Finn Kydland and Edward Prescott’s Contribution to Dynamic Macroeconomics: The Time Consistency of Economic Policy and the Driving Forces Behind Business Cycles
1 Introduction

Finn Kydland and Edward Prescott have been awarded the 2004 Bank of Sweden Prize in Economic Sciences in Memory of Alfred Nobel for their fundamental contributions to two closely related areas of macroeconomic research. The first concerns the design of macroeconomic policy. Kydland and Prescott uncovered inherent imperfections—credibility problems—in the ability of governments to implement desirable economic policies. The second area concerns business cycle fluctuations. Kydland and Prescott demonstrated how variations in technological development—the main source of long-run economic growth—can lead to short-run fluctuations. In so doing, they offered a new and operational paradigm for macroeconomic analysis based on microeconomic foundations. Kydland and Prescott’s work has transformed academic research in economics, as well as the practice of macroeconomic analysis and policymaking.

1.1 General background

During the early postwar period, macroeconomic analysis was dominated by the view marshalled by Keynes (1936). In this view, short-run fluctuations in output and employment are mainly due to variations in aggregate demand, i.e., in investors’ willingness to invest and consumers’ willingness to consume. Moreover, macroeconomic stabilization policy can, and should, systematically control aggregate demand so as to avoid recurring fluctuations in output. These ideas largely reflected the experience from the Great Depression, when a deep protracted trough in aggregate output, along with falling employment and capital utilization, were observed throughout the western world. Keynesian macroeconomic analysis interpreted these phenomena as failures of the market system to coordinate demand and supply, which provided an obvious motive for government intervention.

Until the mid-1970s, the dominating Keynesian paradigm seemed quite successful in explaining macroeconomic fluctuations. But real-world developments in the late 1970s revealed serious shortcomings of the earlier analysis. It could not explain the new phenomenon of simultaneous inflation and unemployment. This so-called stagflation seemed closely related to shocks on the supply side of the economy: oil price hikes and the worldwide slowdown of productivity growth. Such supply shocks had played only a subordinate role in the Keynesian framework. Moreover, conventional macroeconomic policy, based on existing theory, was unable to cope with the new problems. Rather, monetary and fiscal policy appeared to make matters worse in many countries by accommodating private-sector expectations of high price and wage increases. This occurred despite the stated objective of governments and central banks to maintain low and stable inflation.

Keynesian models were also criticized on methodological grounds. Models used in applied work built on broad theoretical and empirical generalizations (“reduced forms”) summarizing the relationships governing the main macroeconomic variables, such as output, inflation, unemployment, and consumption. Robert Lucas’s research in the early and mid-1970s (Lucas 1972, 1973, 1976) pointed to the drawbacks of this approach, in particular that the relationships between macroeconomic variables are likely to be influenced by economic policy itself. As a result, policy analysis based on these relationships might turn out to be
erroneous. Lucas concluded that the effects of macroeconomic policy could not be properly analyzed without explicit microeconomic foundations. Only by carefully modeling the behavior of individual economic agents, such as consumers and firms, would it be possible to derive robust conclusions regarding private-sector responses to economic policy. The building blocks of such an analysis—e.g., consumers’ preferences, firms’ technologies, and market structures—are likely to be robust to changes in economic policy.

As the Lucas critique rapidly gained wide acceptance, development of an alternative and operational macroeconomic framework was called for. This was a daunting task, however. Such a new framework had to be based on solid microeconomic foundations. It also had to give an integral role to economic policy and economic agents’ perceptions of how policy is determined. The award-winning contributions by Kydland and Prescott appeared in two joint articles, which took decisive steps forward in these respects.

1.2 The contributions in brief

“Rules Rather than Discretion: The Inconsistency of Optimal Plans”, from 1977, studies the sequential choice of policies, such as tax rates or monetary policy instruments. The key insight is that many policy decisions are subject to a fundamental time consistency problem. Consider a rational and forward-looking government that chooses a time plan for policy in order to maximize the well-being of its citizens. Kydland and Prescott show that if given an opportunity to re-optimize and change its plan at a later date, the government will generally do so. What is striking about this result is that it is not rooted in conflicting objectives between the government and its citizens, nor is it due to the ability of unrestricted policymakers to react to unforeseen shocks. The result, instead, is simply a problematic logical implication of rational dynamic policymaking when private-sector expectations place restrictions on the policy decisions.

A significant upshot is that governments unable to make binding commitments regarding future policies will encounter a credibility problem. Specifically, the public will realize that future government policy will not necessarily coincide with the announced policy, unless the plan already encompasses the incentives for future policy change. In other words, sequential policymaking faces a credibility constraint. In mathematical terms, optimal policy decisions cannot be analyzed solely by means of control theory (i.e., dynamic optimization theory). Instead they should be studied as the outcome of a game, where current and future policymakers are modeled as distinct players. In this game, each player has to anticipate the reaction of future players to current play: rational expectations are required. Kydland and Prescott analyzed general policy games as well as specific games of monetary and fiscal policymaking. They showed that the outcome in a rational-expectations equilibrium where the government cannot commit to policy in advance—discretionary policymaking—results in lower welfare than the outcome in an equilibrium where the government can commit.

Kydland and Prescott’s 1977 article had a far-reaching impact not only on theoretical policy analysis. It also provided a new perspective on actual policy experience, such as the stagflation problem. The analysis showed that a sustained high rate of inflation may not be the consequence of irrational policy decisions; it might simply reflect an inability of policymakers to commit to monetary policy. This insight shifted the focus of policy analysis
from the study of individual policy decisions to the design of institutions that mitigate the
time consistency problem. Indeed, the reforms of central banks undertaken in many countries
as of the early 1990s have their roots in the research initiated by Kydland and Prescott.
Arguably, these reforms are an important factor underlying the recent period of low and
stable inflation. More broadly, the insight that time inconsistency is a general problem for
economic policymaking has shifted the focus not only towards normative research on the
optimal design of institutions such as central banks, but also towards positive research on
the interaction between economic decision-making and political institutions. It has inspired a
large cross-disciplinary literature at the intersection between economics and political science.

“Time to Build and Aggregate Fluctuations”, from 1982, proposed a theory of business
cycle fluctuations far from the Keynesian tradition. In this article, Kydland and Prescott
integrated the analyses of long-run economic growth and short-run macroeconomic fluctuations,
by maintaining that a crucial determinant of long-run living standards, i.e., growth
in technology, can also generate short-run cycles. Moreover, rather than emphasizing the
inability of markets to coordinate supply and demand, Kydland and Prescott’s business cy-
cle model relied on standard microeconomic mechanisms whereby prices, wages, and interest
rates enable markets to clear. They thus argued that periods of temporarily low output
growth need not be a result of market failures, but could simply follow from temporarily
slow improvements in production technologies.

Kydland and Prescott showed that many qualitative features of actual business cycles,
such as the co-movements of central macroeconomic variables and their relative variabili-
ties, can be generated by a model based on supply (technology) shocks. Using fluctuations
in technology growth of the same magnitude as those measured from data, Kydland and
Prescott also demonstrated that their simple model could generate quantitatively significant
cycles. It thus appeared that technology shocks should be taken seriously as a cause of
business cycles.

From a methodological point of view, Kydland and Prescott’s article answered Lucas’s
call for an alternative to the Keynesian paradigm. It was the first study to characterize the
general equilibrium of a full-fledged dynamic and stochastic macroeconomic model based on
microeconomic foundations. This required solving a set of interrelated dynamic optimization
problems, where consumers and firms make decisions based on current and expected future
paths for prices and policy variables, and where the equilibrium price sequences are such
that private-sector decisions are consistent with clearing markets at all points in time and
all states of the world. Kydland and Prescott showed that this challenging analysis could
be carried out in practice by extensive use of numerical methods. Their empirical approach
relied on model simulation, based on so-called “calibration”, and on comparing the synthetic
data from simulations with actual data. Such calibration can be regarded as a simple form of
estimation, where model parameters are assigned values so as to match the model’s long-run
macroeconomic features with those in the data and render the behavior of individual agents
in the model consistent with empirical microeconomic studies.

Kydland and Prescott’s work on business cycles initiated an extensive research program.
Successively more sophisticated dynamic models of business cycles have been formulated,
solved numerically, and compared to data using both calibration methods and econometric
estimation. Kydland and Prescott’s emphasis on supply shocks led researchers to reconsider the origins of business cycles and assess the relative importance of different shocks. Their results were established for well-functioning markets, while subsequent research considered various market imperfections and examined their implications. As a result of these efforts, current state-of-the-art business-cycle models give prominence to both supply and demand shocks. These models rely on explicit microeconomic foundations to a much larger extent than did earlier Keynesian models. For example, so-called “new-Keynesian” models, which have become a standard tool for analyzing monetary policy, have a core similar to Kydland and Prescott’s original model, but incorporate frictions in the form of “sticky” prices and wages.

Kydland and Prescott’s two articles have central themes in common. Both articles view the macroeconomy as a dynamic system, where agents—private agents and policymakers—make rational, forward-looking, and interrelated decisions. Both articles provide insights into postwar developments in the world economy, in terms of private-sector or government behavior. Both articles offer a new perspective on good macroeconomic policy, leading to a reconsideration of policymaking institutions and a different approach to stabilization policy. Separately, each of the articles spawned a large independent literature. In the following, we describe the contributions in more detail.

2 Time consistency of economic policy

In the late 1960s and early 1970s, macroeconomic research paid particular attention to the expectations held by private agents. A first step was to emphasize expectations as important determinants of economic outcomes. Friedman (1968) and Phelps (1967, 1968) based their natural-rate theories of unemployment on the expectations-augmented Phillips curve, where the relationship between actual inflation and unemployment depends on expected inflation. A second step was to study expectations formation in more depth. Lucas (1972, 1973) based his analysis on the rational-expectations hypothesis, according to which economic agents make the best possible forecasts of future economic events given available information, including knowledge of how the economy functions, and where the best possible forecast presumes that other agents act according to the same principle, now and in the future.

Kydland and Prescott’s analysis of economic policy design added a new dimension to expectations formation. Their model endogenized government decision-making by assuming that governments choose policy in order to maximize the welfare of their citizens. Kydland and Prescott followed Lucas in assuming that the private sector’s expectations about future government policy are rational; they also followed Friedman and Phelps in assuming that those expectations are important determinants of economic outcomes. Under these assumptions, Kydland and Prescott showed—by way of a general argument as well as specific examples—that government policymaking is subject to a time consistency problem.

Kydland and Prescott’s 1977 paper contained several related contributions, both methodological and substantive. First, they pointed to the general origin of the time consistency problem: without a commitment mechanism for future policy, the government faces an additional constraint in policymaking because its policy has to be credible. In other words,
price to the remaining consumers. The so-called Coase conjecture (1972) holds that pricing will occur at marginal cost because consumers are forward-looking, whereby the monopolist actually competes in price with his future selves. Formal game-theoretic analyses of this problem have later been provided by Stokey (1981), Bulow (1982), and Gul, Sonnenschein, and Wilson (1986).

3 The driving forces behind business cycles

The last two decades have witnessed radical changes in the theory and practice of business cycle research, and—more generally—in the predominant views on business cycle phenomena. Keynesian analysis from the early postwar period relied on a set of relationships among aggregate variables (“reduced forms”) that were intended to “sum up” the interactions between various structural relationships. Although each such relationship was motivated by microeconomic theory of consumer and firm behavior, it was usually not explicitly derived from such theory. More importantly, different macroeconomic relationships were not based on a common microeconomic structure when used together in applied macroeconomic analysis.

Estimated versions of such business cycle models were widely used in practical forecasting and policy-oriented evaluations of monetary and fiscal policy interventions. By the mid-1970s, the Lucas critique (Lucas, 1976) had pointed to serious problems with this approach. Estimated reduced-form relationships could not be expected to be robust to changes in policy regimes or in the macroeconomic environment. Macroeconomic developments emphasized this critique when seemingly stable macroeconomic relationships, based on historical data, appeared to break down in the 1970s. In particular, the new stagflation—high unemployment combined with high inflation—played havoc with the Phillips curve, which had earlier seemed to trace out a stable negative relationship between the rates of inflation and unemployment. The experiences of the 1970s also called into question the predominant idea that business cycles are driven mainly by changes in demand. Instead, the contemporary macroeconomic fluctuations seemed to be caused largely by supply shocks, such as the drastic oil price hikes in 1973-74 and 1979 and the worldwide slowdown in productivity growth as of the mid-1970s.

Lucas proposed formulating a new macroeconomic theory on firmer ground, i.e., on an explicit microeconomic structure instead of postulated aggregate relationships. This structure would include assumptions about consumers and their preferences, firms and their technologies, the information of these agents, in what specific markets they interact, and so on. On the basis of these deep parameters, general-equilibrium implications for aggregate variables would be derived and confronted with data. Consumers’ preferences and firms’ technologies were not likely to be affected by changes in fiscal or monetary policy regimes or in the macroeconomic environment, even though the behavior of consumers and firms would be affected. Hence, quantitative analysis based on microeconomic underpinnings is likely to be more robust to such regime changes and thus more useful in policy analysis than models based on historical aggregate relationships.

Unfortunately, Lucas’s guidelines were not accompanied by an operational prescription for implementing them. The development of an alternative macroeconomic modelling approach, which would satisfy even the minimal requirement of deriving joint predictions for the
main macroeconomic variables from sound microeconomic foundations, seemed a daunting task. Such a theory would have to be dynamic to properly model investment, consumption, and other intertemporal decisions on the basis of optimal, forward-looking behavior of firms and households. Simple dynamic models with rational expectations certainly existed and a research program on how to econometrically estimate such models was underway, following the pathbreaking work by Sargent (1977, 1978, 1979). These models involved drastic simplifications, however, and essentially required representing the economy—or parts of it—by a few linear relationships. Around 1980, traditional (likelihood-based) econometric estimation of dynamic, non-linear models on a rich enough form to be operationally used in quantitative macroeconomic analysis seemed out of reach.

Kydland and Prescott’s 1982 paper transformed macroeconomic analysis in several dimensions. Indeed, it provided a blueprint for rendering Lucas’s proposal operational. In their modeling, Kydland and Prescott relied on a stochastic version of the neoclassical growth model, which has since become the core of much macroeconomic modeling. They showed that technology shocks, i.e., short-run variations around the positive growth trend for technology that makes economies grow in the long run, could be an important cause of output fluctuations. In today’s macroeconomic models, supply shocks typically play an important role alongside demand shocks. In their model solution, Kydland and Prescott relied on numerical solution and computer simulation to an extent not previously implemented in economics. Nowadays, numerical analysis of economic models is an indispensable element in the tool kit of graduate students in economics. In their empirical implementation, Kydland and Prescott relied on so-called calibration, a simple but informative form of estimation when confronting new models with data. Since then, new macroeconomic theory is frequently compared with data using these methods. In all these ways, Kydland and Prescott’s work changed not only the basic methodology of business cycle analysis, but also our perspective on the importance of various types of shocks and their propagation mechanisms.

### 3.1 The general idea

We begin by outlining the general features of Kydland and Prescott’s business cycle theory. Next, we review their methodology, and outline a specific simple example of model formulation, along with a brief look at empirical implementation.

Kydland and Prescott set out to integrate business cycle theory and growth theory. Since they viewed technology shocks as potentially important sources of short-run output fluctuations, it seemed natural to turn to the neoclassical growth model—the workhorse of growth theory ever since the research of Robert Solow (1956). Another reason for using the neoclassical growth model was related to the problem of distinguishing the “short run” (cycles) from the “long run” (growth); as the long run, by necessity, is a sequence of short runs. Moreover, most variables of interest in growth theory and business cycle theory coincide.

Kydland and Prescott’s starting point was the fact that the U.S. economy, and many other Western economies as well, had grown at an average annual rate of around 2 percent for approximately 100 years, increasing output by a factor of seven. Their hypothesis was that technology growth might be an important determinant, not only of long-term living standards, but also of short-term fluctuations, to the extent that technology growth displays
variations over time. One way of measuring technology growth relies on growth accounting, another tool developed by Solow (1957). Based on certain assumptions about the working of the economy (constant returns to scale, perfect competition, and market clearing), consistent with the model economy studied by Kydland and Prescott, this procedure accounts for the part of output growth due to the growth of inputs (labor and capital, notably). The residual component—the “Solow residual”—is then interpreted as technology growth. Kydland and Prescott (1982) assumed a standard deviation for technology shocks of the same magnitude as for the Solow residuals. Measurement based on Solow residuals implies relatively large variations in technology growth over time, a substantial part of which appear at business cycle frequencies. More refined methods have subsequently been used (see Section 3.4 below).

Conceptually, Kydland and Prescott studied a closed-economy dynamic, stochastic general equilibrium model with perfect competition and no market frictions. How do technology shocks translate into output movements in this model? A positive technology shock in period $t$ represents a higher-than-average growth rate of total factor productivity, i.e., a large increase in the economy’s ability to produce output from given supplies of capital and labor. Higher productivity raises wages, so labor supply in period $t$ increases as workers find work more profitable than leisure. Thus, two effects serve to raise period $t$ output: the direct effect of higher productivity and the indirect effect of higher labor input. The return to capital increases as well, but the capital stock in period $t$ is predetermined. Thus, if the technology shock in period $t$ had been foreseen, the implied increase in the period-$t$ return to capital could also have led to higher investment in previous periods, thus raising output in period $t$ through a third, indirect channel.

The boost in period-$t$ output has dynamic consequences. Part of the increase in output is consumed, while the remainder is saved and invested. The split depends on consumers’ preferences and the expected longevity of the productivity shock. Theory and microeconomic evidence indicate a desire to smooth consumption over time, and the portion of a temporary increase in output that is saved depends on the preference for smoothing. The less quickly the productivity shock is expected to die out, the more profitable will it be to save and invest. Kydland and Prescott based their technology growth series on the data, which feature significant positive autocorrelation, thus leading to an investment response to a current shock which is higher than if technology growth were uncorrelated over time. This raises the capital stock in period $t+1$, while technology is still above trend due to autocorrelation. Incentives for higher than normal labor supply thus remain, and—if the increase in the capital stock is large and technology shocks are sufficiently autocorrelated—labor supply in period $t+1$ will be more above trend than in period $t$, as will investment.

These dynamic effects constitute the model’s “propagation mechanism”, whereby an “impulse” of a temporary technology shock shapes the path of future macroeconomic variables. The mechanism is stable, i.e., the effects of an impulse eventually die out, because the technology growth process is mean-reverting and because decreasing returns to capital bring investment back to trend.

The theory delivers time series for macroeconomic variables broadly consistent with data. Due to the propagation mechanism, all macroeconomic aggregates display high autocorrelation and high co-movement, and the volatility of investment is higher than that of output, which is higher than that of consumption. The economy goes through booms and busts,