked on this problem before Finn left Carnegie Mellon to join the faculty of the Norwegian School of Business and Economics in 1973. In academic year 1974–75, I visited the Norwegian School of Business and Economics, and in the spring of 1975 Finn and I returned to this problem. This is when we wrote our paper “Rules Rather than Discretion: The Inconsistency of Optimal Plans” (published in 1977), one of the two papers for which Finn and I were awarded the Nobel Prize.

In previous research (Kydland and Prescott 1974), we had considered time-consistent stationary policy rules. These rules have the property that they are a fixed point of the mapping that specifies the best rule today as a function of the rule that will be used in the future. The fact that these rules were not optimal led us to our key insight: the best event-contingent policy plan is not time-consistent. By this I mean that the continuation of a plan is not optimal at some future point in the event-time tree. For example, it is always best to tax the returns on existing capital but not tax the returns on new investments. The reason is that a tax on existing capital is a lump-sum tax and there is no associated distortion, whereas any taxes on future returns of current investments are distortionary. But capital investments today become existing capital tomorrow, and tomorrow the best policy action is to tax their returns.

This leads to the conclusion that being able to commit has value and that having discretion has costs. The only method of commitment is to follow rules. That is why we concluded that the time inconsistency of optimal plans necessitates following rules. Some societies have had considerable success in following good, but time-inconsistent, policy rules, and as a result their citizens enjoy a high standard of living. Other societies have limited success in this regard, and as a result their citizens suffer economic hardships.

This need for rules in organizational settings has long been recognized. That is why all agree that rule by a good set of laws is desirable. Rule by law is a political institution to get around the time consistency problem. What was new in our research was that this principle holds for macroeconomic policy counter to what everyone thought at the time.

D. *A Success in Following a Good Monetary Policy Rule*

A notable example of a success in following a good, but time-inconsistent, rule is the one maintaining a low and stable inflation rate. Before describing an institution that is proving effective in getting commitment to this good rule in many countries, I will first describe one reason why the price stability policy rule is time-inconsistent.

Consider an economy in which the nominal wage rate is set above the market-clearing level in some sectors, given the inflation rate specified by the rule. This outcome could be the result of industry insiders in each of a number of industries finding this action in their best interest given the wages chosen by the insiders in other industries and the expected inflation rate. If the price stability policy rule is followed, ex post, a distortion occurs that results in low employment. This distortion can be reduced by having inflation in excess of the amount specified by the rule. With the time-consistent monetary policy rule, inflation will be at that level at which the marginal value of higher inflation in reducing the distortion will just equal the marginal cost of the higher inflation. The equilibrium outcome is high inflation and no reduction in the distortion. Commitment to the best rule will not result in high inflation, just the labor market distortion.

I turn now to an institution that is proving successful in sustaining this rule: an independent central bank. Members of this organization have a vested interest in following this rule, for if it is not followed, they would incur the risk that they would suffer in the future. If inflation has been excessive and a new administration is elected, people in the organization will be replaced and the size of the central bank cut. Thus members of this organization have a vested interest in the rule being followed.

The increased stability of the economy and the improved performance of the payment and credit system may be due in part to the diffusion of findings of Finn's and my "Rules Rather than Discretion" paper. People now recognize much better the importance of having good macroeconomic institutions such as an independent central bank.

To find the time-consistent policy, we de facto considered a game. In the simplest case, the value function of an individual is $v(k, K)$ and that of the policy maker $v(K, K)$, where k is a given individual's capital stock and K is the capital stock of every other individual. Note that within the class of policies that treat individuals anonymously, all individuals order policies in the same way that the policy maker does. At the first stage of each period, the policy maker selects the policy that is best for the representative individual and the rule by which policy will be selected in the future.

III. The Transformation of Macroeconomic Research

The title of this address is "The Transformation of Macroeconomic Policy and Research." I turn now to the research part of the title. The methods used in macroeconomic research were different prior to Finn's and my paper "Time to Build and Aggregate Fluctuations" (1982). The new methodology crystallized in the summer of 1979 when Finn and I did the research for and wrote our "Time to Build" paper.[1]

Before specifying the new research methodology, I have to discuss

[1] An earlier paper (Kydland and Prescott 1978) has many of the features of our "Time to Build" paper, including time to build and technology shock. An even earlier working paper (Prescott 1974) has a monetary shock model.

what the key business cycle facts are and why they led economists to falsely conclude that business cycle fluctuations were not in large part equilibrium responses to real shocks. Then I will specify the methodology that Finn and I developed and used to quantitatively determine the consequences of these shocks for business cycle fluctuations.

I emphasize that what is important is the methodology and that this methodology can be and is being used to quantitatively determine the consequences of both nominal and real shocks. By "real shocks" I mean not only technology shocks but also tax shocks, terms of trade shocks, labor market policy shocks, and so on. By using these methods, the profession has learned so much. No longer do economists just conjecture and speculate. Instead they make quantitative statements as to the consequences of various shocks and features of reality for business cycle fluctuations and other phenomena. The "Time to Build" paper began a constructive and fruitful research program.

A. *Business Cycle Facts*

In the 1970s after the development of dynamic economic theory, it was clear that something other than the system-of-equations approach was needed if macroeconomics was to be integrated with the rest of economics. I want to emphasize that at that time macroeconomics meant business cycle fluctuations. Growth theory, even though it dealt with the same set of aggregate economic variables, was part of what was then called microeconomics, as was the study of tax policies in public finance.

Business cycles are fluctuations in output and employment about *trend*.[2] But what is trend? Having been trained as a statistician, I naturally looked to theory to provide the definition of trend, with the plan to then use the tools of statistics to estimate or measure it. But theory provided no definition of trend, so in 1978 Bob Hodrick and I took the then-radical step of using an operational definition of trend.[3] With an operational definition, the measurement procedure defines the concept.

Our trend is just a well-defined statistic, where a statistic is a real-valued function. The family of trends that Bob Hodrick and I considered (Hodrick and Prescott 1980) had a parameter that determined the smoothness of the trend. We selected this parameter so that the trend

[2] Lucas (1977, 9) defines business cycles as recurrent fluctuations of output and employment about trend but does not provide a definition of trend.

[3] A shortened version of this 1978 Carnegie Mellon working paper is a 1980 Northwestern University working paper. At the time, this paper was largely ignored because the profession was not using the neoclassical growth model to think about business cycle fluctuations. But once the then-young people in the profession started using the neoclassical growth model to think about business cycles, the profession found the statistics reported in this paper of interest.

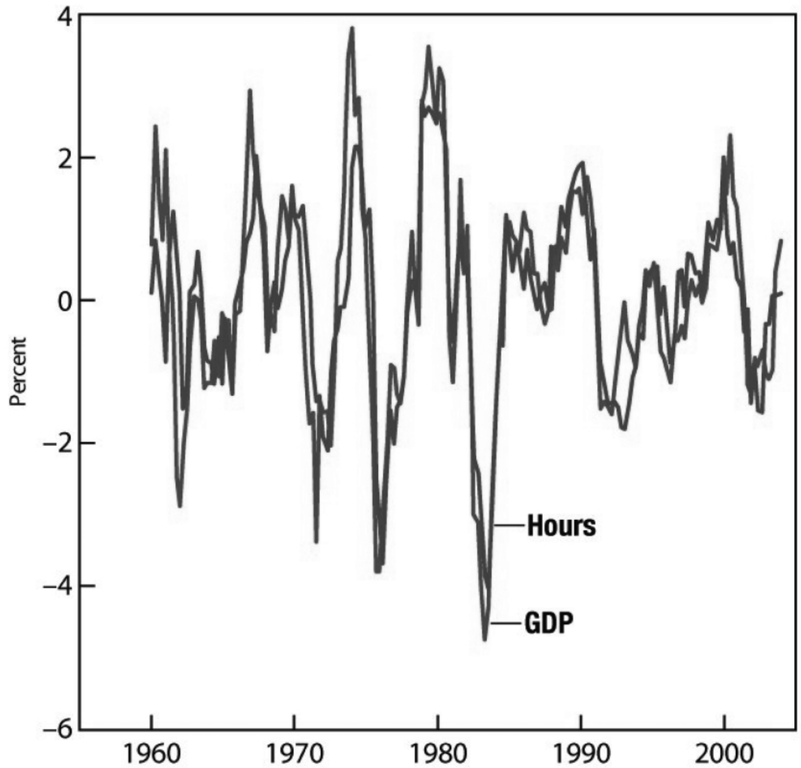

FIG. 1.—Deviations from trend of U.S. GDP and hours per person 16–64

statistic mimics the smooth curve that economists fit through the data. Later we learned that actuaries use this family of smoothers, as did John von Neumann when he worked on ballistic problems for the U.S. government during World War II.[4] A desirable feature of this definition is that with the selection of smoothing parameters for quarterly time series, there are no degrees of freedom and the business cycle statistics are not a matter of judgment. Having everyone looking at the same set of statistics facilitated the development of business cycle theory by making studies comparable.

One set of key business cycle facts is that two-thirds of business cycle fluctuations are accounted for by variations in the labor input, one-third by variations in total factor productivity, and virtually zero by variations in the capital service input. The importance of variation in the labor input can be seen in figure 1. This is in sharp contrast to the secular behavior of the labor input and output, which is shown in figure 2.

[4] See Stigler's (1978) history of statistics.

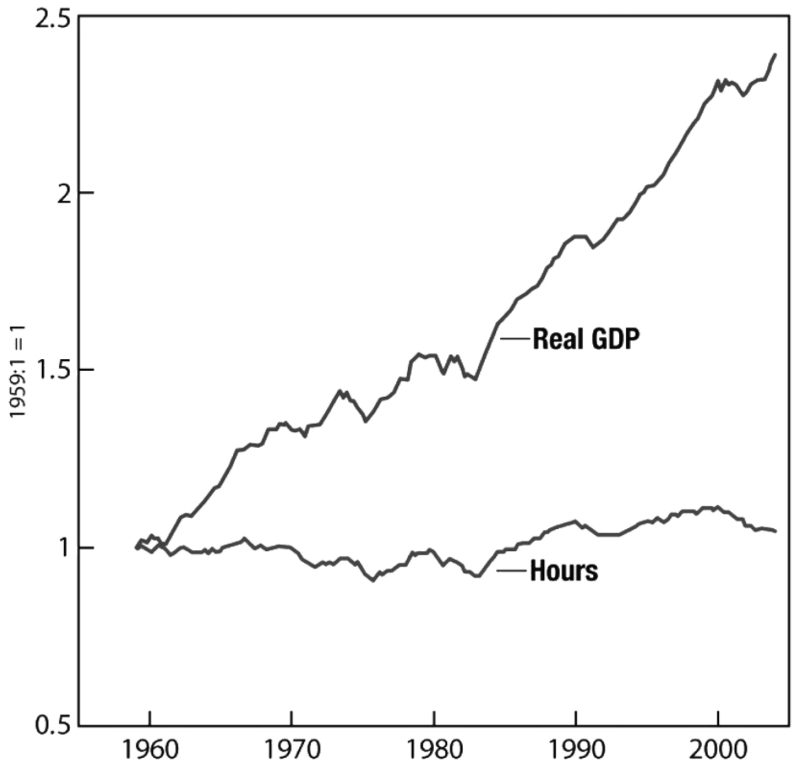

Fig. 2.—Indices of per capita real GDP and hours per person 16–64

Secularly, per capita output has a strong upward trend, whereas the per capita labor input shows no trend.

A second business cycle fact is that consumption moves procyclically; that is, the cyclical component of consumption moves up and down with the cyclical component of output. A third fact is that, in percentage terms, investment varies 10 times as much as consumption. Consequently, investment variation is a disproportionate part of cyclical output variation. This is shown in figure 3.

B. Inference Drawn from These Facts

Now why did economists looking at these facts conclude that they ruled out total factor productivity and other real shocks as being a significant contributor to business cycle fluctuations? Their reasoning is as follows. Leisure and consumption are normal goods. The evidence at that time was that the real wage was acyclical, which implies no cyclical substitution

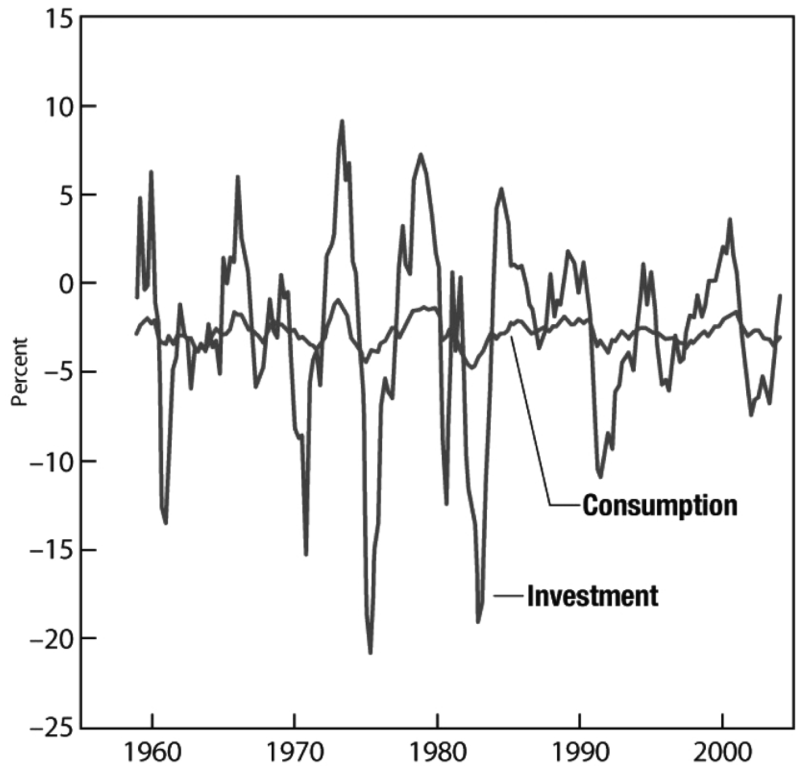

FIG. 3.—Deviations from trend of U.S. consumption and investment per person 16–64

effects. This leaves only the wealth effect. Therefore, in the boom in which income is high, the quantity of leisure should be high when in fact it is low. This logic is based on partial equilibrium reasoning, and the conclusion turned out to be wrong.

In the 1970s a number of interesting conjectures arose as to why the economy fluctuated as it did. Most were related to finding a propagation mechanism that resulted in Lucas's monetary surprise shocks having persistent real effects. With this theory, leisure moves countercyclically in conformity with observations. But the deviations of output and employment from trend are not persistent under this theory, when in fact they are persistent. This initiated a search for some feature of reality that when introduced gives rise to persistent real effects. To put it another way, economists searched for what Frisch called a propagation mechanism for the effects of monetary surprises.

Fischer (1977) and Taylor (1980) provided empirical and theoretical evidence in support of their conjecture that staggered nominal wage contracting might be the mechanism by which monetary shocks gave rise to persistent real effects on output and employment. Another conjectured mechanism of that era is the cost of changing nominal prices. In that era almost no one thought real shocks were an important contributor to business cycle fluctuations. I say "in that era" because earlier, Wicksell ([1907] 1953), Pigou (1927), and others held the view that real shocks were an important contribution to business cycles. At the time Finn and I were agnostic on whether they were important and did consider them in a paper (Kydland and Prescott 1978) that was the precursor to our "Time to Build" paper. No matter what the shocks were, we thought that there had to be some propagation mechanism, and our candidate was time to build. The model economy in "Time to Build" had surprises that led to labor supply errors, a propagation mechanism, and persistent technology shocks.

C. *Macroeconomics and Growth Theory before the "Time to Build" Paper*

Posttransformation macroeconomics of the 1970s largely ignored capital accumulation. Growth theory was concerned with the long-term movements in the economic aggregates, whereas macroeconomics was concerned with the short-term movements in output and employment. Virtually no connection was made between the then-dormant growth theory and the dynamic equilibrium theories of business cycles. Probably the reason was that short-term movements in output are accounted for in large part by movements in the labor input, whereas long-term growth in living standards is accounted for by increases in the capital service input and in total factor productivity.

Kydland and I decided to use the neoclassical growth model to study business cycle fluctuations in the summer of 1979. The methodology that we developed came to be called the real business cycle model.[5] This is unfortunate, for the methodology can be used to answer questions concerning the consequences of both real and monetary policy surprise shocks. I will not discuss these monetary applications in this address because Kydland does in his address. This is appropriate given that he and his collaborators, and not I, are leaders in the study of the consequences of monetary policy for business cycles.

D. *The Methodology*

The model Finn and I develop and use in our "Time to Build" paper builds on the contributions of many economists, many of whom have

[5] The term *real business cycle* was introduced by Long and Plosser (1983), who developed a dynamic stochastic equilibrium model with fluctuations in industry and aggregate outputs.

been awarded the Nobel Prize. The importance of the contributions of Simon Kuznets and Richard Stone in developing the national income and product accounts cannot be overstated. These accounts reveal a set of growth facts, which led to Solow's (1956) *classical* growth model, which Solow (1970) calibrated to the growth facts. This simple but elegant model accounts well for the secular behavior of the principal economic aggregates. With this model, however, labor is supplied inelastically and savings is behaviorally determined. There are people in the classical growth model economy, but they make no decisions. This is why I, motivated by Frisch's Nobel address delivered in 1969, refer to this model as the classical growth model.

The steps in Finn's and my methodology are as follows.

Step 1: Start with the neoclassical growth model.—Central to the neoclassical growth model is the Solow-Swan aggregate production function. As explained in Solow (1956, n. 7), the theory underlying the aggregate production function is a theory of the income side of the national accounts.[6] With competitive factor and product markets and entry and exit of production units, factor claims against product exhaust product. In addition, output is maximized given the quantities of the factor inputs supplied.

The function F_t is the period t aggregate production function that specifies the output that is produced as a function of the inputs

$$c_t + x_t = y_t = F_t(k_t,\ h_t), \tag{1}$$

where c is consumption, x is investment, y is output, k is the capital service input, and h is the labor service input. One unit of capital provides one unit of capital services, and capital depreciates geometrically at rate δ. Thus

$$k_{t+1} = (1 - \delta)k_t + x_t. \tag{2}$$

We also introduced a multiperiod requirement for building new capacity because we thought it might be an important shock propagation mechanism.[7]

For the growth model to be neoclassical, the savings-investment and labor-leisure decisions must be decisions of the households. Finn and I introduced an *aggregate* or stand-in household with preferences ordered by the expected discounted value of utility flows from consump-

[6] For partial equilibrium models, this was recognized by Marshall and Wicksell at the end of the nineteenth century, but Solow saw it in the general equilibrium context.

[7] Hansen (1985) shows that this feature of reality is not central to understanding business cycle fluctuations and is best abstracted from.

tion and leisure; that is, the household maximizes the expected value of

$$\sum_{t=0}^{\infty} \beta^t u(c_t, 1 - h_t), \qquad (3)$$

where c is consumption and $1 - h$ is leisure. The aggregation theory underlying this aggregate household is based in part on the first welfare theory, namely, that a competitive equilibrium maximized some weighted average of individual utilities, absent externalities.

Previously, others had effectively endogenized the savings decision by analyzing the optimal growth path because, by the second welfare theorem, the optimal path is the competitive equilibrium path for this model.[8] But in order for the model to be used to study business cycle fluctuations, the labor supply decision must be endogenized as well.[9]

Step 2: Modify the national accounts to be consistent with the theory.—Prior to our work, macroeconomics was concerned with developing a theory of the national accounts statistics. With our approach, preferences and technology are the given, not the national accounts statistics. This means that we had to modify the national accounts to be consistent with the theoretical abstraction or model we used. The most important modification when studying business cycles is to treat consumer durable expenditures as an investment in the same way that expenditures on new housing and home improvement are treated as investments in the national accounts. Once this is done, services of consumer durables and consumer durable rental income must be imputed, in much the same way as is currently done for owner-occupied housing. This increases investment share of output and has consequences for the cyclical behavior of the economy. What led us to think about this issue is that consumer durable expenditures are highly variable, behaving very similarly to producer durable investments and not like consumer expenditures on nondurable goods and services.

Step 3: Restrict the model to be consistent with the growth facts.—The growth facts are that consumption and investment shares of output are roughly constant, as are labor and capital cost shares. All the variables and the real wage grow over time except for labor supply and the return on

[8] Cass (1965) and Koopmans (1965) in deterministic situations establish the existence of an optimal path and characterize properties of this optimal path. Diamond (1965) studies the competitive equilibrium path in an overlapping generations economy with capital accumulation. In his economy, people live two periods. Brock and Mirman (1972) deal with the problem of optimal growth when there are stochastic shocks to the technology. These studies are in the nonquantitative theory tradition.

[9] Auerbach, Kotlikoff, and Skinner (1983) carry out a deterministic dynamic applied general equilibrium analysis with endogenous labor supply in which they evaluate tax policies.

capital, which are roughly constant. This leads to a Cobb-Douglas production function. These facts also imply the constancy of the capital-output ratio and of the rental price of capital.

Two key growth facts are that the real wage and consumption grow at the same secular rate as real output per capita, whereas labor supply displays no secular trend. This restricts the period utility function to be of the form

$$u(c,\ 1-h) = \frac{[cg(1-h)]^{1-\sigma}-1}{1-\sigma}. \tag{4}$$

We set $\sigma = 1$. The value of the parameter σ is not tied down by the growth facts, and other observations have to be used to guide its selection. The principal evidence used in its selection is comparisons of the return on capital for fast- and slow-growing economies. The modest difference for these returns led to the selected value. Fortunately, it turned out that our findings are not sensitive to this parameter, because at the time of our work, this key economic parameter had not been tightly tied down.

With $\sigma = 1$, the above utility function is

$$\log c + g(1-h). \tag{5}$$

The nature of the g function matters. The growth facts do not tie down the elasticity of substitution between leisure today and leisure tomorrow, and this parameter turned out to be key for deriving the predictions of the growth model for business cycle fluctuations. Subsequently, this key parameter has been tied down.

Step 4: Introduce a Markovian shock process.—We wanted something in our model economy that led to labor supply errors and something to propagate these errors. Here, by "labor supply errors" I mean the difference between the optimal labor supply decision given individuals' information set and the decision that they would make if they observed the state of the economy without observation error. We introduced a total factor productivity (TFP) shock that is independent over time and assumes that agents see the value of TFP with noise prior to making their labor supply decisions. We also introduced a second highly persistent autoregressive TFP shock. In order to use the Kalman filter, the two shocks and measurement errors are all normally distributed.

Step 5: Make a linear-quadratic approximation.—The next step is to determine the steady state of the economy when the variances of the TFP shocks are zero. Then a linear-quadratic economy is constructed that has the same first two derivatives at the steady state. This linear-quadratic economy displays the growth facts, and its equilibrium is easily computed. The behavior of this economy will be arbitrarily close to that of the economy we began with for sufficiently small variances of the two TFP shocks and the measurement errors. It turned out that it is extremely close even for variances far bigger than the ones we introduced.[10]

Step 6: Compute the competitive equilibrium process.—The next step is to compute the recursive competitive equilibrium stochastic process.

Step 7: Simulate the model economy.—The equilibrium stochastic process is used to generate a time-series realization of the model economy. If the number of observations in the period being considered is N, a time series of length significantly greater than N is generated and the last N observations considered. A longer time series is generated because we wanted a draw from the invariant distribution for the state of the economy as a starting point of the model's sample path.

Step 8: Examine the key business cycle statistics and draw scientific inferences.—The next step is to compare the key business cycle statistics for the model and the actual economy. I emphasize that the *identical statistics* for the model and the actual economy are compared.

One important statistic is the standard deviation of the cyclical component of output. What we defined to be the cyclical component of output is first computed for the actual economy and the standard deviation determined. The identical procedure is followed for realizations of the equilibrium process of the model economy. This means that the model is simulated to generate the time series of output and other series. Next the cyclical component of output is computed and its standard deviation determined. This is done many times so that the first two moments of the sampling distribution of the standard deviation of the model's cyclical output statistic can be determined.

If the sampling distribution of this statistic in question is concentrated about some number, this number specifies how variable the economy would have been if TFP shocks were the only shocks. If the sampling distribution of this statistic is not concentrated, theory does not provide a precise accounting. But the sampling distribution is highly concentrated provided that the number of quarterly observations is at least 100.

Step 9: Check for consistency with observations on individual households and firms.—How to carry out this step is subtle and will be described by example. I show in Section V the consistency of the willingness of the stand-in household and that of the people being aggregated to intertemporally substitute leisure. Here, *leisure* is shorthand for nonmarket productive time. Before showing this consistency, I must first report

[10] Danthine and Donaldson (1981), who computed the exact equilibrium for the stochastic model using computationally intensive techniques, found this to be the case.

what business cycle theorists have found using steps 1–8 of this methodology.

IV. Using the Methodology in Business Cycle Research

As reported in our paper "Time to Build and Aggregate Fluctuations" (Kydland and Prescott 1982), if the willingness of people to intertemporally substitute leisure is one or greater and TFP shocks are highly persistent and of the right magnitude, then business cycles are what the neoclassical growth model predicts. This includes the amplitude of fluctuation of output, the serial correlation properties of cyclical output, the relative variability of consumption and investment, the fact that capital stocks peak and bottom out later than output does, the cyclical behavior of leisure, and the cyclical output accounting facts.

Subsequently, I found (Prescott 1986) that the shocks were highly persistent and the TFP shocks of the right magnitude. Conditional on the intertemporal elasticity of leisure substitution being almost one or greater, the neoclassical growth model predicts business cycle fluctuations. If these fluctuations did not occur, there would be a puzzle. Further, productivity shocks are *the* major contributor to fluctuations in the period 1954–81 in the United States. I emphasize that this does not imply that productivity shocks are the major contributor in other periods and in other countries. The methodology that we developed must be used to estimate how important these shocks are in each period in each country.

We did find that persistent shocks that had consequences for the steady state of the deterministic growth model give rise to business cycle fluctuations if and only if the intertemporal elasticity of leisure is one or greater. This finding turned out to be robust. Greenwood, Hercowitz, and Huffman (1988) find that if, on average, TFP shocks are nonneutral with regard to consumption and investment, the conclusions hold. Rotemberg and Woodford (1992) introduce imperfect competition and show that the finding is overthrown only if monopoly rents are far in excess of what they could be. With imperfect competition restricted to be consistent with labor cost share, Hornstein (1993) and Devereux, Head, and Lapham (1996) show that the importance of TFP shocks for business cycle fluctuations hardly changes. With the introduction of monopolistic competition, model-TFP shock variance is picked so that the model Solow-TFP variance matches the actual economy's Solow-TFP change variance. In these monopolistic competitive worlds, Solow-TFP is a complex statistic and is not total factor productivity.

Investment in the model economy varies smoothly, as does aggregate investment in the actual economy. Investment at the plant level, however, is not smooth, and a natural question is whether this has consequences for modeling business cycles. Fisher and Hornstein (2000) find that having plants that make lumpy inventory investment in equilibrium does not change the estimates of the contribution of TFP shocks to fluctuations. For investment in plant and equipment, Thomas (2002) develops an economy that displays lumpy investment at the plant level. When calibrated to the growth facts and establishment investment statistics, the findings for business cycles using her abstraction are virtually the same as those using the neoclassical growth model.

Ríos-Rull (1995) uses a carefully calibrated overlapping generations model and finds that the estimated importance of TFP shocks for business cycle fluctuations does not change. Within this framework, Ríos-Rull (1994) then shuts down financial markets, so holding physical capital is the only way to save. This extreme version of market incompleteness does not affect the estimate of the importance of TFP shocks. Introducing uninsurable idiosyncratic risk (see Krusell and Smith 1998) does not affect the estimate either. Hansen and Prescott (2005) deal with capacity utilization constraints that are occasionally binding. With their introduction, the nature of the predictions for business cycles changes a little, but in a way that results in observations being in even closer conformity with theory.

Using this methodology, Danthine and Donaldson (1990) and Gomme and Greenwood (1995) investigate the consequences of various non-Walrasian features for business cycle fluctuations. There are interesting implications for relative variability of consumption for those with large capital ownership and those with no capital ownership. But the basic finding holds for such model economies.

Cooley and Hansen (1995) and Freeman and Kydland (2000) find that introducing money and a transaction technology does not alter the conclusion as to the importance of TFP shocks. Ohanian and Stockman (1994) consider an economy with nominal contracting in one sector and flexible prices in the other. They find that business cycles in this world are essentially the same as they are in worlds with all prices flexible. Using the methodology, McGrattan (2005) finds that the neoclassical growth model with sticky wages and monetary shocks does not display the key business cycle facts. If technology and taxes are added, the growth model can display the key business cycle facts. She finds that sticky wages dampen fluctuations.

To summarize, introducing nominal contracting does not alter the finding that the neoclassical growth model must have a high intertemporal substitution elasticity of leisure if it is to generate business cycle fluctuations. Introducing nominal contracting and monetary shocks does not alter Finn's and my finding that productivity shocks are the major contributor to business cycle fluctuations in the United States in the 1954–80 period we consider in our "Time to Build" paper.

But to generate business cycles of the magnitude and nature observed, the aggregate intertemporal elasticity of leisure must be one or greater.[11] A variety of micro and macro evidence that supports this number had to be found before it was safe to conclude that the neoclassical growth model predicts business cycle fluctuations of the quantitative nature observed.

V. Aggregation Theory Implies a High Intertemporal Substitution

The principal problem with the models that many economists used to estimate the intertemporal substitution elasticity of leisure is that they predict that the margin of adjustment in aggregate labor supply is hours per worker and not the fraction employed, which is not the case. Over the business cycle, most of the variation in the aggregate number of hours worked is in the fraction of people working and not in the hours worked per worker.

A. *Rogerson Labor Indivisibility*

Rogerson (1984, 1988) studies a static world in which people either work a standard workweek or do not work. He shows that in this world, the aggregate substitution elasticity between leisure and consumption is infinite unless the fraction employed is one. Rogerson's aggregation result is every bit as important as the one giving rise to the aggregate production function.[12] In the case of production technology, the nature of the aggregate production function in the empirically interesting cases is very different from that of the individual production units being aggregated. The same is true for the aggregate or a stand-in household's utility function in the empirically interesting case.

To summarize, if the principal margin of adjustment in aggregate hours is the employment rate e and not hours per employee h, then the aggregate substitution elasticity is much bigger than the elasticity of the individuals being aggregated. In dynamic settings, as shown by Hansen (1985), the intertemporal elasticity of leisure substitution is infinite with the Rogerson labor indivisibility.

Given that the principal margin of adjustment is e and not h, *the aggregate elasticity of substitution between leisure today and leisure tomorrow is*

[11] For reviews of many more business cycle studies, see *Frontiers of Business Cycle Research* (Cooley 1995).

[12] Rogerson uses the Prescott and Townsend (1984*a*, 1984*b*) lottery commodity point. This simplifies the analysis but does not change the results because lottery equilibria are equivalent to Arrow-Debreu equilibria; see Kehoe, Levine, and Prescott (2002) and Prescott and Shell (2002).

large. Thus aggregate observations are consistent with individual observations with respect to people's willingness to intertemporally substitute leisure.

Multiple margins determine the fraction of the working-age population that works in a given period. Particularly important for the single male and female, labor supply is the fraction of potential working life that the individual spends working. This fraction is smaller for those who retire early or enter the workforce later in life. Heckman and MaCurdy (1980) find that, as Rogerson's theory predicts, the labor supply for married females is highly elastic, with some estimates being as high as *10*. For all working-age people, weeks of vacation and the number of holidays are another important margin of adjustment in labor supply.

B. Business Cycle Implications of Labor Indivisibility

Hansen (1985) derives the consequence of the Rogerson (1988) assumption for business cycle fluctuations and develops a stand-in household for a type. He finds that in worlds with labor indivisibility, fluctuations induced by productivity shocks alone give rise to fluctuations *10* percent greater than those observed. Given that other factors also contribute to business cycle fluctuations, this indicates that the aggregate intertemporal elasticity of leisure substitution is not infinite as in his model world.

Hansen's findings led Finn and me to introduce both margins of labor supply adjustment. We numerically found that the only margin used is the fraction employed with the standard production function.[13] The natural question is *why*? Hornstein and Prescott (1993) answer this question.[14] We permitted both margins to be adjusted. The key modification is that a worker's output y is

$$y = Ahk^{\theta}, \tag{6}$$

where h is the workweek length of this individual and k is the capital stock that this individual uses. A consequence is that payment per hour is an increasing function of h.

Crucial for our methodology is that *all* the growth facts hold for this modification of the neoclassical growth model. The key feature of this

[13] In Kydland and Prescott (1991), we added modest resource costs of moving between the market and the nonmarket sectors. This resulted in an adjustment of both the hours and the employment rate margins. These costs were selected so that the relative margin of these adjustments for the model economy matched those for the actual economy.

[14] Sherwin Rosen (1978) had pointed out that workweeks of different lengths are different commodities and their price is not, in general, proportional to the length of the workweek. Introducing this feature of reality into an applied dynamic general equilibrium model of business cycles did not occur until Kydland and Prescott (1991). Earlier, Hansen and Sargent (1988) had two workweek lengths, regular time and regular time plus overtime.

model is that capital used by one individual is not used by another in the period. For the calibrated economy, the finding is that only the e margin is used, except in extreme cases in which all are employed. Only with $e = 1$ is $h > \bar{h}$, where $\bar{h}$ is the endogenously determined "standard" week length.

C. The Life Cycle and Labor Indivisibility

I do not have a simple intuitive explanation as to why there is an endogenously determined standard workweek in the Hornstein and Prescott (1993) world. I do have one for a simple finite lifetime model economy. To keep notation simple, time $t \in [0, 1]$. There is no capital accumulation, and there is some measure of identical people.

Essential for the fixed workweek outcome is that the households' problem is not convex in consumptions and leisure. This nonconvexity naturally arises because workweeks of different lengths are different commodities and their prices are not proportional to their length. Reasons for this are that commute time for most jobs is not productive activity, time required to get set up and to keep current can be substantial, and marginal productivity may fall beyond some workweek length because people get bored or tired. Even if marginal productivity does not fall, the marginal disutility of each additional hour of work increases.

The key theoretical element is a nonlinear mapping from time allocated to the market to units of the labor services supplied. Using the inverse mapping of market hours h to units of labor services l to eliminate h in the additively separable utility flow function yields the lifetime utility function

$$\int_0^1 [u(c) - v(l)]dt. \tag{7}$$

The function u is an increasing, differentiable, concave function with $u'(0) = -\infty$ and $u'(\infty) = 0$. The production function is $c = wl$, so the equilibrium real wage is w.

The function v is depicted in figure 4. The key feature is that the function is discontinuous at zero. The standard workweek is $\bar{h}$ for which $l = \bar{l}$.

The intertemporal budget constraint is

$$\int_0^1 cdt \leq \int_0^1 wldt. \tag{8}$$

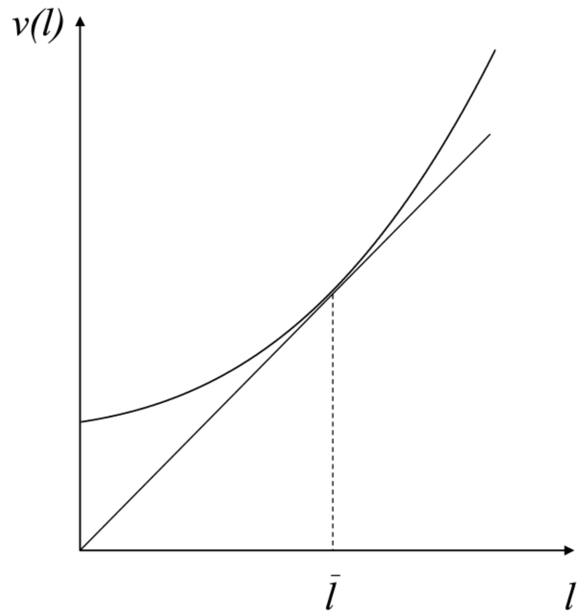

FIG. 4.—Disutility of labor supply

In this world, people work the standard workweek some fraction of their life or work their entire life.

The first case is the empirically interesting one and will be considered. Whenever people work, they work the same l at every instance. With this restriction, the lifetime utility function becomes

$$u(c) - ev(l) - (1 - e)v(0), \tag{9}$$

where c is consumption at every instance of time and e is the fraction of lifetime worked. If the $\bar{e}$ that satisfies

$$w\bar{l}u'(\bar{e}w\bar{l}) - v(\bar{l}) - v(0) = 0 \tag{10}$$

also satisfies $\bar{e} < 1$, it is optimal for individuals to work fraction $\bar{e} < 1$ of their lifetime and to work workweeks of length $\bar{h} = f(\bar{l})$. Otherwise $e = 1$ and $h \geq \bar{h}$.

What gets determined is the fraction of the population that works at each instance of time and the fraction of each individual lifetime worked. Who works at a given point in time is not determined. If the wage varied over time, for some $\bar{w}$ all would work when $w(t) > \bar{w}$ and not all when $w(t) < \bar{w}$.

The important result is that the fraction working the standard workweek adjusts, and not the length of the workweek unless all are employed. This result is quite general, requiring only that preferences are time-additively separable. The implication is that in the aggregate, the intertemporal leisure elasticity substitution is large whenever the margin of adjustment is the fraction of the population working.

VI. Supporting Empirical Evidence for Aggregate Elasticity of One

Step 9 of the methodology was to check consistency of the aggregate model assumptions with other macro and micro observations. As business cycle theorists found, the aggregate elasticity of substitution between leisure this period and leisure next period must now be about one. I now review non–business cycle evidence and find that this number is strongly supported by micro observations and by other macro observations.

A. *Evidence from a Consequence of Tax Rates across Countries and across Time*

Good statistics are now available on labor supply and tax rates across the major advanced industrial countries. My measure of aggregate labor supply is aggregate hours worked in the market sector divided by the number of working-age people. This is the measure that is appropriate given the theoretical abstraction being used.

Given that the effect of the marginal effective tax rate on labor supply depends on this substitution elasticity and given that tax rates vary considerably, these observations provide an almost ideal test of whether this elasticity is near one. The set of countries that I consider (Prescott 2004) are the Group of Seven countries, which are the large advanced industrial countries. The differences in marginal tax rates and labor supply are large: Canada, Japan, and the United States have rates near 0.40, and France, Germany, and Italy have rates near 0.60. The prediction based on a substitution elasticity of one is that Western Europeans will work one-third less than North Americans and Japanese. This prediction is confirmed by observations. Added evidence for this substitution elasticity is that it explains why labor supplies in France and Germany were nearly 40 percent greater during the 1970–74 period than they are today. These countries increased their marginal effective tax rate from 40 percent in the early 1970s to 60 percent today.

To summarize, observations on aggregate labor supply across countries and across time imply an intertemporal leisure substitution elasticity near one.

B. Recent Evidence from Major Contractions and Expansions

Additional evidence is provided by the study of recent major contractions. Three advanced industrial countries with reasonably good economic statistics suffered a 20 percent or more loss in output per capita relative to a 2 percent trend in the last quarter of the twentieth century. The countries are Japan in the 1990s and New Zealand and Switzerland in the 1970s and 1980s. The behavior of labor supply during these extended periods of nonbalanced growth implies the same substitution elasticity as business cycle fluctuations.[15]

C. Life Cycle Labor Supply Evidence

There is a close connection between the labor supply elasticity and the intertemporal leisure substitution elasticity. If there were no nonconvexities and all have the same utility function as the aggregate stand-in household, a unit elasticity of substitution between leisure today and leisure tomorrow implies a Frischian labor supply elasticity of $h/(1 - h)$. For the United States, the fraction of productive time allocated to the market h is near 0.25, which implies a Frischian elasticity of labor supply of three if the intertemporal substitution elasticity is one as macroeconomists found. Micro studies that estimated lifetime labor supply are the studies of interest for further examining the consistency of aggregate findings and micro observations.

The one such study that presented a challenge for macroeconomists is the article by MaCurdy (1981). He uses life cycle data to estimate the labor supply elasticity abstracting from human capital investment. The reason for this abstraction almost surely was limited computer power when he did his study. MaCurdy's estimate is an order of magnitude less than the number macroeconomists need to rationalize aggregate behavior. What led MaCurdy to this estimate is that the hump in hours is far smaller in percentage terms than the hump in wages over the lifetime.

Recently, Imai and Keane (2004) resolved the conflict. They examined the life cycle pattern of male labor supply. They used more powerful algorithms and computers than were available when MaCurdy did his study. These tools permitted them to incorporate on-the-job human capital investment in their explicit dynamic optimization model. Their model uses both the Ben-Porath (1967) optimal on-the-job human capital investment and the Weiss (1972) optimal life cycle labor supply.

Thus Imai and Keane (2004) took into consideration the value of human capital people acquire when working. With this adjustment, the

[15] See the Kehoe and Prescott (2002) volume for a number of economic depression studies.

life cycle wage schedule is much flatter than life cycle labor supply. This adjustment dramatically increases the estimate of the labor supply elasticity from 0.3 to 3.7. As pointed out previously, a labor supply elasticity of 3.7 corresponds to an intertemporal leisure elasticity of substitution of 1.2 if the fraction of productive time allocated to the market is 0.25, as it is for the United States. Also of interest in the Imai and Keane study is that the real interest rate that rationalizes individual choice is close to the average real return on capital obtained using the neoclassical growth model and the national accounts. The conformity of micro and macro findings with regard to people's willingness to intertemporally substitute both leisure and consumption is comforting.

D. *Evidence from Behavior of Organizations*

Another problem with the cross-sectional labor economists' estimates is the maintained hypothesis that people are not in organizational settings that have a fixed workweek length. Fitzgerald (1998) introduces team production with both supervisors and workers. Equilibrium is characterized by a fixed workweek length. An equilibrium outcome is that hours worked is not a choice variable of individuals. What is determined in equilibrium is how many hours a week a production unit operates. The individuals working for an organization cannot vary hours worked. In this world when people are promoted from worker to supervisor, their wages increase, but their hours worked do not change. Under the incorrect maintained hypothesis that they can vary their hours, these observations would result in a zero estimate of labor supply elasticity, even if it is in fact large.

To summarize, aggregate observations imply that the intertemporal substitutability of leisure is near one. Aggregation theory implies that whenever the principal margin of adjustment is the fraction employed and not hours per person employed, the aggregate intertemporal elasticity of substitution is large. This finding is consistent with all the micro observations, so no conflict arises between micro and macro observations.

VII. Significance of Business Cycle Research

We learned that a major part of business cycle fluctuations is the optimal response to real shocks. The cost of a bad shock cannot be avoided, and policies that attempt to do so will be counterproductive, particularly if they reduce production efficiency. During the current oil crises, I was pleased that policies were not instituted that adversely affected the economy by reducing production efficiency. This is in sharp contrast to the oil crises in 1974 and 1980 when, rather than letting the economy respond optimally to a bad shock so as to minimize its cost, policies were instituted that adversely affected production efficiency and depressed the economy much more than it would otherwise have been.

To summarize, concern has shifted away from business cycle fluctuations toward more important things. One important thing is setting up a good tax system. Finn's and my work sheds light on the most important economic parameter in the design of a tax system, the aggregate labor supply elasticity. In finding that technology shocks are important for fluctuations, our research program has been important in shifting the profession's attention to how economic institutions affect total factor productivity.

VIII. Beyond Business Cycle Research

The methodology that Finn and I developed and used to study business cycles is equally applicable to studying other phenomena. In this section I will briefly review two successful applications of this methodology and one very interesting open puzzle. While presenting evidence that the labor supply elasticity is three, I already effectively reviewed one highly successful application—namely, my study (Prescott 2004) assessing the role of taxes in accounting for the huge differences in labor supply across the advanced industrial countries and the huge fall in labor supply in Europe between the early 1970s and the mid-1990s.

A. *The U.S. and U.K. Stock Markets*

An interesting question is, why did the value of the stock market relative to GDP vary by a factor of 2.5 in the United States and 3.0 in the United Kingdom in the last half of the twentieth century? Other variables display little secular variation relative to GDP, whether they are corporate after-tax profits or corporate physical capital relative to GDP.

Clearly the single-sector neoclassical growth model does not suffice for studying the market value of corporate equity. The model must have both a corporate and noncorporate sector. Fortunately, the national accounts report the components of value added for the corporate sector as well as for government business, household business, and unincorporated business sectors. Various adjustments must be made to the accounts to bring them into conformity with the model, such as using producer prices for both inputs and outputs to the business sector.

An equilibrium relation is that the market value of corporations is equal to the value of their productive assets. The national capital accounts provide measures of the value of tangible capital. But corporations also own large amounts of intangible capital, including organization capital, brand names, and patents, which also affect the market value of corporations. These assets cannot be ignored when determining what theory says the value of the stock market should be. This presents a problem for determining the fundamental value of the stock market—a problem that McGrattan and I solve (see McGrattan and Prescott 2005*b*).

We find that the secular behavior of the value of the U.S. stock market is as theory predicts. What turn out to be important for the movement in the value of corporations relative to GDP are changes in tax and regulatory policies. If the tax rate on distributions by corporations is 50 percent rather than 0 percent, the value of corporations will be only half as large, if their stock of productive assets is held fixed.

Our study uses a neoclassical growth model and connects the model to national income and product data, tax data, and sector balance sheet data. We submitted the paper to a British journal. The editor rightfully insisted that we do the analysis for the U.K. stock market as well as for the U.S. stock market. We were nervous as to what theory and measurement would say and were happy when we found that the behavior of the value of the U.K. stock market was also in conformity with theory. Here is an example of the power of the macroeconomic methodology that Finn and I developed.

The excessive volatility of stock prices remains. Indeed, our study strengthens this puzzle. Stocks of productive capital vary little from year to year, whereas stock prices sometimes vary a lot. I am sure this volatility puzzle will be resolved in the not too distant future by some imaginative neoclassical economist. However, resolving the secular movement puzzle is progress.

This example illustrates how macroeconomics has changed as a result of the methodology that Finn and I pioneered. It is now that branch of economics in which applied dynamic equilibrium tools are used to study aggregate phenomena. The study of each of these aggregate phenomena is unified under one theory. This unification attests to the maturity of economic science when it comes to studying dynamic aggregate phenomena.

B. The Great U.S. Depression

The welfare gains from eliminating business cycles are small or negative. The welfare gains from eliminating depression and creating growth miracles are large. Cole and Ohanian (1999) broke a taboo and used the neoclassical growth model to study the Great U.S. Depression. One of their particularly interesting findings is that labor supply on a per adult basis in the 1935–39 period was 25 percent below what it was before the Depression. Recently, Cole and Ohanian (2004) showed how New Deal cartelization could very well have been the reason for the low labor supply using the methodology described in this address. The rapid recovery of the U.S. economy subsequent to the abandonment of these cartelization policies supports their theory.

C. A Business Cycle Puzzle

An economic boom in the United States began with an expansion relative to trend in early 1996 and continued to the fourth quarter of 1999. Then, a contraction set in and continued until the third quarter of 2001. At the peak, detrended GDP per working-age person was 4 percent above trend and labor supply 6 percent above average. None of the obvious candidates for the high labor supply were operating. There was no war with temporarily high public consumption that was debt-financed, tax rates were not low, TFP measured in the standard way was not high relative to trend, and there was no monetary surprise that would give rise to high labor supply. This is why I say this boom is a puzzle for the neoclassical growth model.

Why did people supply so much labor in this boom period? The work of McGrattan and Prescott (2005*b*), which determines the quantitative predictions of theory for the value of the stock markets, suggests an answer. The problem is one of *measurement*. During this period (see McGrattan and Prescott 2005*a*), there is evidence that unmeasured investment was high, as was unmeasured income. Therefore, output and productivity were higher than the standard statistics indicate. The measurement problem is to come up with estimates of this unmeasured intangible investment. With these improved measurements of economic activity, theory can be used to determine whether or not the puzzle has been solved.

This example illustrates the unified nature of aggregate economics today. The real business cycle model was extended and used to understand the behavior of the stock market, and that extended model in turn is now being used to resolve a business cycle puzzle.

IX. Ragnar Frisch's Vision Realized

I conclude this address with an ode to Frisch, who was awarded the first Nobel Prize in Economics in 1969. Frisch's Nobel address is entitled "From Utopian Theory to Practical Applications: The Case of Econometrics" (1970). He is the father of quantitative neoclassical economics, which is what he is referring to by the word *econometrics* in the title.[16]

Prior to Frisch's creating the Econometric Society in 1930 and launch-

[16] Frisch (1970, 12) reports that the English mathematician and economist Jevons (1835–82) dreamed that we would be able to quantify neoclassical economics.

ing *Econometrica* in 1933, neoclassical economists did little to verify their theoretical results by statistical observations. Frisch writes in his Nobel address that the reason was in part that statistics then available were of poor quality and in part that neoclassical theory was not developed with systematic verification in view. The American Institutionalists and German Historical schools pointed this out and advocated letting the facts speak for themselves. The impact of these schools on economic thought was minimal. To quote Frisch, "Facts that speak for themselves, talk in a very naive language" (1970, 16). Now theory derives its concepts from measurement, and in turn theory dictates new measurement. The latter is what McGrattan and I are currently doing to resolve the puzzle of why U.S. employment was so high at the end of the 1990s.[17]

In the 1960s Frisch was frustrated by the lack of progress in his quest to make neoclassical economics quantitative and referred to much of what was being done then as "playometrics." It is a little unfair to criticize those studying business cycles at that time for not using the full discipline of neoclassical economics. All the needed tools were not yet part of the economist's tool kit. Some of these tools that are crucial to the study of business cycles are Lindahl's extension of general equilibrium theory to dynamic environments; Savage's statistical decision theory as uncertainty is central to business cycles; Arrow and Debreu's extension of general equilibrium theory to environments with uncertainty; Blackwell's development of recursive methods that are needed in computation; Lucas and Prescott's development of recursive competitive equilibrium theory;[18] and, of course, the computer.

Particularly noteworthy is Lucas's role in the macroeconomic revolution. In the very late 1960s and early 1970s he revolutionized macroeconomics by taking the position that neoclassical economics should be used to study business cycles. Others had dreamed of doing it, but Lucas actually figured out ways to do it. In his paper "Expectations and the Neutrality of Money" (1972), he creates and analyzes a dynamic stochastic neoclassical model economy that displays the Phillips curve, which is a key equation in the system-of-equations macro models. I can think of no paper in economics as important as this one. The key prediction based on this theoretical analysis—namely, that there is no exploitable trade-off between inflation and employment—was confirmed in the 1970s when attempts were made to exploit the then-perceived trade-off.

[17] I am pleased to report that very recently, McGrattan and I have just resolved this puzzle.

[18] This was further developed in Prescott and Mehra (1980). The published version of "Investment under Uncertainty" did not include the section formally defining the recursive equilibrium with policy and value functions depending on both an individual firm's capacity and the industry capacity and was an industry equilibrium analysis.

But Lucas's work is not *quantitative* dynamic general equilibrium, and only nine years later did Finn and I figure out how to quantitatively derive the implications of theory and measurement for business cycle fluctuations using the full discipline of dynamic stochastic general equilibrium theory and national accounts statistics. That we have learned that business cycles of the quantitative nature observed are what theory predicts is testimony to the grand research program of Ragnar Frisch and to the vision and creative genius of Robert Lucas.

On nearly every dimension I am in agreement with what Frisch advocated in his Nobel Prize address, but on one dimension I am not. Like Frisch, I am a fervent believer in the democratic process. The dimension on which I disagree is how economists and policy makers should interact. His view is that the democratic political process should determine the objective, and economists should then determine the best policy given this objective. My view is that economists should educate the people so that they can evaluate macroeconomic policy rules and that the people, through their elective representatives, should pick the policy rule. I emphasize that Finn's and my "Rules Rather than Discretion" paper finds that public debate should be over rules and that rules should be changed only infrequently, and with a lag to mitigate the time consistency problem.

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