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Modern Macroeconomics in Practice: How Theory Is Shaping Policy*

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ABSTRACT

Theoretical advances in macroeconomics made in the last three decades have had a major influence on macroeconomic policy analysis. Moreover, over the last several decades, the United States and other countries have undertaken a variety of policy changes that are precisely what macroeconomic theory of the last 30 years suggests. The three key developments that have shaped macroeconomic policy analysis are the Lucas critique of policy evaluation due to Robert Lucas, the time inconsistency critique of discretionary policy due to Finn Kydland and Edward Prescott, and the development of quantitative dynamic stochastic general equilibrium models following Finn Kydland and Edward Prescott.

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Over the last three decades, macroeconomic theory and the practice of macroeconomics by economists have changed significantly—for the better. Macroeconomics is now firmly grounded in the principles of economic theory. These advances have not been restricted to the ivory tower. Over the last several decades, the United States and other countries have undertaken a variety of policy changes that are precisely what macroeconomic theory of the last 30 years suggests.

The evidence that these theoretical advances have had a significant effect on the practice of policy is often hard to see for policymakers and advisers who are involved in the hurly-burly of day-to-day policymaking, but easy to see if one steps back and takes a longer-term perspective. Examples of the effects of theory on the practice of policy include increased central bank independence, adoption of inflation targeting and other rules to guide monetary policy, increased reliance on consumption and labor taxes instead of capital income taxes, and increased awareness of the costs of policies that distort labor markets.

Three key developments in academic macroeconomics have shaped macroeconomic policy analysis: the *Lucas critique* of policy evaluation due to Robert Lucas (1976), the *time inconsistency critique* of discretionary policy due to Finn Kydland and Edward Prescott (1977), and the development of quantitative dynamic stochastic general equilibrium models following Finn Kydland and Edward Prescott (1982).[1] Lucas argued that economic theory implies that preferences and technology are invariant to the rule describing policy but that decision rules describing private agents' behavior are not. In a series of graphic examples, he showed that then standard policy analyses which presumed invariance of decision rules lead to dramatically undesirable policy prescriptions. Kydland and Prescott argued that a regime in which policymakers set state-

contingent rules once and for all is better than a discretionary regime in which policymakers sequentially choose policy optimally given their current situation.

The practical effect of the Lucas critique is that both academic and policy-oriented macroeconomists now take policy analyses seriously only if they are based on quantitative general equilibrium models in which the parameters of preferences and technologies are reasonably argued to be invariant to policy. The time inconsistency critique has been a major influence on the practice of central banking and fiscal policymaking over the last 30 years.

The quantitative general equilibrium models that were developed in response to the Lucas critique have become increasingly sophisticated over time, including models with financial market imperfections, sticky prices and other monetary nonneutralities, imperfect competition, incomplete markets, and other frictions. (See Cooley, 1995.) These models have yielded four robust properties of optimal monetary and fiscal policies under commitment:

1. Monetary policy should be conducted so as to keep nominal interest rates and inflation rates low.
2. Tax rates on labor and consumption should be roughly constant over time.
3. Capital income taxes should be roughly zero.
4. Returns on debt and taxes on assets should fluctuate to provide insurance against adverse shocks.

Macroeconomists have also been profitably applying the basic tools of general equilibrium theory, computational techniques, and a deep understanding of key features of the data to a wide area of phenomena outside of narrowly defined macroeconomics. These include income differences across countries, fertility behavior across time and countries, the dynamics of the size distribution of firms, and the efficiency costs of the welfare state. A good illustration of this kind

of work is the study of differences in labor market performance between the United States and Europe. Although work of this kind has not yet directly affected policy, it will once its policy lessons, carefully grounded in theory and data analysis, are clearly communicated to policymakers and the public.

Here we have focused on the role of theory shaping policy. In practice, of course, causality runs in both directions. Theorists often work on problems motivated by specific policy questions and specific experiences. Policymakers' mind-sets and attitudes are influenced, perhaps subconsciously, by apparently remote developments in theory. Nevertheless, the most straightforward reading of developments in macroeconomic policy is that they were strongly influenced by developments in macroeconomic theory.

Modern Theoretical Developments

Expectations and Macroeconomic Policy Analysis

The Lucas critique led economists to understand that people's decision rules change when the way policy is conducted changes. Lucas (1976) forcefully argued that the question "How should policy be set today?" was ill-posed. In most situations, people's current decisions depend on their expectations of what future policies will be. Those expectations depend, in part, on how people expect policymakers to behave. Macroeconomists now agree, therefore, that any sensible policy analysis must include a clear specification of how a current choice of policy will shape expectations of future policies.

To see more concretely why analyzing policy requires specifying how policy will be set in the future, consider two examples. First, consider a monetary authority deciding on monetary policy for today. This authority needs to forecast how variables such as inflation and output will behave now and in the future, which means that it must forecast private behavior in the future.

But the decisions of private actors depend on their expectations about future monetary policy. If private actors expect tight monetary policy in the future, they will react to current price and wage pressures in one way; if they expect to lose monetary policy in the future, they will react differently. Thus, the monetary authority cannot predict how the economy will respond to a policy decision today unless it can also predict how people's expectations of future monetary policy will change as a result of the current decisions. The monetary authority also needs to predict how its own behavior will change in the future as a result of its current actions.

Next, consider a fiscal authority deciding how to tax capital income. This authority needs to forecast how output, investment, and other variables will respond to its decisions. Investment decisions, for example, depend on investors' expectations of future tax rates. If investors expect future tax rates to be low, then they'll invest more today; if high, then less today. Consequently, the fiscal authority cannot predict how investment will respond, for example, to a tax cut today unless it knows how people's expectations of future tax rates will change as a result of the cut. The fiscal authority also needs to predict how its own future behavior will change as a result of its current actions.

With this concern over expectations in mind, macroeconomists now agree that a coherent framework for the design of economic policy consists of three parts: a model to predict how people will behave under alternative policies, a welfare criterion to rank the outcomes of alternative policies, and a description of how policies will be set in the future.

A commitment regime is the easiest environment to describe how future policies are set. In such a regime, all policies for today, tomorrow, the day after, and so on are set today and cannot be changed. These policies could be contingent on various events that might occur in the future. The model can then be used to predict the consequences of various plans for policy and can

be used to find the optimal plan. This procedure has its origins in the public finance tradition stemming from Ramsey (1927), so this sequence of optimal policies is referred to as *Ramsey policies* and their associated outcomes as *Ramsey outcomes*.

Time Inconsistency Problem

The Lucas (1976) critique addressed situations in which expectations of future policies affect current decisions. The Lucas critique thus leads naturally to thinking about policy evaluation as comparing alternative sets of rules that describe policy both now and in the future. In practice, of course, societies may not be able to commit to future policies. In a series of graphic examples, Kydland and Prescott (1977) (soon followed by Calvo, 1978; Fischer, 1980) analyzed policies with and without commitment and showed that Ramsey policies are often *time inconsistent*; that is, outcomes with commitment are different from those without commitment. Their examples suggest that time inconsistency problems arise when people's current decisions depend on expectations of future policies. Since people's decisions have been made by the time the future date arrives, the government often has an incentive to renege on the Ramsey policies.

To better understand this problem, consider again examples from monetary and fiscal policy. The monetary policy example is motivated by the work of Kydland and Prescott (1977) and Barro and Gordon (1983). Assume that at the beginning of each period, wage setters choose nominal wages so as to attain a target level of real wages. The monetary authority then chooses the inflation rate. If inflation is higher than wage setters expected, then real wages are lower than the target level, firms demand more labor, and output is higher than its natural rate (which is its level when real wages are at their target level). The monetary authority wants to maximize society's welfare, which is increasing in output and decreasing in inflation. As output increases, the natural assumption is that the marginal benefits of increases in output fall because of diminishing

marginal utility. We assume in addition that as inflation increases, the marginal costs of increases in inflation rise. This assumption holds in many general equilibrium models.

To see that there is a time inconsistency problem in this setup, consider the best outcomes under commitment, the Ramsey outcomes. We think of commitment as a situation in which at the beginning of time society prescribes a rule for the conduct of monetary policy in all periods. The monetary authority then simply implements the rule. The best rule under commitment prescribes zero inflation in all periods. Under this rule, real wages are equal to their target level. To see why zero inflation is optimal, consider a rule that prescribes positive inflation. Wage setters anticipate positive inflation and set their nominal wages to be appropriately higher. Under this policy, real wages are still at their target level, output is unaffected, but inflation is positive. Clearly this outcome is worse than one under a policy that prescribes zero inflation.

Consider next outcomes with no commitment. We think of no commitment as a situation in which in each period the monetary authority chooses policy optimally given the nominal wages that wage setters have already chosen. In the resulting outcome, called the *static discretionary outcome*, inflation is necessarily positive while output is at its natural rate. To see why inflation is necessarily positive, suppose, by way of contradiction, that inflation rates are zero so that wage setters set their wages anticipating zero inflation. Once the nominal wages are set, however, the monetary authority will deviate and generate inflation in order to raise output. Hence, inflation must be positive. To see why output is at its natural rate, note that wage setters rationally anticipate the actions of the monetary authority so that real wages are at their target level. In the static discretionary outcome, inflation is at a high enough level so that the marginal cost of deviating to an even higher inflation rate is equal to the marginal benefit of increased output.

In the case of fiscal policy, a good example of the time inconsistency problem is based on Kydland and Prescott (1977). Consider a model in which the government needs to raise revenue from proportional taxes on capital and labor income to finance a given amount of government spending. Under commitment, society chooses a rule for setting tax rates in all periods, and the fiscal authority implements the rule. At any instant, the stock of capital is given by past investment decisions; however, the supply of labor can be changed relatively quickly. The key influence on investment decisions that determine the capital stock in the future is the after-tax return expected in the future, whereas the key influence on labor supply decisions is the current after-tax wage rate. So the government's best policy for current tax rates is to tax capital at high rates and labor at low rates. This policy does not distort capital supply decisions, since the capital stock is fixed and irreversible in that capital goods cannot be directly converted into consumption goods. The policy also ensures that labor supply is not distorted much, since the tax rates on labor are low. For future tax rates, the best policy is to commit to set low rates on capital to stimulate investment and to raise the rest of the needed revenue with higher rates on labor.

Consider next the outcomes with no commitment. In each period, the fiscal authority still has an incentive to tax capital income heavily, since the capital stock is fixed, and to tax labor income lightly to avoid distorting labor supply. Without commitment, however, investors today rationally expect that high taxes on capital income will continue into the future—since such taxes are preferred in each time period—and investment will be low. In equilibrium, the capital stock is smaller than it would be under commitment, and both output and welfare are correspondingly lower than they would be under commitment.

The message of examples like these is that discretionary policymaking has only costs and no benefits, so that if government policymakers can be made to commit to a policy rule, society

should make them do so. Our examples have no shocks. In stochastic environments the optimal policy rule is contingent on the shocks that affect the economy. A standard argument against commitment and for discretion is that specifying all the possible contingencies in a rule made under commitment is extremely difficult, and discretion helps policymakers respond to unspecified and unforeseen emergencies. This argument is less convincing than it may seem. Every proponent of rule-based policy recognizes the necessity of escape clauses in the event of unforeseen emergencies or extremely unlikely events. These escape clauses will, of course, reintroduce a time inconsistency problem, but in a more limited form. Almost by definition, deviations from such rules will occur rarely; hence, the time inconsistency problem arising from the escape clauses will be small. Commitment to a rule with escape clauses is not unworkable.

What can be done to ameliorate the time inconsistency problem short of commitment? A superficially attractive approach is to pass legislation requiring the monetary or the fiscal authority to abide by rules. This approach is more problematic than it may seem. In most macroeconomic environments with time inconsistency problems, given an initially established rule, all members of society (or a large majority) would like to deviate from it. Legislatures will have a strong incentive to allow the monetary or fiscal authority to deviate from the established rule. To be effective, therefore, attempts to ameliorate the time inconsistency problem must impose costs on policymakers of deviating from the earlier agreed-upon rules.

The most widely studied ways to impose such costs rely on either reputation or trigger strategy mechanisms. Such mechanisms can lead to better outcomes under discretion than the static discretionary outcomes. Indeed, if policymakers discount the future sufficiently little, these mechanisms can lead policymakers to choose the Ramsey outcomes.

Our illustration of such mechanisms draws on Chari, Kehoe, and Prescott's (1989) analysis of the Kydland and Prescott (1977) and Barro and Gordon (1983) monetary policy example. Consider the following trigger strategy mechanism in an infinite horizon version of this example. In this mechanism, as long as the monetary authority has chosen the Ramsey policies in the past, wage setters expect it to continue to do so; however, if the monetary authority has ever deviated from the Ramsey policies, wage setters expect it to choose the static discretionary policies forever in the future. With these beliefs of private agents, the monetary authority understands that if it unexpectedly inflates, it gets a current gain from the associated rise in output but a loss in all future periods equal to the difference in welfare between the static discretionary outcome and the Ramsey outcome. In this situation, if the monetary authority discounts the future sufficiently little, then it will not deviate. Although the use of trigger strategy mechanisms is appealing, one difficulty is that many outcomes can result from trigger strategies, and how society will coordinate on a good outcome is not obvious.

Another device for ameliorating the time inconsistency problem is to delegate policy to an independent authority (Rogoff, 1985). One notion of what it means for an authority to be *independent* is that society faces large costs to dismiss the authority and replace it with another. We illustrate this device in the Kydland and Prescott (1977) monetary policy example, modified to include potential policymakers who differ in terms of their aversion to inflation. Suppose the appointed policymaker is extremely averse to inflation. After wage setters have chosen their nominal wages, this policymaker finds engineering a surprise inflation very costly. Wage setters anticipate this behavior, and the outcome is low inflation and output at its natural rate.

Note that if dismissing the authority is not costly, the delegation device is not effective. The authority will be dismissed after wage setters have set their nominal wages, and an authority

more representative of society will be appointed. Wage setters will anticipate this behavior, and the outcomes will simply be the static discretionary outcomes. Making it costly to dismiss the authority essentially makes it costly for society to deviate from some set of rules and, hence, introduces a specific form of commitment.

Yet another device for ameliorating the time inconsistency problem is to set up institutions that ensure that policies cannot be implemented until several periods after they are chosen. To see the advantage of such implementation lags, recall the fiscal policy example. There, without commitment, the optimal policy is to set the tax rate of capital income high, since the capital stock is determined entirely by past investment decisions, and to set the tax rate on labor income low, since labor supply decisions are determined primarily by current tax rates. Suppose that the fiscal authority still chooses tax rates on capital and labor income, but that now these tax rates can only be implemented several periods after they are chosen. Under such institutions, choosing a high tax rate on capital income will tend to reduce investment, at least until the implementation date, and will lead to a corresponding reduction in the capital stock. In this environment, the delay in implementation means that policymakers are forced to confront at least part of the distortions arising from high capital taxation.

Optimal Rules and Monetary Policy

Macroeconomists can now tell policymakers that to achieve optimal results, they should design institutions that minimize the time inconsistency problem by promoting a commitment to policy rules. However, to what particular policies should policymakers commit themselves? For many macroeconomists considering this question, quantitative general equilibrium models have become the workhorse model, and they turn out to offer surprisingly sharp answers. Macroeconomists now generally agree on four properties that optimal policies should have and on when

qualifications of those properties are appropriate. One of the four properties applies to monetary policy; the other three, primarily to fiscal policy.

Optimal Rules for Monetary Policy

In the area of monetary policy, the optimal rule is to set policy so that nominal interest rates and inflation will be low. This result is due to the celebrated work of Milton Friedman (1969), which it has been defended and supplemented by more recent work based on standard public finance principles.

Friedman's argument stems from an analysis of the forces determining money-holding decisions. Money has benefits to individuals and therefore to society by reducing the costs of making transactions. From each individual's perspective, the opportunity cost of money is the forgone nominal interest that could be obtained by investing it instead. From society's perspective, the opportunity cost of producing money is close to zero. Thus, society should conduct monetary policy so that the nominal interest rate equals the opportunity cost of producing money and is therefore close to zero. This recommendation for monetary policy is known as the *Friedman rule*. (This rule should not be confused with a *k*-percent rule for monetary aggregates also advocated by Friedman.) This recommendation holds in both deterministic and stochastic environments.

An alternative way to implement the Friedman rule is to pay interest on money. Although it may be technologically difficult to pay interest on currency, it is possible to pay interest on checking accounts and other means of making transactions. This reasoning suggests that eliminating policies that limit interest payments on demand deposits, such as Regulation Q, move us closer to the Friedman rule.

Phelps (1973) made what looked at first like a compelling argument that a nominal interest rate close to zero is unlikely to be optimal in practice. He noted that if government revenue must be raised through distorting taxes, the optimal policy is actually to tax all goods, including the liquidity services derived from holding money, so that the optimal interest rate is substantially greater than zero. Chari, Christiano, and Kehoe (1996) showed, however, that for a class of economies consistent with the growth facts on the absence of long-term trends in the ratio of output to real balances, a nominal interest rate close to zero is in fact optimal, even if government revenue must be raised through distorting taxes. For such economies, money acts like an intermediate good, and for well-known public finance reasons, taxing intermediate goods is not optimal.

An intuitive way to think about the Friedman rule's prescription that the nominal interest rate be zero is that it prescribes that the risk-adjusted real rate of return on money should be the same as the (risk-adjusted) real rate of return on other assets. In a deterministic environment no risk adjustments are needed, so that the Friedman rule implies deflation at the real interest rate. Some economists have interpreted the Friedman rule as always requiring deflation at the real interest rate. Chari, Christiano, and Kehoe (1996), however, showed that this interpretation is mistaken by showing that in a plausible parameterized stochastic environment, even though the optimal nominal interest rate is still zero, there is no deflation. Indeed, under the optimal policy the inflation rate is roughly zero because money turns out to be a hedge against real fluctuations, paying out relatively more in bad times and relatively less in good times. Indeed, money turns out to be enough of a hedge so that even at zero inflation, its risk-adjusted real rate of return equals that on other assets.

We turn now to some qualifications. In some well-known macroeconomic models, positive nominal interest rates are optimal. Typically, in these models, if the government had a rich enough set of fiscal instruments, then a zero nominal interest rate would be optimal, but positive nominal interest rates can make sense if the set of instruments available to the government is restricted.

Positive nominal interest rates are optimal in sticky price models with nominal prices or wages set in a staggered fashion and in which the government is restricted to uncontingent nominal debt and uncontingent consumption taxes. Absent such stickiness, even when the government is so restricted, zero nominal interest rates are optimal and volatile inflation is used to make nominal debt mimic real state contingent debt (Chari, Christiano, and Kehoe, 1991). If nominal prices or wages are set in a staggered fashion, then such inflation volatility is costly because fluctuations in inflation induce undesirable fluctuations in relative prices. In this setting, optimal monetary policy trades off two desirable goals. One is to maintain price stability to avoid the misallocations induced by fluctuations in relative prices. The other goal is to minimize the social waste of using inefficient methods of conducting transactions. Not surprisingly in this setting, optimal monetary policy involves a compromise between positive interest rates to reduce inflation and promote price stability and a nominal interest rate of zero (Benigno and Woodford, 2003; Khan, King and Wolman, 2003; Siu, 2004; Schmitt-Grohé and Uribe, 2004). The undesirable fluctuations in relative prices can be avoided if either state-contingent debt or state-contingent consumption taxes are available (Correia, Nicolini, and Teles, 2004).

Another set of environments in which positive nominal interest rates are optimal has a restricted set of assets available to share risk among individuals. In this setting, lump-sum transfers financed by printing money redistribute income from the temporarily rich to the temporarily

poor. The reason is that inflation imposes a larger tax on those who hold more money and, in this setting, households who hold more money are the temporarily rich. Such transfers provide a form of risk sharing and therefore help raise welfare. Optimal monetary policy trades off the benefits of risk sharing against the social waste of using inefficient methods of conducting transactions, and that involves a positive nominal interest rate (Levine, 1991). Here, also, a rich enough set of fiscal policy instruments can provide a partial remedy, risk sharing, and allow the monetary authority to follow the Friedman rule (da Costa and Werning, 2003).

Thus, modern macroeconomic theory argues that positive nominal interest rates are optimal only if the set of instruments available to the government is restricted. Since this situation is highly likely in practice, optimal monetary policy involves a compromise between the goals of zero nominal interest rates and other goals. The robust finding is not that nominal interest rates should be literally zero but that nominal interest rates and inflation rates should be low.

The practical definition of low interest rates and inflation rates is a subject of continuing discussion, particularly because of biases in measuring inflation rates due to quality changes. Although no consensus has emerged on the definition of low inflation, most macroeconomists agree that a sustained inflation in excess of 3 percent per year is unacceptably high.

The Evolution of Monetary Policy

Over the last three decades, a variety of specific monetary policy proposals consistent with macroeconomic theory's developments have been debated and implemented around the world. Central bankers and other monetary policymakers have begun to concentrate on price stability and inflation control as their main objectives. Many countries have changed their institutional frameworks for monetary policymaking in an apparent recognition of the time inconsistency problem. These changes have emphasized the importance of characteristics key to mini-

mizing that problem—credibility, transparency, and accountability—as well as clear statements, or rules, about the objectives of monetary policy and the methods by which that policy will respond to varying circumstances. All these changes point to a shift in the world toward the rule-based method of policymaking which is prescribed by modern macroeconomic theory.

Two kinds of institutional changes are especially evident in the practice of monetary policy. Central banks have become substantially more independent of the political authorities, and to an increasing extent, the charters of central banks have emphasized the primacy of inflation targeting and price stability.

An extensive empirical literature has argued that central bank independence helps reduce inflation rates without any adverse consequences on output. Figure 1, which reproduces Figure 1A from Alesina and Summers (1993), shows that countries with more independent central banks tend to have lower inflation rates. Alesina and Summers (1993) also show that countries with more independent central banks do not suffer in terms of output performance. One interpretation of these findings is that institutions that promote central bank independence ameliorate the time inconsistency problem. Under this interpretation, the findings in the literature support the key feature of the Kydland and Prescott (1977) example: reducing the time inconsistency problem ameliorates inflation but has no effect on output.

Bernanke et al. (1999) have argued that inflation targeting is moving toward a rule-based regime. Their idea (p. 24) is that “inflation targeting requires an accounting to the public of the projected long run implications of its short run policy actions.” This accounting can help ameliorate the time inconsistency problem by ensuring that the long-run implications of short-run policy actions are explicitly taken into account in the policymaking process.

In practice, inflation targeting often involves setting bands of acceptable inflation rates. (See, for example, Bernanke and Mishkin 1997.) In theoretical models without private information, optimal policy does not involve setting bands, but rather involves specifying exactly what the monetary authority should do in every state. In this sense, such models imply that the monetary authority should have no discretion. Athey, Atkeson, and Kehoe (2005) construct a model in which the monetary authority has private information about the economy and show that the optimal policy allows for limited discretion in that it specifies acceptable ranges for inflation and gives the monetary authority complete discretion within those ranges. In this way, Athey, Atkeson, and Kehoe provide a theoretical rationale for the type of inflation targeting often seen in practice.

Perhaps the most vivid example of both the movement toward independence and the movement toward a rule-based method of policymaking is to be found in the charter of the European Central Bank (ECB). Article 105 of the treaty establishing the central bank states that "the primary objective" of the European System of Central Banks (ESCB) shall be to "maintain price stability." Article 107 of the treaty emphasizes and protects the independence of the central bank by mandating that "neither the ECB, nor a national central bank, nor any member of their decision-making bodies shall seek or take instructions from Community institutions or bodies, from any government of a Member State or from any other body." Furthermore, the Maastricht Treaty and the Stability and Growth Pact contain provisions restricting fiscal policies in the member countries in order to make the pursuit of price stability easier.[2] The change in the conduct of European monetary policy is especially marked for countries other than Germany in the European monetary union.

Over the last 20 years, monetary policy in the United Kingdom has also moved in the direction of greater independence as well as toward rule-based policymaking. After experiencing a major exchange rate crisis, the United Kingdom adopted a form of inflation targeting in October 1992. In May 1997 (and subsequently formalized by the Bank of England Act of 1998), the Bank of England gained operational independence from the government. The Bank of England is now specifically required primarily to pursue price stability and only secondarily to make sure that its policies are consistent with the growth and employment objectives of the government. The government periodically sets an inflation target, currently 2 percent, and the central bank is given broad freedom in achieving this target. As part of the inflation target, the government also sets ranges for acceptable fluctuations in inflation. If inflation moves outside its target range, the central bank is required to report on the causes for this deviation, the corrective policy action the central bank plans to take, and the time period within which inflation is expected to return to its target range.

The movement toward rule-based monetary policy is widespread. By 2002, 22 countries had adopted monetary frameworks that emphasize inflation targeting (Truman, 2003). The following countries are listed by the date in which inflation targeting was adopted (and in some cases readopted): in 1989, New Zealand; in 1990, Chile; in 1991, Canada and Israel; in 1992, the United Kingdom; in 1993, Australia, Finland, and Sweden; in 1995, Spain and Mexico; in 1997, Czech Republic and Israel (again); in 1998, Poland and Korea; in 1999, Brazil, Chile (again), and Colombia; in 2000, Thailand and South Africa; in 2001, Hungary, Iceland, and Norway; in 2002, Peru and the Philippines. These countries have all openly published their inflation targets and have described their monetary framework as one of targeting inflation. Clearly, inflation tar-

geting is worldwide; the countries range from developed economies to emerging market economies. The number of countries adopting targeting inflation is growing over time.

The first country to adopt inflation targeting, New Zealand, has gone the furthest in setting up a rule-based regime. Before 1989, monetary policy in New Zealand was far from being rule-based. As Nicholl and Archer (1992, p. 316) describe:

> New Zealand experienced double digit inflation for most of the period since the first oil shock. Cumulative inflation (on a Consumer Price Index (CPI) basis) between 1974 and 1988 (inclusive) was 480 percent. . . . Throughout the period, monetary policy faced multiple and varying objectives which were seldom clearly specified, and only rarely consistent with achievement of inflation reduction.

In 1989, the government of New Zealand adopted legislation mandating that the objective of the central bank be to maintain a stable general level of prices. The government and the governor of the central bank must agree to a policy target, which specifies an acceptable range for inflation. Since the act was adopted, the inflation rate has fallen considerably and has been well below 5 percent per year over the last decade or so.

Figure 2 displays the inflation experiences for four countries—the United Kingdom, New Zealand, Canada, and Sweden—that have adopted inflation targeting. The four panels of Figure 2 show the inflation rates before and after the date of the inflation targeting regime, marked by a vertical line. The bands in the figure following the adoption of the inflation targeting regime depict ranges of inflation as specified in the regime. Although the countries did not always remain within the target range for inflation after adopting inflation targeting, inflation fell substantially in all the countries after the adoption of inflation targeting. The literature contains ongoing con-

troversy about whether this decline was solely due to inflation targeting, but also offers substantial consensus that inflation targeting played an important role in the decline.

Even in countries that have not explicitly adopted inflation targeting, the institutional framework for the conduct of monetary policy has changed in a way consistent with modern macroeconomic theory. In the United States, for example, the central bank has been moving toward openness and targeting for the last 25 years. The Full Employment and Balanced Growth Act of 1978 (commonly referred to as the Humphrey-Hawkins Full Employment Act) required the Federal Reserve Board of Governors to report periodically to Congress on the planned course of monetary policy. Furthermore, the Federal Reserve Board has changed some policies in ways that increase transparency. For example, the minutes of Federal Open Market Committee (FOMC) meetings are now released substantially sooner than they used to be, and the FOMC's decisions regarding its interest rate target are now released immediately after the meeting. A large academic literature motivated by Taylor (1993) has argued that the Fed has effectively moved toward a rule-based regime and is therefore well placed to solve the time inconsistency problem.

Although the changes in the practice of monetary policy documented above cannot be definitively linked to the recent theoretical developments in macroeconomics, the most straightforward explanation for these changes is that they are due to the identification of the time inconsistency problem by macroeconomic theorists.

Optimal Rules and Fiscal Policy

The macroeconomics and public finance literature on proportional tax systems is based on an analysis that taxes distort two key types of decisions: the static trade-off between consumption and leisure and the intertemporal trade-off between current and future consumption.

Taxes on both labor income and consumption distort the static trade-off. When people contemplate working for an extra hour in the market, they balance the disutility of the extra work against the utility from the extra consumption they will have as a result. An extra hour of work at pre-tax wage *w* yields extra after-tax income of $(1-\tau_l)w$ and allows additional after-tax consumption of $(1-\tau_l)w/(1+\tau_c)$, where τ_l is the tax rate on labor income and τ_c is the tax rate on consumption. This balancing act implies that the distortion of taxes on the labor supply is summarized by the *tax-induced labor wedge* τ, defined so that $1-\tau=(1-\tau_l)/(1+\tau_c)$. Notice that consumption taxes distort the static trade-off in much the same way as do taxes on labor income.

A tax on capital income reduces the return to savings and clearly distorts the intertemporal trade-off. A constant capital income tax can easily be shown to be equivalent to an increasing sequence of consumption taxes. A pattern of consumption taxes that rise over time raises the price of future consumption relative to current consumption and therefore also distorts the intertemporal trade-off. Interestingly, constant consumption taxes do not change the relative price of consumption over time and thus do not distort the intertemporal trade-off.

Principles and Properties of Optimal Tax Systems

The problem of designing optimal fiscal policy is to raise the needed amount of revenue while distorting the static and the intertemporal trade-offs as little as possible. Studies of optimal fiscal policy have argued that optimal policies should be based on two principles. First, similar goods should be taxed at similar rates. More specifically, the consumption of commodities that enter preferences and production technologies in similar ways should be distorted in similar ways. Second, if preferences are homothetic in commodities and separable from labor, then all commodities should be taxed at a uniform rate.

These principles can be applied to dynamic stochastic economies, such as those commonly modeled in the macroeconomics literature, by reinterpreting each commodity as the consumption good at a different date and state. The first principle—similar goods, similar taxes—implies that the optimal policy is to distort the static trade-off in the same way at all dates and states. To apply the second principle, note that in most quantitative general equilibrium models, preferences are assumed to be homothetic in consumption at different dates and separable from labor. Since uniform commodity taxation is optimal with these assumptions, it follows that the intertemporal trade-off should not be distorted.

In dynamic stochastic environments, one tax system that is consistent with these principles and with the requirement that the present value of the government budget be balanced at each state has three properties. First, tax rates on labor and consumption should be roughly constant over time. Second, capital income taxes should be roughly zero. Third, returns on debt and taxes on assets should fluctuate so as to balance the government's budget in a present value sense at each state.

To see how the first two properties follow from the principles, note that when labor and consumption tax rates are constant, the static trade-off is distorted in the same way in all dates and states. When capital income taxes are zero, the intertemporal trade-off is not distorted.

The third property follows from the requirement that the government budget stay balanced in a present value sense and is a useful feature of dynamic stochastic models: the intertemporal trade-off does not depend on the pattern of returns on debt and taxes across states but only on an appropriately weighted average of taxes across states. To maintain the government budget balance while keeping tax rates on labor and consumption constant in a stochastic environment and not distorting the intertemporal trade-off, some other source of revenue must fluctuate. Ap-

propriately designed state-contingent returns on debt or state-contingent taxes on assets are such a source of revenue. To see how state-contingent returns on debt can be such a source of revenue, consider a policy that issues debt with low returns when revenue needs are high and issues debt with high returns when revenue needs are low. This policy can ensure that the government budget is balanced in a present value sense at each state even though taxes on consumption, labor income, and capital income are roughly the same both across time and states. Note that under this policy, the government is insuring itself against fluctuations in revenues and expenditures.

One concern raised with this analysis is that state-contingent government debt is rarely observed in practice. But this concern is exaggerated because there are several ways to implicitly make returns on government debt state-contingent. One is to issue nominal debt and let inflation rates be high when revenue needs are high and low when revenue needs are low. Under this policy, nominal debt that does not appear to be contingent becomes state-contingent in real terms (Lucas and Stokey, 1983; Lucas, 1986). A second implicit way to make returns on government debt state-contingent is to issue uncontingent debt at many different maturities and then use the fluctuations in the term structure of interest rates to induce the needed fluctuations in the present value of government debt (Angeletos, 2002). A third way is to combine uncontingent debt with fluctuating consumption taxes in order to induce the needed fluctuations in the value of government debt measured in units of consumption. This approach, however, requires offsetting fluctuations in labor income taxes to ensure that the distortions in the static trade-off remain roughly constant (Correia, Nicolini, and Teles, 2003). A fourth way is to have capital income be taxed when revenue needs are high and subsidized when revenue needs are low (Chari, Christiano, and Kehoe, 1994). Note that it is essential that the tax system subsidize capital income when revenue

needs are low in order to ensure that the taxation when revenue needs are high does not introduce an intertemporal distortion.

When none of these ways of making government debt state-contingent are available, keeping the static trade-off roughly constant is impossible. Then, as Barro (1979) and Aiyagari et al. (2002) have pointed out, labor income taxes will have a random walk flavor. Others have argued, however, that this characteristic does not survive in the long run (Werning, 2005).

The Practice of Fiscal Policy

The practice of fiscal policy has not yet changed as dramatically as monetary policy in response to macroeconomic theory's changes. Modern macroeconomists apparently still have much work to do to communicate the policy implications of their theoretical research. One key insight in particular deserves special emphasis: for optimal economic results, fiscal policies must minimize intertemporal distortions. The evidence continues to grow that such distortions can have large effects on aggregate outcomes.

Intertemporal distortions can arise not only from explicit taxes on capital income but also from other sources. For example, the prospect of an expropriation of capital acts like a tax on capital income in terms of the incentives to invest. So does political corruption that distorts the production of investment goods.

One illustration of the role of the intertemporal distortions in accounting for the enormous variability in incomes across countries is due to Chari, Kehoe, and McGrattan (1997). They found that intertemporal distortions can account for most of the observed differences in per capita income across countries. Their argument has two parts: per capita income variation across countries is due to variations in capital-output ratios across countries, and variations in capital-output ratios are due to variations in intertemporal distortions. Building on the work of Mankiw,

Romer, and Weil (1992), the first part of the argument uses an aggregate production function that has physical capital, organization capital, and labor as inputs, with the share of income going to each factor of production equal to one-third. If technology is the same across countries and physical capital and organization capital are subject to the same distortions, then the log of output per worker relative to the mean of the log of output per worker in the world can be shown to be equal to twice the log of the capital-output ratio relative to the mean of the log of the world capital-output ratio.[3] Figure 3, taken from Chari, Kehoe, and McGrattan (1997), plots the relationship between the relative log of output per worker against twice the relative capital-output ratios. Clearly, variations in capital-output ratios play an important role in accounting for variations in output per worker across countries.

In the second part of their argument, Chari, Kehoe, and McGrattan (1997) noted that the relative price of investment to consumption goods affects intertemporal decisions. They assumed that variations in this relative price across countries occur because of distortions emanating from a variety of government policies. Under this assumption, this relative price can be used to measure the intertemporal distortions directly. They found that variations in these distortions across countries can account for most of the variations in capital-output ratios across countries and that, within a country, fluctuations in the distortions can produce the type of development miracles and disasters seen in the data. In this sense, countries that have adopted policies that minimize intertemporal distortions have been successful and those that have not done so have been unsuccessful.

As the importance of the role of the intertemporal distortions becomes more widely recognized, minimizing such distortions may be adopted as a standard fiscal policy focus in coun-

tries of all sizes. If so, theory predicts that poor countries will have a better chance of becoming rich.

There is some evidence that developed countries are beginning to recognize the importance of intertemporal distortions in affecting economic performance. For example, capital income tax rates in the United States have fallen over the last two decades. Table 1, from Gravelle (2004), displays effective marginal tax rates on U.S. capital income and shows that these tax rates have fallen from 47 percent in the 1950s to 28 percent in the 2000s. More recently, in the United States capital gains tax rates and dividend tax rates have been reduced, and tax-preferred savings accounts have been expanded considerably.

One reason capital income has historically been taxed heavily may be the time inconsistency problem of fiscal policy. The fact that capital income taxes have been falling could be interpreted as indirect evidence that societies and policymakers have begun to understand the time inconsistency problem and have begun to make changes to address it.

Quantitative general equilibrium models have begun to make inroads in the analysis of tax policy. Although such models have not yet proved to be helpful in analyzing the role of fiscal policy over the business cycle, they are now an often-used workhorse in the analysis of fiscal policy over the longer term. For example, in response to a request from the President's Advisory Panel on Tax Reform to analyze the consequences of tax reform proposals, "the Treasury Department used variants of three standard economic growth models to estimate the dynamic response associated with the Panel's reform options . . . a neoclassical growth model, an overlapping generations (OLG) life-cycle model, and a Ramsey growth model" (Report of the President's Advisory Panel, 2005, p. 224).

Extending the Bounds of Macroeconomics

Macroeconomic theorists have long focused on frictions in the labor market as a source and propagation mechanism for business cycles. Over the last few years, a significant focus of macroeconomic research has been the effects of government policies on the secular trends of labor markets. The distinguishing feature of this research is that it is based on quantitative general equilibrium models along the lines inspired by Kydland and Prescott (1982). Although the work in this area has not yet progressed to definitive policy prescriptions, it is beginning to offer powerful insights into what may have caused some problems in labor markets and what sorts of policy changes might be part of the solutions.

An issue that has captured much scientific and popular attention has been the recent stubbornly high rates of unemployment in Europe. Figure 4 shows the behavior of average unemployment rates in Europe and the United States from 1956 to 2003. Until the late 1970s, unemployment was roughly two percentage points lower in Europe than in the United States. Since about 1980, European unemployment increased significantly while U.S. unemployment decreased. By 2003, unemployment averaged more than 9 percent in Europe, compared with only about 5 percent in the United States.

Another way to examine labor markets is to focus on employment rates, measured as the annual average hours worked per adult of working age. Figure 5 displays the behavior of this measure of employment rates in Europe and the United States from 1956 to 2003. According to this figure, employment steadily declined over the entire period in Europe, whereas in the United States, it was roughly stable until the 1980s and then sharply increased.

What explains these contrasting patterns? The macroeconomics literature has advanced three explanations for these patterns: labor market rigidities, taxes, and unemployment benefits.

Labor Market Rigidities

One widely held view is that labor markets are much more rigid in Europe than in the United States. For example, European legal employment protections that make it difficult to fire workers are typically more stringent than those in the United States. Hopenhayn and Rogerson's (1993) general equilibrium model points to two opposing forces of firing costs on unemployment: the costs make firms more reluctant to fire workers, thereby reducing unemployment; but at the same time they make firms more reluctant to hire workers in the first place, thereby raising unemployment. The overall effect is ambiguous and depends on the details of the microeconomic shocks affecting individual firms' employment decisions. Using cross-country evidence, Nickell (1997) finds that the effect of hiring costs is also ambiguous.

Although the effect of firing costs on unemployment is ambiguous, the effect on productivity in the Hopenhayn and Rogerson (1993) model is not. Firing costs tend to inhibit the efficient reallocation of labor to more productive firms and thereby reduce aggregate productivity. Thus, this model implies that welfare can be raised by reducing firing costs. Note that if workers cannot borrow against future earnings to invest in general human capital, then firing costs may provide incentives for firms to invest in such capital and thus raise productivity, as in the models of Acemoglu and Pischke (1999) and Chari, Restuccia, and Urrutia (2005).

Taxes

Prescott (2002) and Rogerson (2005) have pointed to differences in taxes as a key source of the differences in European and U.S. labor market experiences. To study this possibility, the discipline of general equilibrium theory is essential, because the effect of taxes on labor market outcomes depends not only on how tax revenue is raised but also, as Rogerson (2005) emphasizes, on how it is used. A tax has both a substitution effect that reduces the incentive to work

and an income effect that increases the incentive to work, but the way in which tax revenue is spent can alter the income effects.

To see why the details of how tax revenues are spent are important, suppose first that the revenue is used to provide public goods that are poor substitutes for private consumption. Then, as long as the utility function has near unit elasticity of substitution between consumption and leisure, the income and substitution effects nearly cancel so that labor supply effects of taxes are approximately zero. Hence, to a first approximation, the public good expenditures crowd out private consumption dollar for dollar. Suppose next that the revenue is either transferred back to private citizens in a lump-sum fashion or, equivalently, used to purchase private goods for citizens. Then taxes have only a substitution effect—because the expenditures offset the income effect—and labor supply falls.

Prescott (2002) cleverly sidestepped these issues by noting that in a general equilibrium model, the details of the expenditures are captured by their effects on consumption. Prescott began his analysis by noting that in a general equilibrium model with a stand-in household, the first-order condition determining labor supply equates the marginal rate of substitution between consumption and leisure to the after-tax marginal product of labor. Given consumption and the capital stock, this condition thus implies a relation between employment and the tax-induced labor wedge. In this approach, the details of how government revenues are spent play a role in determining labor supply only through its effects on consumption and the capital stock.

Assuming that both the utility function and the production function have unit elasticity of substitution, and using long-term averages to pin down share parameters, Prescott showed that this simple theory works surprisingly well in accounting for employment observations for the G-7 countries for the 1970s and the 1990s. With these functional form assumptions, the marginal

rate of substitution is proportional to $c/(1-l)$, where c denotes consumption and l the fraction of time in market work, whereas the after-tax marginal product of labor is proportional to $(1-\tau)y/l$, so that the consumption-to-output ratio, c/y, summarizes the effects of the details of expenditures as well as other aspects of the model, such as capital income taxes. Table 2 is reproduced from Prescott (2002). The closeness between the predictions of his simple model and the data is remarkable.

The Prescott analysis works well in a comparison of the early 1970s and the mid-1990s, in part because tax policies clearly changed dramatically during this time. Using his analysis to compare the 1950s and the 1970s, however, does not work as well. Evidence of large changes in tax rates from the 1950s to the 1970s is hard to find, even though Figure 5 shows a sustained decline in employment rates over this period. As Prescott has acknowledged, his analysis likewise does not work well for the Scandinavian countries that have both high tax rates and high employment.

Rogerson (2005) has built on Prescott's analysis to allow for secular shifts from agriculture and industry toward services. Rogerson argued that changes in taxes and in industry composition can account for the bulk of observed differences in employment between Europe and the United States.

These analyses focus on the division of time between market work and all forms of nonmarket activities—including both unemployment and being out of the labor force. As such, these analyses have sharp implications for the behavior of the employment rate. Since they do not distinguish between search activities and other nonmarket activities that lead households to be classified as out of the labor force, they are silent about differences in unemployment rates between Europe and the United States.

Unemployment Benefits

One possible reason for why the unemployment rate is higher in Europe than in the United States is that unemployment benefits are more generous in Europe. A reasonable conjecture is that this greater generosity leads to higher unemployment rates by making workers more reluctant to accept job offers. The problem with this conjecture is that it seems contradicted by facts; in the 1960s and 1970s, unemployment benefits were much more generous in Europe than in the United States, while unemployment rates were lower in Europe than in the United States. Ljungqvist and Sargent (1998) developed a model that focuses on the division of time between market work and the search activities of unemployed workers while abstracting from considerations of nonmarket activities other than search. They showed that in the 1960s and 1970s, more generous unemployment benefits, together with higher firing costs, led Europe to have lower unemployment rates than in the United States, whereas in the 1980s, the same benefits and firing costs led to the opposite relationship.

The key difference between the earlier and later periods is that microeconomic turbulence, measured as fluctuations in individual worker productivities, has increased over time in both Europe and the United States (see Gottschalk and Moffitt, 1994). As microeconomic turbulence increases, more workers find themselves in low-productivity jobs as well as in unemployment. If unemployment benefits are generous, as they are in Europe, then unemployed workers' reservation wages fall by only a small amount as turbulence increases, and the flow of workers out of unemployment does not change much. Hence, with increased microeconomic turbulence, the overall unemployment rate rises. If unemployment benefits are meager, as they are in the United States, then workers' reservation wages fall sharply as turbulence increases, and the out-

flow from unemployment rises nearly one-for-one with the inflow. Hence, the unemployment rate does not change much.

The Ljungqvist and Sargent (1998) model assumes that workers are risk-neutral, in which case unemployment compensation has no benefits and is costly because it distorts the search decision. As the model stands, the policy implication is that government-provided unemployment benefits should be eliminated. With risk aversion and imperfections in private markets for unemployment insurance, unemployment insurance has benefits that need to be weighed against the induced distortions in search decisions. A growing literature has begun to analyze these tradeoffs (for example, Atkeson and Lucas, 1992; Hopenhayn and Nicolini, 1997; Shimer and Werning, 2005).

In our view, explanations of patterns in European and American labor markets based on labor market rigidities, taxes, and unemployment benefits all have plausible appeal, but the quantitative importance of each has not been definitively established.

Conclusion

Here we have argued that macroeconomic theory has had a profound and far-reaching effect on the institutions and practices governing monetary policy and is beginning to have a similar effect on fiscal policy. The marginal social product of macroeconomic science is surely large and growing rapidly.

Those economists caught up in the frenzy of day-to-day policymaking often view their colleagues who toil in the ivory towers of academe as having no power to affect practical policy and those economists who whisper in the ears of presidents and Congress members as having the ability to dramatically affect policy. The truth, as we have argued, is very far from this view. The course of practical policy is affected primarily by the institutions we devise and how well presi-

dents and Congress members understand economic trade-offs. The day-to-day economic adviser is useful to the extent that the adviser can educate policymakers about trade-offs, but is largely irrelevant otherwise. It is easy to see why those economists caught up in the whirlwind of day-to-day policymaking miss the dramatic changes in policy that result from slow, secular changes in institutions, practices, and mind-sets.

The toilers in academe are uniquely placed to develop analyses of institutions and to educate the public and policymakers about economic trade-offs. The essence of our argument is that, at least in macroeconomics, these toilers have delivered large returns to society over the last several decades.

Notes

[1]The use of dynamic general equilibrium models in macroeconomics has a long tradition dating back, at least, to Robert Solow (1956).

[2]Note that these practical concerns are consistent with the work of Sargent and Wallace (1985), who emphasized that monetary and fiscal policy are linked by a single government budget constraint, so that responsible monetary policy is impossible without responsible fiscal policy.

[3]With a production function of the form $y = Ak^{\alpha}l^{1-\alpha}$, it is straightforward to show that

$$\log\left(\frac{y}{l}\right) = \frac{1}{1-\alpha}\log A + \frac{\alpha}{1-\alpha}\log\frac{k}{y}.$$

Using the assumption that *A* is the same across countries, removing means, and setting $\alpha = 2/3$ gives the relationship described in the text.

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Table 1

Effective U.S. Marginal Tax Rates on Capital Income, 1953–2003

Time Period	%
1953–59	47.3
1960s	35.8
1970s	41.3
1980s	35.3
1990s	30.5
2000–03	28.3

Source: Gravelle (2004)

Table 2

G-7 Countries' Predicted and Actual Labor Supply Employment*

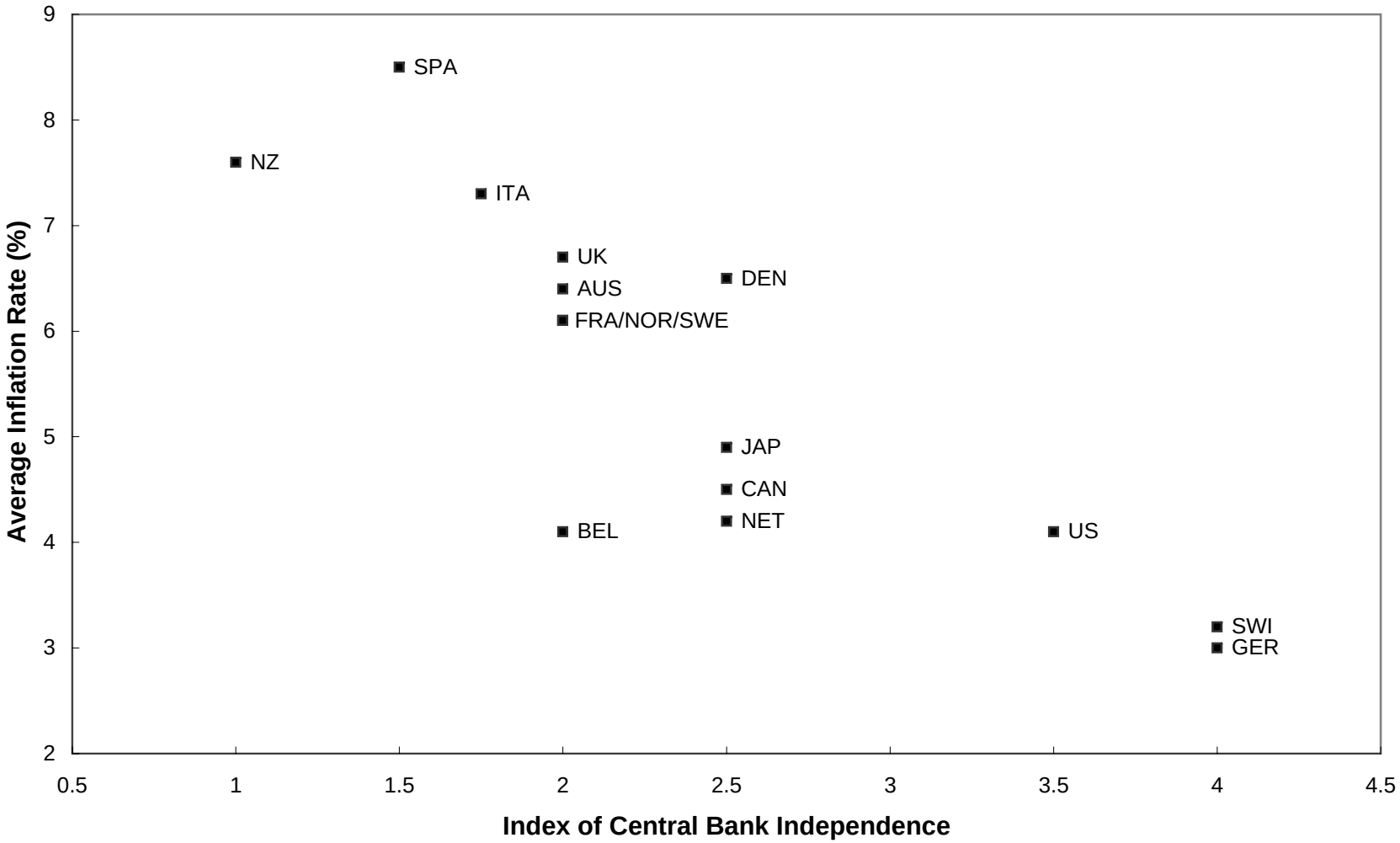
			Labor Supply in 1970–74	
Country	**Tax rate τ**	**Consumption-Output Ratio *c/y***	**Actual**	**Predicted**
Germany	.52	.66	24.6	24.6
France	.49	.66	24.4	25.4
Italy	.41	.66	19.2	28.3
Canada	.44	.72	22.2	25.6
United Kingdom	.45	.77	25.9	24.0
Japan	.25	.60	29.8	35.8
United States	.40	.74	23.5	26.4

Source: Prescott (2002)

*Hours worked per week per person aged 15–64

Figure 1
Central Bank Independence vs. Inflation

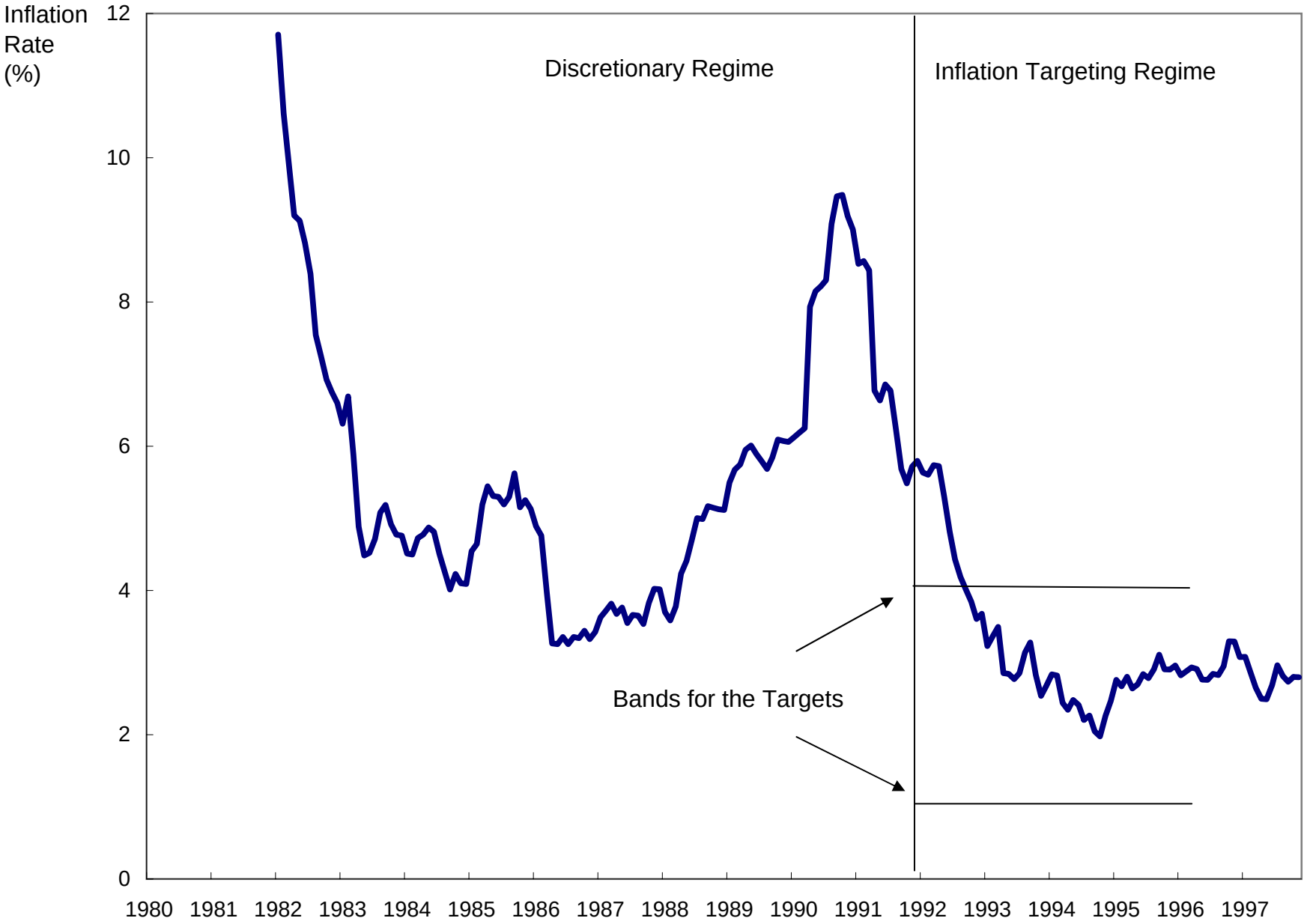
Measures of Central Bank Independence vs. Average Rates of Inflation in 16 Countries, 1973–88



Source: Alesina and Summers (1993)

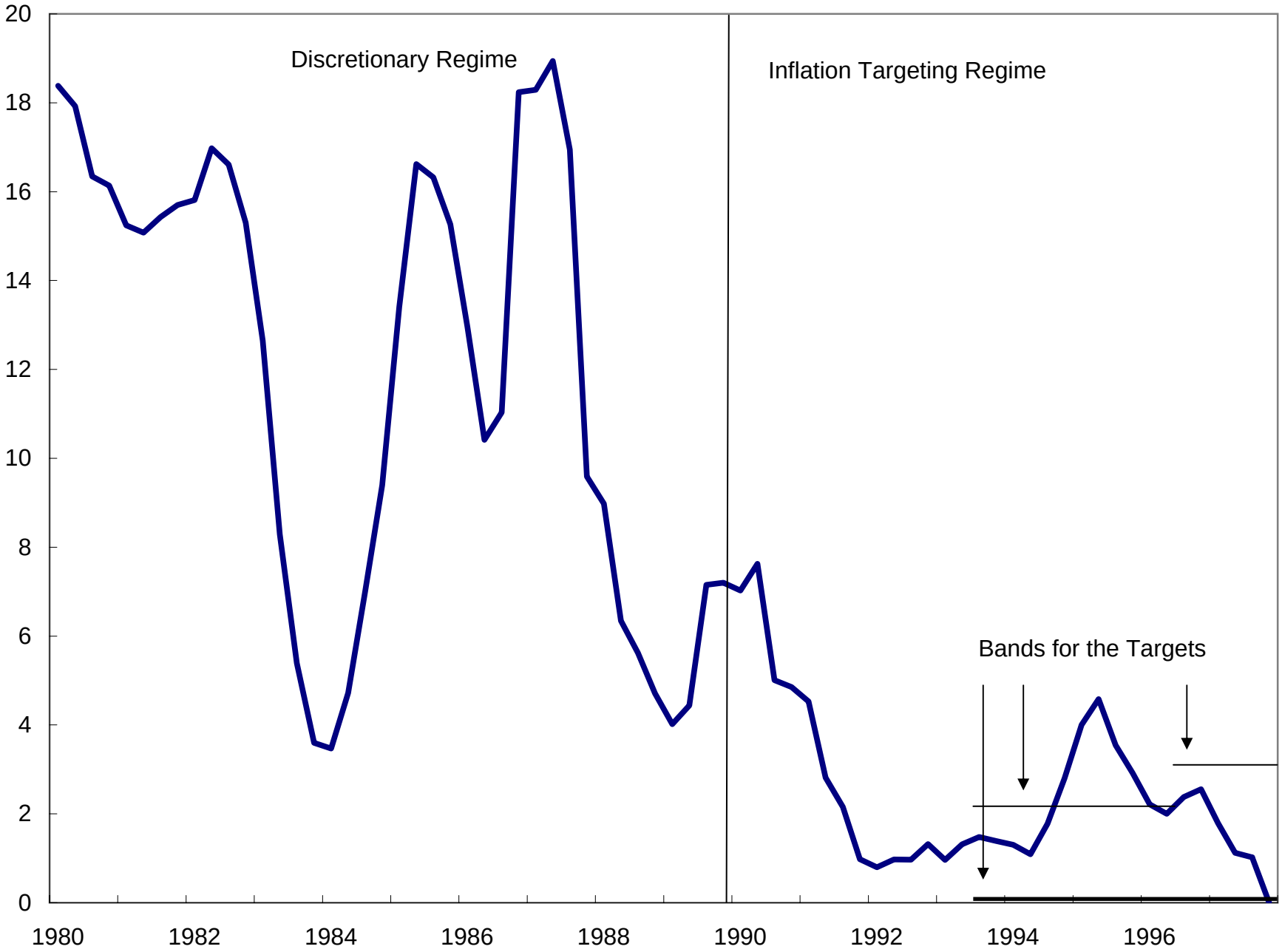
Figures 2
Examples of Inflation in Discretionary and Targeting Regimes, 1980–98

Figure 2a
United Kingdom



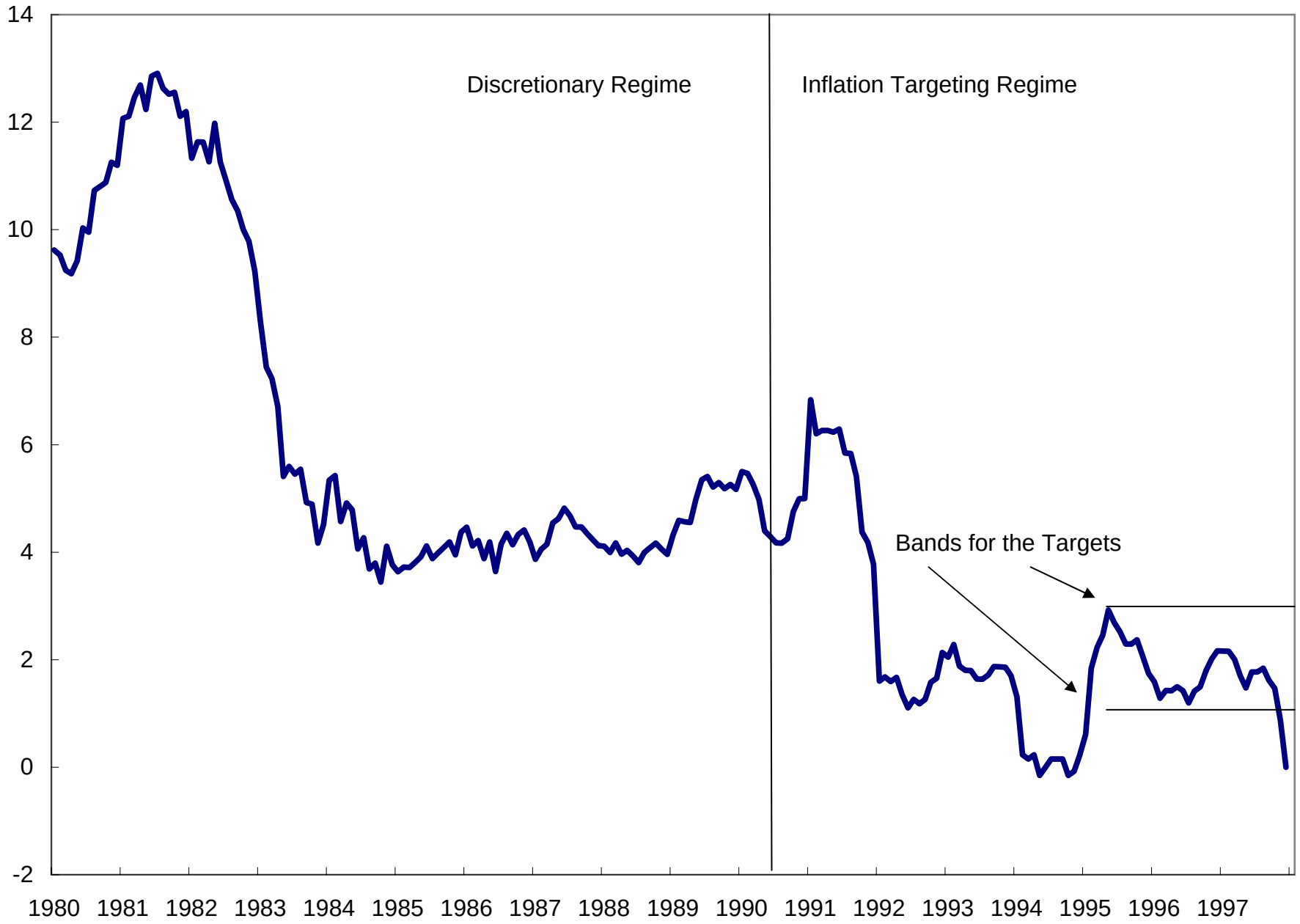
Source: Bernanke et al. (1999)

Figure 2b
New Zealand



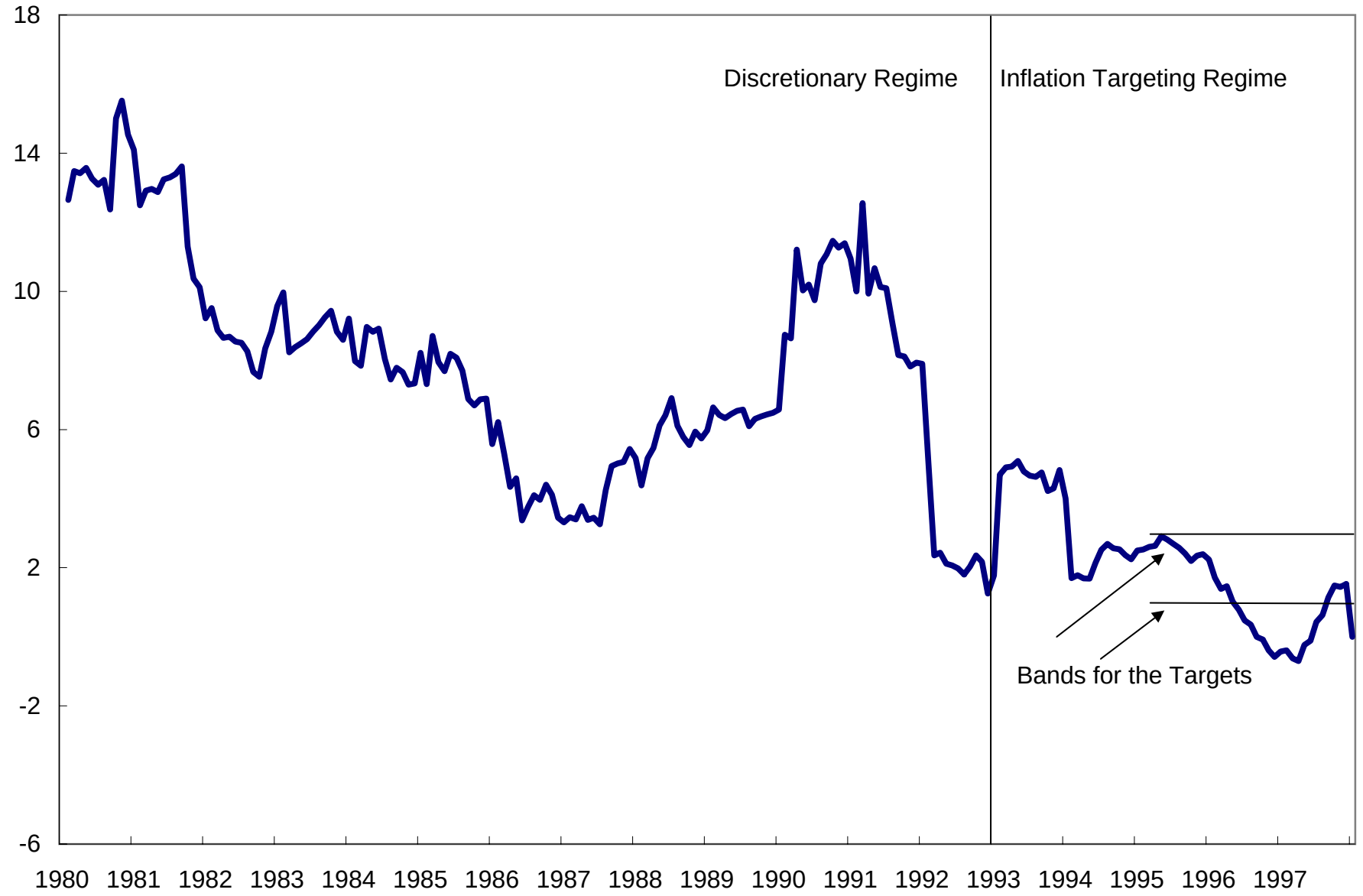
Source: Bernanke et al. (1999)

Figure 2c
Canada



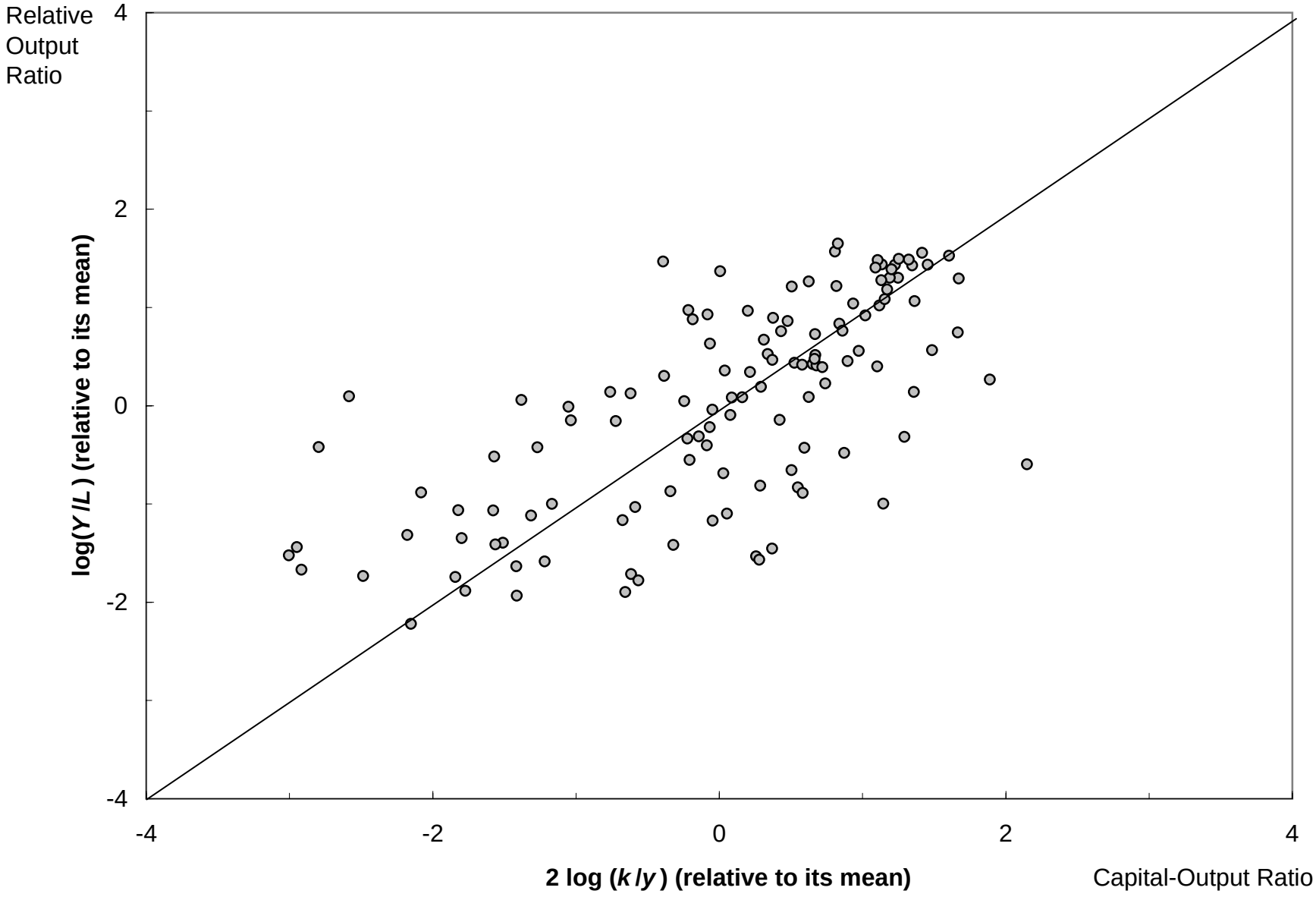
Source: Bernanke et al. (1999)

Figure 2d
Inflation in Discretionary and Targeting Regimes—Sweden



Source: Bernanke et al. (1999)

Figure 3
The Relationship Between Capital-Output Ratios and Relative Income Levels in 125 Countries During the Period 1950–85



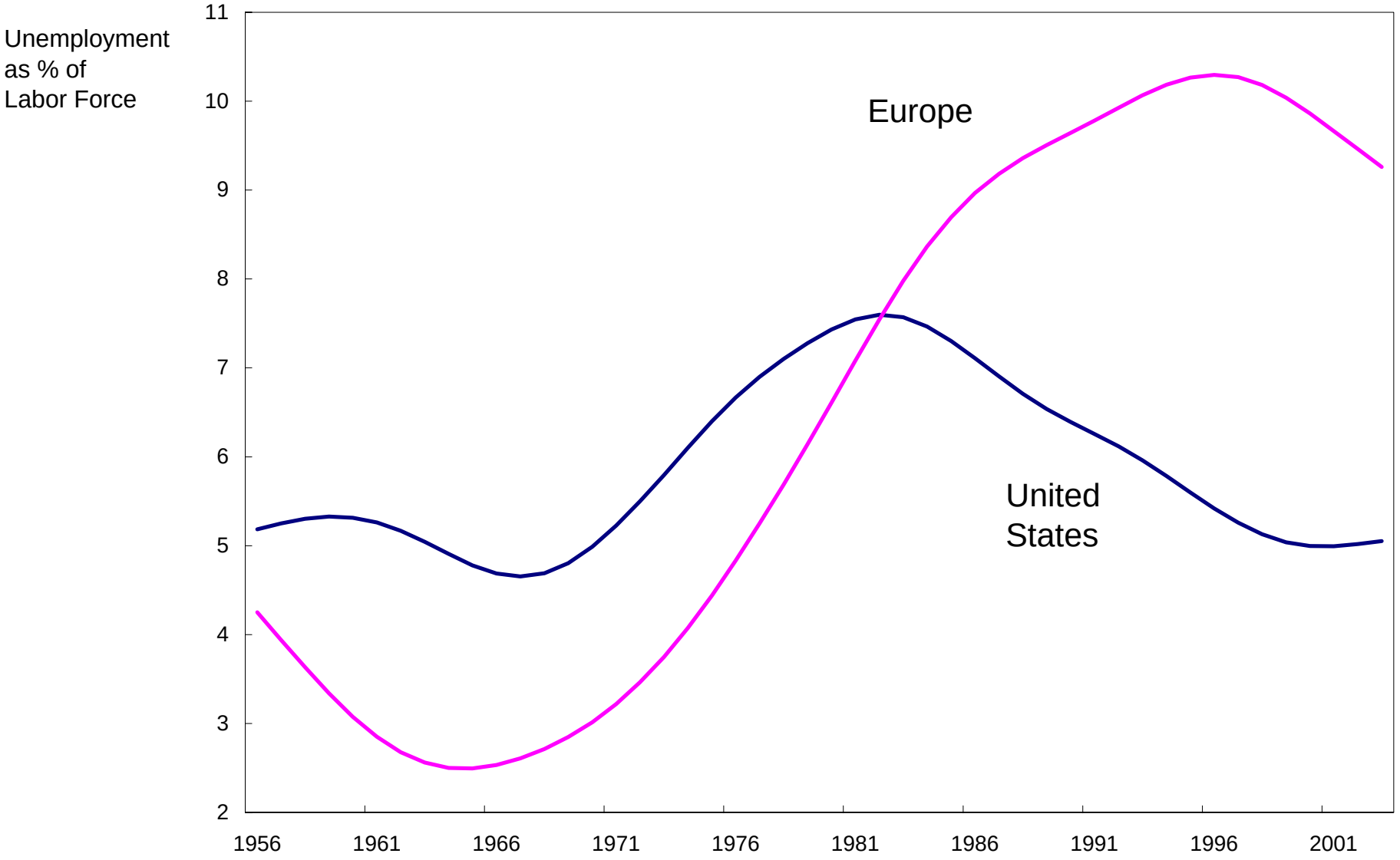
Source: Chari, Kehoe, and McGrattan (1997)

Figure 3

Note: If countries $i = 1, \ldots, I$ have an aggregate production function for aggregate output of the form $Y_i = AK_i^{2/3}L_i^{1/3}$ with common productivity parameter A and country-specific (broadly measured) capital K_i and labor L_i, then relative to their respective means, $\log(K_i / L_i) - 2\log(K_i / Y_i)$.

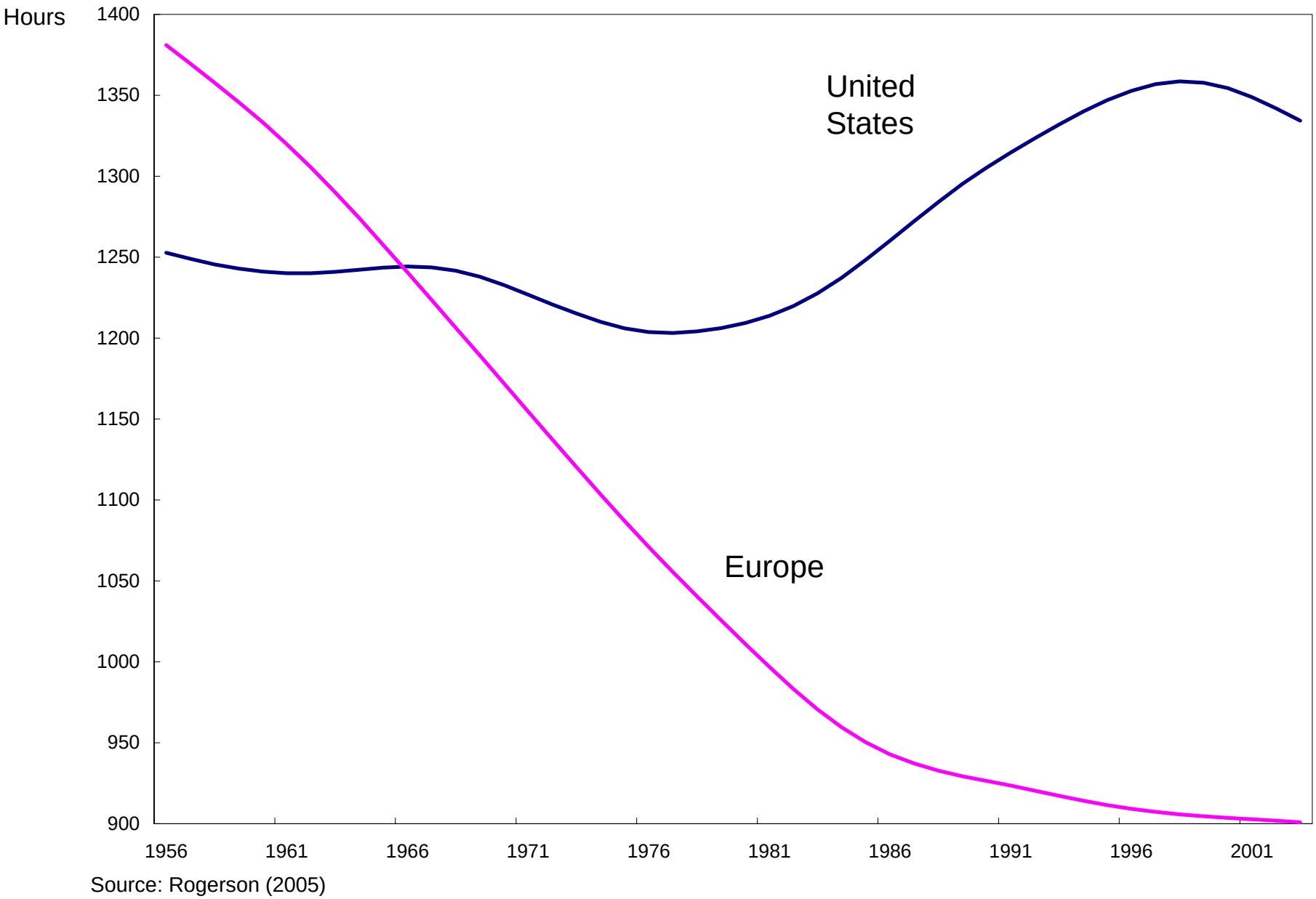
Figures 4–5
Unemployment and Employment in Europe and the United States, 1956–2003

Figure 4
Unemployment Rates



Source: Rogerson (2005)

Figure 5
Average Annual Hours Worked



Source: Rogerson (2005)

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The Heterogeneous State of Modern Macroeconomics: A Reply to Solow*

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ABSTRACT

Robert Solow has criticized our 2006 *Journal of Economic Perspectives* essay describing "Modern Macroeconomics in Practice." Solow eloquently voices the commonly heard complaint that too much macroeconomic work today starts with a model with a single type of agent. We argue that modern macroeconomics may not end too far from where Solow prefers. He is also critical of how modern macroeconomists use data to construct models. Specifically, he seems to think that calibration is the only way that our models encounter data. To the contrary, we argue that modern macroeconomics uses a wide variety of empirical methods and that this big-tent approach has served macroeconomics well. Solow also questions our claim that modern macroeconomics is firmly grounded in economic theory. We disagree and explain why.

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We welcome this opportunity to respond to the comments of Robert Solow on our 2006 *JEP* essay. Solow eloquently voices the commonly heard complaint that too much of modern macroeconomics starts with a model with a single type of agent. In our response we clarify that modern macroeconomics does not end there—and may not end too far from where Solow prefers. Most macroeconomic research over the last 20 years has precisely been about incorporating the heterogeneity and the rich interactions that Solow seems to think it needs. Solow also seems to think that essentially the only way that modern macroeconomists confront the data is through calibration. To the contrary, a key characteristic of modern macroeconomics is the heterogeneity in empirical strategies, including estimation, that are used to discipline the models using data. Finally, Solow questions our claim that modern macroeconomics is firmly grounded in economic theory. We disagree and explain why.

Before we elaborate on our assertions, we must acknowledge, with gratitude, that the way we build models and use data—what might be called the *style* of modern macroeconomics—owes much to Solow's seminal contributions to our profession. When he wrote down a single production function with aggregate labor and capital in his growth model, he sacrificed realism for an abstraction that has proven invaluable. In his growth accounting, he showed us how to use this abstraction in order to provide quantitative answers to economic questions.

In his comments on our essay, Solow provides a beautiful illustration of the struggle that engages academic macroeconomists every day. On the one hand, Solow says,

> My general preference is for small, transparent, tailored models, often partial equilibrium, usually aimed at understanding some little piece of the (macro-) economic mechanism.

On the other hand, he also says,

> A modern economy is populated by consumers, workers, pensioners, owners, managers,

> investors, entrepreneurs, bankers and others, with different and sometimes conflicting desires, information, expectations, capacities, beliefs and rules of behavior. Their interactions in markets and elsewhere are studied in other branches of economics; mechanisms based on those interactions have been plausibly implicated in macroeconomic fluctuations. To ignore all this in principle does not seem to qualify as mere abstraction—that is setting aside inessential details. It seems more like the arbitrary suppression of clues merely because they are inconvenient for cherished preconceptions.

Clearly, it is impossible to have a small model which incorporates all the richness that Solow sees in a modern economy.

So model builders need to be selective, to try to capture in their models only what is essential in order to study the issue at hand. To do so, we design models to answer specific questions, not to reproduce the entire modern economy. Building a model to study a specific question requires first understanding the economic mechanism required to provide an answer—and that is easier to do, of course, when the mechanism and the model are simple. In this sense, we share Solow's preference for "small, transparent, tailored" models. However, answering the kinds of macroeconomic questions that we ask typically requires the use of general equilibrium models.

Solow seems to think that using that sort of model requires ignoring all the rich heterogeneity which he sees in the modern economy. While that may have been true many years ago, today it is not. Most macroeconomists today work hard to examine economic mechanisms based on the kinds of myriad interactions that Solow seems to have in mind, and they incorporate into their models whatever heterogeneity is needed to answer their particular questions.

We offer just a few recent examples. Ríos-Rull (1996) develops a life-cycle model with consumers, workers, and pensioners and uses it to ask questions about the quantitative sources of business cycle fluctuations. Krusell and Smith (1998), building on Aiyagari's (1994) important con-

tribution, develop an incomplete markets model in which heterogeneous consumers have conflicting desires and use that model to ask questions about business cycle fluctuations. Rogerson and Wallenius (forthcoming) develop a life-cycle model in which agents have different capacities for supplying labor and use their model to ask questions about tax rates and average employment rates across countries. Bernanke, Gertler, and Gilchrist (1999) and Cooley, Marimon, and Quadrini (2004) develop models with investors, entrepreneurs, and bankers who have conflicting desires and use these models to study the role of financial constraints over the business cycle.

Macro research has thus evolved in the direction Solow might recommend. Yet that does not rectify what seems to be his principal complaint, which has to do with the order in which we do things. Modern macroeconomists generally start with a model with a single type of agent and then enrich it with the details necessary to answer the question at hand. Solow prefers to start with a model with eight types of agents and then trim away the unnecessary details, in order to end up with a small model. To answer any particular question, though, does it really matter that we start with a single type of agent and boost it to three types while he starts with eight types of agents and cuts back to three? Analogies about school colors and carrots aside, there does not seem to be much of substance here to argue about.

Solow is also critical of how modern macroeconomists use data to construct models. Specifically, he seems to think that the only way our models encounter data is through calibration. Again, while this may have been true years ago, today it is not. Modern macroeconomic research today takes a wide variety of econometric approaches to confront both the micro aspects and the macro implications of general equilibrium models with data. These approaches do include calibration, but they also include maximum likelihood estimation, Bayesian estimation, case studies, and natural experiments on both micro and aggregate data. We think this big-tent approach to data analysis serves macroeconomics well: it allows us to look for clues about the quantitative magnitudes of

various mechanisms in a wide variety of sources using a wide variety of methods.

Solow also takes issue with the claim that modern macroeconomic models are firmly grounded in economic theory. What distinguishes modern macroeconomics is its method: building models at the level of individual households and firms and using these models to attempt to answer aggregate questions. Solow argues that any aggregate excess demand functions that are homogeneous of degree zero and satisfy Walras' Law are just as firmly grounded in economic theory as any modern macroeconomic model. This argument implies that building macroeconomic models from the ground up, that is, from the level of individual households and firms, has no special virtue over writing down systems of behavioral equations. Solow's argument is based on an appeal to the Sonnenschein-Mantel-Debreu result, which implies that if we have only aggregate data, then theory imposes little discipline on how we model aggregates. Fortunately for macroeconomics, the Sonnenschein-Mantel-Debreu result notwithstanding, discipline is available elsewhere. If we have microeconomic data on how individual households and firms behave, then theory imposes discipline on the behavior of aggregates over and above Walras' Law and zero degree homogeneity.

The way macroeconomists use microeconomic data to discipline their models is still developing. Solow approvingly cites the work of Hansen and Heckman (1996), who suggest ways to improve the process of using micro evidence to build macro models. Interestingly, Hansen and Heckman argue that for this process to succeed, *microeconomists* must change the way they do business. Indeed, Hansen and Heckman (1996, pp. 100–101) contend that

> much recent micro research is atheoretical in character and does not link up well with macro general equilibrium theory. . . . A redirection of micro empirical work toward providing input into well-defined general equilibrium models would move discussions of micro evidence beyond discussions of whether wage or price effects exist, to the intellectually more important questions of what the micro estimates mean and how they can be

used to illuminate well-posed economic questions.

We agree with Hansen and Heckman's decade-old proposal. Their proposed redirection of micro empirical work is now well under way, and it will be useful once empirical microeconomics is as firmly grounded in the principles of economic theory as modern macroeconomics has been. For promising recent examples of this redirection, see the work of Lee and Wolpin (2006) and their references.

We don't mean to suggest that the challenges facing modern macroeconomics are small. Macroeconomists are still at the stage of figuring out which mechanisms are likely to be quantitatively promising for answering specific questions. Long before one formalizes a mechanism by writing down a detailed model and estimates it, using statistical procedures to determine if the mechanism is promising is desirable. Which procedure is the best for this purpose is the subject of heated debate. While currently the most popular procedure is vector autoregressions, we prefer another, business cycle accounting, because it relies more on economic theory. (See our 2007 work with McGrattan.) Regardless of the specifics, because it is firmly grounded in economic theory, macroeconomics is poised to make major advances on these challenges.

Near the end of his comments, Solow wonders why bright and enterprising economists are attracted to modern macroeconomics. We think the answer is simple: the attractions of modern macroeconomics are similar to the attractions that led Robert Solow to develop the growth model and James Tobin to develop portfolio theory and Paul Samuelson to develop the overlapping generations model. These economists, like others before and since, were attracted to using what was then the frontier of economic theory in an attempt to shed light on the day's challenging macroeconomic questions.

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