Chapter Title: The Rise and Fall of U.S. Inflation

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The Rise and Fall of U.S. Inflation

Facts

Figure 1.1 plots the annual rate of inflation in the U.S. consumer price index since World War II. Inflation was low during the late 1950's and early 1960's, swept upward into the 1970's, and then fell abruptly with Volcker's stabilization in the early 1980's. If we take for granted that inflation is under the control of the Federal Reserve, how can we explain these observations?

Two interpretations

This essay evaluates two interpretations based on policy makers' beliefs about the Phillips curve. In both, the Federal Reserve authorities learn the natural rate of unemployment theory from a combination of experience and *a priori* reasoning. The stories differ in how the natural-rate theory is cast. I call the first story the triumph of natural-rate theory and the second one the vindication of econometric policy evaluation.[1, 2]

[1] Our subtext is Keynes's observation that 'madmen in authority are the slaves of some defunct economist.'

[2] I recommend J. Bradford De Long's (1997) informative and colorful description of the emergence of high inflation in the U.S. in the 1970's. De Long uses elements of both stories. De Long's discussant John Taylor (1997) endorses a version of the first story and asserts his view that '... changing economic theories and opinions about inflation are the ultimate cause of the changes in actual inflation.'

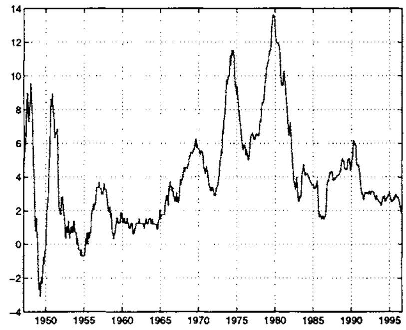

Figure 1.1. Monthly inflation, CPI, all items. 13-month centered moving average.

The triumph of natural-rate theory

Adherence to the gold standard and then to the rules of Bretton Woods gave the U.S. low inflation and low expectations of inflation. In 1960, Paul Samuelson and Robert Solow found a Phillips curve in the U.S. time series for inflation and unemployment. They taught that the Phillips curve was exploitable and urged raising inflation to reduce unemployment.[3] Within a

[3] This account comes from reading page 192 of Samuelson and Solow (1960). Important qualifications appear elsewhere in their paper. On page 193 they express reservations about exploiting the trade-off when they say that 'it would be wrong, though, to think that our Figure 2 menu that relates obtainable price and unemployment behavior will maintain its same shape in the longer run. What we do in a policy way during the next few years might cause it to shift in a definite way. ... it might be that the low-pressure demand would so act upon wage and other expectations as to shift the curve downward in the longer run – so that over a decade, the economy might enjoy higher price stability than our present-day estimate would indicate.' My two stories omit many details, including important reservations in Samuelson and Solow (1960) and the research inspired by it. (Jorge Luis Borges's character Funes the Memorious did the opposite by remembering so much that he would see no pattern or model.) But please read Chapter 10 before thinking that I treat Samuelson and Solow unkindly.

decade, Samuelson and Solow's recommendation was endorsed by many macroeconomists and implemented by policy makers. To everyone's dismay, over time the Phillips curve shifted adversely: inflation rose, but unemployment on average didn't fall. In the meantime, Edmund Phelps (1967), Milton Friedman (1968), and Robert E. Lucas, Jr. (1972) created and refined the concept of the natural rate of unemployment which assigned a central role to people's expectations about inflation in locating the Phillips curve. The natural-rate theory allowed only a temporary trade-off between inflation and unemployment and explained the observed adverse shifts in the Phillips curve. Its rational expectations version meant that policy makers should ignore any temporary Phillips curve trade-off and strive only for low inflation. These ideas diffused among academics, then influenced policy makers, and ultimately promoted the lower inflation rates of the 1980's and 1990's. Thus, events were shaped by policy makers' beliefs - some false, others true - and the actions those beliefs inspired.

Robert E. Lucas, Jr. (1976) used Samuelson and Solow's method for deducing policy recommendations from a statistical Phillips curve as an example of erroneous methodology. While Lucas's reasoning soon banished Samuelson and Solow's method from scientific research centers in economics, the method survived and prospered within the Federal Reserve System, a fact that inspires an alternative account of post 1960 inflation in the U.S.

The vindication of econometric policy evaluation

The alternative interpretation ascribes Volcker's conquest of inflation partly to the success of the econometric and policymaking procedures that Lucas challenged in his Critique. The vindication story begins with the same initial conditions, namely, the history of inflation and unemployment and the associated state of expectations inherited by policy makers in 1960.[4] Similarly, this story assumes that the data conformed to the natural rate hypothesis, whether or not the policy makers realized it. Policy makers accepted Samuelson-Solow's 1960 Phillips curve as an exploitable trade-off; they also adopted their methods for learning from data and for deducing policy recommendations. Recurrently, they re-estimated a distributed lag Phillips curve and used it to reset a target inflation-unemployment rate pair. Phelps, Friedman, and Lucas advocated identifying peoples' expectations of inflation as the hidden state variable positioning the Phillips curve, but they were ignored. Decisions emerged from econometric policy evaluation. That method revealed an adversely shifting Phillips curve, which when interpreted mechanically,[5] led policy makers to pursue lower inflation.[6]

To complete the vindication story, I describe the post 1960 history of U.S. inflation in terms of an adaptive theory of policy. The theory originates with a minimal departure from rational expectations[7] and accounts for features of the data that rational expectations misses. Compelling arguments made in the 1970's by proponents of rational expectations changed the way macroeconomists built and estimated models, and left adaptive expectations outmoded. Nevertheless, I recall adaptive expectations. The original form of adaptive expectations posited that agents form expectations about a variable x as a fixed geometric distributed lag of past values of x (Cagan (1956), Friedman (1957), Muth (1960)). A more modern form incorporates forecasting functions like those in rational expectations models but with coefficients that adapt to fit recent data. In both forms,

[4] The vindication story has been told before, for example, by Sims (1988) and Chung (1990).

[5] I.e., without trying to identify expectations in a natural-rate Phillips curve.

[6] Or would have led. See Chapter 9.

[7] It incorporates more optimizing behavior than do the three examples in Lucas (1976) or the one in Lucas (1972), each of which assumed arbitrary government policy.

adaptive expectations play essential roles in generating the inflation observations and in improving theoretical outcomes. To construct the historical account, I first revisit old issues such as whether, in a distributed lag model for expectations of inflation, the sum of the weights on lagged inflation should be unity, as proposed by Solow (1968) and Tobin (1968). I explain the significance of this issue within the context of Phelps' (1967) model of setting inflation under the natural-rate hypothesis. I then connect a sequence of ideas: drifting coefficients, self-confirming equilibria, least squares and other adaptive or recursive learning algorithms, convergence of least squares learners to self-confirming equilibria, and recurrent dynamics along escape routes from self-confirming equilibria. I integrate these ingredients to account for the post-War II inflation in terms of drifting coefficients that embody the evolving beliefs of an adaptive government adjusting its naive view of a Phillips curve in the light of recent evidence. I take an important idea from Sims (1988): an adaptive model allows a government to learn from past attempts to exploit the Phillips curve and to discover a version of the natural-rate hypothesis that instructs it to reduce inflation. I add to Sims's insight an account of how the escape route dynamics of our adaptive system can spontaneously generate regime shifts caused by their learning-inspired nonlinearities.

This account of the post 1960 inflation process denies that inflation policy is made in a vacuum or occurs as a natural experiment, as in Lucas (1972 or 1976). Instead, it asserts that inflation policy emerges gradually from an adaptive process.[8] Though this vindication story backs away slightly from rational expectations, it imposes more restrictions on government policy than does the triumph of the natural-rate story, which occasionally shifts free parameters describing government behavior to

[8] See Sims (1982) and Sargent (1983) for discussions of whether regime changes ought to be posited in explaining macroeconomic time series.

fit the facts. Also, the retreat from rational expectations is sufficiently small that the cross-equation restrictions forming the econometric hall mark of rational expectations continue to play a leading role.

Readers's guide

Because I assemble diverse arguments, some of which appear at first to be detours, I offer the following guide. The reader who temporarily loses the path of the argument can reorient himself by consulting this guide. A glossary defines key terms.

The Lucas critique

Chapter 2 reviews and modifies the Lucas Critique. It describes circumstances in which the Critique is ignored, recalls Sims's (1982) doubts, and sets the stage for the adaptive models in the second half of the essay.

Time-consistency and credible plans

Chapters 3 and 4 describe rational expectations models and the literature on sustainable plans in macroeconomics. Chapter 4 is technically difficult, but can be skipped without losing the book's main line argument. Chapter 3 describes a one-period version of the Kydland-Prescott economy and Chapter 4 studies an infinite horizon version. When supplemented with best response or least squares dynamics, the model of Chapter 3 explains the acceleration of inflation but not the stabilization under Volcker. Because it explains more, Chapter 4's model of a repeated economy with credible government policies predicts less. Multiple equilibria are essential to the theory of credible plans and present enough outcomes paths to subvert confidence that we can explain either the acceleration in inflation or Volcker's stabilization with this model.

The agnosticism from Chapter 4 is familiar to students of game theory (see e.g., Maskin and Tirole (1994)). The remainder of the essay explores alternative modifications of the basic model that might produce the observed outcome history. Relative to the sustainable-plan setting of Chapter 4, I shall introduce two restrictions on the government: one on its strategy space, another on its knowledge. I adhere to the rational expectations benchmark and economize on free parameters. I embrace minimalism to discipline my venture into the wilderness of bounded rationality.

Adaptive expectations and the Phelps problem

Chapter 5 starts our departure from rational expectations by returning to the origin of the natural-rate hypothesis with Phelps (1967). This chapter considers two ideas: the Phelps problem and the induction hypothesis. The Phelps problem uses an empirical Phillips curve to compute an optimal government decision rule for setting inflation. The induction hypothesis, embedded both in the Friedman-Cagan adaptive expectations model and in the Solow-Tobin test of the natural-rate hypothesis, restricts the sum of weights on lagged inflation in an expectations-formation equation. The authors of that restriction misinterpreted it as a long-run implication of rationality. (Lucas (1972) and Sargent (1971) showed that rational expectations instead imposes a cross-equation restriction.) But when the empirical Phillips curve fulfills the induction hypothesis, the Phelps problem recommends lower inflation rates than when it doesn't. The basis of the Phelps problem, the empirical Phillips curve, is arbitrary throughout Chapter 5. The remaining chapters strive to identify this curve and to explain the Volcker stabilization.

Equilibrium under misspecification

Chapter 6 detours to introduce a new equilibrium concept within the simplest context. I call it an equilibrium with an optimal misspecified forecasting function, and use it to modify a famous model of Margaret Bray (1982). The equilibrium concept merges ideas of Halbert White (1982) with those of John Muth (1961). It mutually determines both a true model and an approximating model. This chapter sets forth a mechanism by which subtly mistaken beliefs can substantially influence outcomes. I apply this equilibrium concept to the Phillips curve example, and use the results to interpret the simulations in Chapter 8.

Two types of self-confirming equilibria

Chapter 7 returns to an unresolved issue from Chapter 5, the arbitrary empirical Phillips curve used in the Phelps problem. Chapter 7 introduces the concept of self-confirming equilibrium to restrict the empirical Phillips curve. I use the concept of a self-confirming equilibrium to interpret and extend King and Watson's (1994) empirical work on the U.S. Phillips curve. Within a vector autoregression, King and Watson described alternative resolutions of the simultaneous equation problem (i.e., should you estimate the Phillips curve by regressing inflation on unemployment or unemployment on inflation?) and their implications for impulse responses to various shocks. By ascribing different prior beliefs to the government, different directions of fit affect self-confirming equilibria. I describe the equilibrium consequences of the direction of fit partly in response to the recent literature proclaiming that the Phillips curve is alive and well.[9] The papers that detect the most validity for the Phillips curve put inflation on the left side.

Chapter 7 displays two examples of self-confirming Phillips curves, designed to match King and Watson's classical and Keynesian identifying assumptions. In each example, beliefs are verified by large data samples. As a means of sustaining better than Nash (Kydland-Prescott time consistent) outcomes, self-confirming equilibria are disappointing. They cause the empirical Phillips curve to deny the induction hypothesis and make the solution of the Phelps problem reproduce the Nash equilibrium

[9] See Jeffrey Fuhrer (1995).

outcome, or something worse. This outcome pattern reflects how the self-confirming equilibria are equivalent or close to the Nash equilibria found in Chapter 3.[10] But Chapter 7 closes with a promising result. It displays an equilibrium where the private sector's forecasting model is wrong in a subtle way and where the outcome is substantially better than the Nash outcome.

Adaptive expectations

There is neither learning nor inference in the models of Chapter 7, only self-confirming sets of government beliefs and policies. Chapter 8 explores additional outcomes when learning is added by slightly modifying the models. I add at most one new free parameter to the models of Chapter 7.[11] I simply replace the assumption that the government and private agents know the moments used to compute the Phillips curve and forecasting function with the assumption that they must estimate sample moments. This leads to Kreps's anticipated utility model, a 1990's adaptive expectations model. I describe two versions of this model that differ in a single gain parameter that sets a data forgetting rate.

If we use a gain that eventually implements least squares and weights all past observations equally, then convergence theorems imply that self-referential systems with least squares learning eventually converge to self-confirming equilibria. Consequently, with such a gain sequence, the adaptive system ultimately adds no outcomes to the pessimistic analysis of Chapter 7. However, new outcomes occur under a gain parameter that is constant and discounts past data. This algorithm is sensible where the government and private agents suspect coefficient drift. The government's use of such an algorithm arrests the force pushing the system toward a self-confirming equilibrium

[10] Such an outcome is familiar from the literature about learning schemes that converge to Nash equilibria.

[11] It depends on whether we count alteration of the gain sequence from $\frac{c}{t^{\alpha}}$ with $\alpha = 1$ to one with $\alpha = 0$ as adding a free parameter or just changing the setting of a parameter α present but hidden in the rational expectations model.

and fosters recurrent deviations away from a self-confirming equilibrium.

Striking simulations under the constant-gain algorithm exhibit spontaneous stabilizations resembling the advent of Volcker. But there is no Volcker. The constant-gain algorithm learns the natural-rate hypothesis in exactly the form that Solow and Tobin expressed it. That and the Phelps problem produce the stabilization. Drifting coefficients play a key role in these stabilizations. I interpret coefficient drift and the behavior that it implies in terms of the categories of Chapters 5, 6, and 7: the induction hypothesis and its impact on the outcome of the Phelps problem; and the ability of a misspecified model that uses the induction hypothesis to approximate the truth. The simulations exhibit an interplay between mean dynamics that push the system toward a pessimistic, self-confirming outcome, and random activity along an escape route from self-confirmation that recurrently expels the system toward the Ramsey outcome.[12] The escape-route dynamics make the drift in the random coefficients seem purposeful. The stabilizations in the simulations originate in monetary policy rules that embody the government's shifting model of the Phillips curve and reflect activation of the induction hypothesis within the Phelps problem. Properties of these simulations form the basis for our vindication of econometric policy evaluation, which we pursue econometrically in Chapter 9.

[12] Our work bears a close connection to that of Evans and Honkapohja (1993) and some of the literature they cite. Evans and Honkapohja describe how agents' use of a drifting coefficient model can induce recurrent shifts between two locally stable rational expectations equilibria. They use this as a way to generate endogenous regime shifts. The mechanism we describe has many common components with theirs but differs in that our system recurrently escapes to something that is not an equilibrium.

Empirical vindication

Chapter 9 computes econometric estimates for two of our 1990's adaptive models for U.S. data and uses them to confirm the vindication story. They reveal how the adaptive algorithm would have approximated the induction hypothesis soon enough to send timely advice through the Phelps problem. The econometric estimates present the mystery of why the stabilization was postponed.

Chapter 10 assembles the various components of our arguments and discusses how they bear on a research program that contemplates occasional and disciplined backing away from rational expectations.

Raw and filtered Data

Despite its disrepute within important academic and policymaking circles,[13] the Phillips curve persists in U.S. data. Simple econometric procedures detect it.

Figure 1.2 plots the unemployment rate for white men over 20 years of age against the CPI inflation rate. Many students of the Phillips curve advocate adjusting the aggregate unemployment rate for movements in the demographic mix. Using an unemployment rate for the single group, white males over 20, helps coax a Phillips curve from the data. Filtering out slowly moving components allows the eye to spot an inverse relationship between inflation and unemployment at business-cycle frequencies. Figure 1.3 plots business cycle components of inflation and unemployment. A frequency decomposition

[13] We witnessed the battering from the press, and the silence from his fellow Governors, that greeted Federal Reserve Board Vice Chairman Alan Blinder's comments in July 1994 at Jackson Hole. I do not believe that Blinder's comments would have excited controversy or exception at any leading macroeconomics seminar.

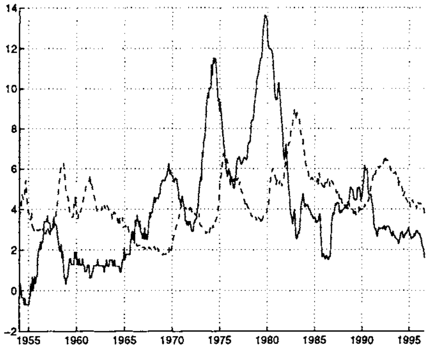

Figure 1.2. Monthly unemployment rate (white males over 20 years, dotted line) and monthly inflation rate (CPI, all items, solid line).

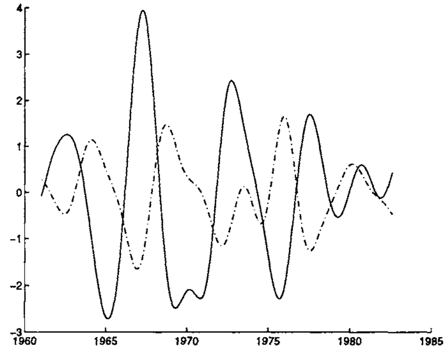

Figure 1.3. Business cycle components of monthly unemployment rate (white males over 20 years, dotted line) and monthly inflation rate (CPI, all items, solid line). These components were extracted using the bandpass filters described by Baxter and King.

has been implemented by using the finite-lag bandpass filter described by Baxter and King (1995).[14]

Figure 1.4 plots monthly inflation against monthly unemployment for the subperiod that interests us most, and Figure 1.5 plots the business cycle components of these two series. A comparison of the two figures indicates how focusing on the business-cycle components sharpens the apparent Phillips curve. Figure 1.5 reveals Phillips loops.

[14] We set Baxter and King's minimum frequency at 24 months, the maximum at 84 months, and the lag-lead truncation parameter at 84.

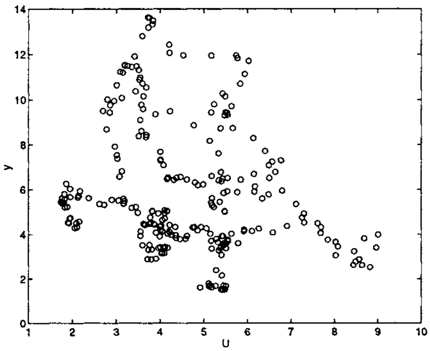

Figure 1.4. Scatter plot of monthly inflation (coordinate axis) against white male unemployment (ordinate), 1960–1982.

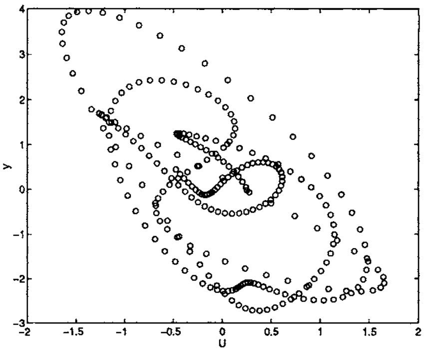

Figure 1.5. Scatter plot of business cycle components of inflation (coordinate axis) against white male unemployent (ordinate), 1960-1982.

Demographic adjustment and drift

In Chapter 9, I use these data to estimate an adaptive model of policy making. I adjust for demographic change by choosing a specific unemployment data set. A broader definition of unemployment would put additional low frequency demographic-shift components into the data. Those might be captured by using a unit root process with small innovation variance to drive the unemployment rate. This essay puts a unit root in the inflation-unemployment process from a different source: the drifting beliefs of a monetary authority cut loose from the discipline of Bretton Woods.